CLIMATE CHANGE

Preserving Montreal Protocol Climate Benefits by Limiting HFCs

With no impending global controls on HFCs, the Montreal Protocol offers a near-term path to preserve its climate benefits.

Guus J. M. Velders,[1]* A. R. Ravishankara,[2] Melanie K. Miller,[3] Mario J. Molina,[4] Joseph Alcamo,[5] John S. Daniel,[2] David W. Fahey,[2] Stephen A. Montzka,[2] Stefan Reimann[6]

The Montreal Protocol is perhaps the most successful international environmental treaty, responsible for global phaseout of the consumption and production of ozone-depleting substances (ODSs), e.g., chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs). Hydrofluorocarbons (HFCs), which do not destroy stratospheric ozone, were considered long-term substitutes for ODSs and are not controlled by the Montreal Protocol. Because most HFCs are potent greenhouse gases (GHGs), they are included in the Kyoto Protocol. But climate benefits provided by this protocol are limited as they apply only to developed countries and over a short time (2008 2012). As we describe below, with no impending global controls on HFCs, inclusion of HFCs under the Montreal Protocol offers a path, starting in the short term, to preserve the climate benefits already achieved by this protocol.

Climate considerations are not new to the Montreal Protocol. Signatory nations acknowledged in the preamble that they are "Conscious of the potential climatic effects of emissions of these substances [ODSs]." The climate contribution of future HCFC emissions was an important consideration for the accelerated phaseout agreed to by the parties in 2007.

Since 2010, 108 nations have signed a declaration stating their "intent to pursue further action under the Montreal Protocol aimed at transitioning the world to environmentally sound alternatives to HCFCs and CFCs" (*1*). Canada, Mexico, and the United States, as well as the Federated States of Micronesia, submitted proposals in 2010 and 2011 to control HFC use by amending the Montreal Protocol. The proposals and declaration were motivated by the interest in limiting climate change from future emissions of HFCs with high global warming potentials (GWPs) (*2*). These proposals were discussed but not adopted at the last two meetings of the Parties to the Montreal Protocol. Negotiations are expected to continue in future meetings as details of the proposals are refined.

At the 2011 Durban climate negotiations, it was decided that new climate commitments will come into effect only from 2020 onward, leaving the coming 8 years or more without any legally binding global measures under a climate agreement to reduce potential climate effects of HFCs and other GHGs. This delay heightens policy and scientific interest in examining the possibilities and consequences of regulating HFCs under the Montreal Protocol.

Climate Benefits of Montreal Protocol

Most ODSs are also potent GHGs (*3*). Thus, reductions in atmospheric ODS concentrations to protect the ozone layer have had the added benefit of providing some climate protection. The radiative forcing (*4*) from ODSs reached 0.32 W/m^2 around 2000 (compared with about 1.5 W/m^2 for CO_2) and has remained nearly constant since. Without the Montreal Protocol, radiative forcing from ODSs could have reached 0.60 to 0.65 W/m^2, or about 35% of that of CO_2, in 2010 (see the graph) (*5*). This direct climate benefit is offset in part (about 30%) by other factors, including indirect radiative forcing from reductions in stratospheric ozone and climate forcing by increased use of ODS substitutes (*5*). Total avoided net annual ODS emissions are estimated to be equivalent to about 10 Gt CO_2/year in 2010, which is about five times the annual reduction target of the Kyoto Protocol for 2008 2012 (*5*). This climate benefit of the Montreal Protocol may be reduced or lost completely in the future if emissions of ODS substitutes with high GWPs, such as long-lived HFCs, continue to increase.

Growth in HFCs as ODS Substitutes

With CFC phaseout completed in 2010 and the scheduled phaseout of most HCFCs by 2030, HFCs are being used more in applications that traditionally used ODSs, e.g., refrigeration and air-conditioning equipment, blowing agents for foams, aerosol sprays, fire protection systems, and solvents (*6*, *7*). The atmospheric abundances of major HFCs used as ODS substitutes (*8*) are increasing 10 to 15% per year in recent years (*9*). Rising use of HFCs is directly attributable to intent and actions of the Montreal Protocol (*7*), hence, the HFC contribution to climate change can be viewed as an unintended negative side effect of these actions.

The current contribution to climate forcing of HFCs used as ODS substitutes is about 0.012 W/m^2 [excluding HFC-23 (*8*)], less than 1% of the total forcing from long-lived GHGs, but it is increasing rapidly (*9*, *10*). Growth rates and projections indicate potential for substantial future increases in emissions and atmospheric abundances of HFCs in the absence of new controls (*9*). These business-as-usual projections are based on increasing demand for ODS substitutes, particularly in developing countries (*11*).

In an upper-range scenario, global radiative forcing from HFCs increases from about 0.012 W/m^2 in 2010 to 0.25 to 0.40 W/m^2 in 2050 (*11*) (see the graph). This corresponds to 14 to 27% of the increase in CO_2 forcing under the range of Intergovernmental Panel on Climate Change (IPCC) business-as-usual scenarios from 2010 to 2050 (*12*). In these scenarios, developing countries replace HCFCs with HFCs by using the same substances and use patterns as adopted by developed countries (*11*).

Wide Range of HFC Lifetimes and GWPs

In recent proposals to amend the Montreal Protocol, production and consumption of HFCs would be reduced in phases from baseline levels. This would encourage the use of alternative substances with low GWPs. The extent to which HFCs or other ODS substitutes will influence climate depends on past and future emissions, atmospheric lifetimes, and the efficiency of these molecules in absorbing infrared radiation. Most fluorocarbons (e.g., CFCs, HCFCs, and HFCs) have a similar ability (within about a factor of three) to trap infrared radiation, on a per-molecule

[1]National Institute for Public Health and the Environment (RIVM), 3720 BA Bilthoven, Netherlands. [2]Earth System Research Laboratory, National Oceanic and Atmospheric Administration (NOAA), Boulder, CO 80305, USA. [3]Touch down Consulting, 1310 La Hulpe, Belgium. [4]University of California, San Diego, La Jolla, CA 92093, USA. [5]United Nations Environment Programme (UNEP), Nairobi, Kenya. [6]Swiss Federal Laboratories for Materials Science and Technology (Empa), CH 8600 Duebendorf, Switzerland.

*To whom correspondence should be addressed. E mail: guus.velders@rivm.nl

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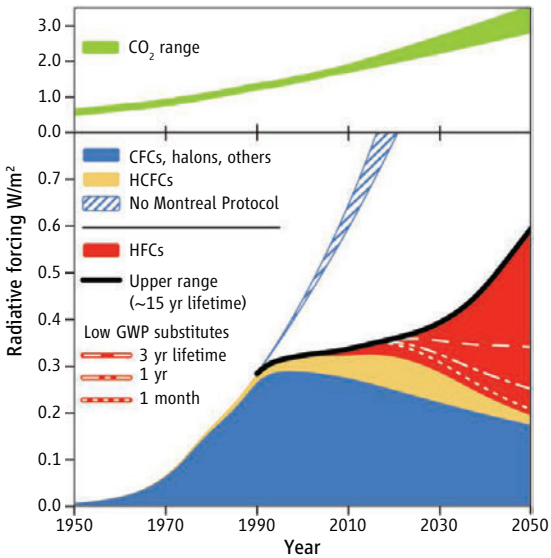
basis, in Earth's atmosphere. Therefore, differences in their relative impact on climate arise primarily from differences in atmospheric lifetimes. The longer the lifetime of a molecule, the larger its potential contribution to climate forcing.

Fully saturated HFCs (molecules with only single bonds), used in significant quantities commercially (e.g., HFC-32, -125, -134a, -143a, and -152a), have atmospheric lifetimes that range from 1 to 50 years (*9*). Their 100-yr GWPs range from 100 to about 4000. Unsaturated HFCs (also referred to as hydrofluoro-olefins, HFOs) have much shorter atmospheric lifetimes, on the order of days to weeks, with correspondingly smaller GWPs (~20 or less). If the current mix of HFCs with an average lifetime of 15 years (average GWP of 1600) were replaced by HFCs with lifetimes less than 1 month (GWP less than ~20), the total HFC radiative-forcing contribution in 2050, even under the high-emission scenario, would be less than the current forcing from HFCs (see the graph). Such choices are currently available.



Projected radiative forcing by ODSs, HFCs, low-GWP substitutes, and CO_2 (*12*). The blue hatched region indicates what would have occurred in the absence of the Montreal Protocol, with 2 to 3% annual production increases in ODSs [data taken from (*5*)]. Added to the radiative forcing from ODSs [data from (*9*)] are the contributions from HFCs from the upper-range scenario [data from (*11*)]. Also shown are the radiative forcing from alternative scenarios in which substitution is made with chemicals having shorter lifetimes (lower GWPs); their contribution is calculated using methods described in (*11*) with the parameters from (*16*). Under the Montreal Protocol, use reductions started in 1989 for CFCs and in 1996 for HCFCs.

Choosing Appropriate Alternatives

Approaches to reduce climate forcing from future HFC use and to preserve climate benefits provided by the Montreal Protocol include (*6*, *13*, *14*) these: (i) replacing high-GWP HFCs with substances that have low impact on climate (e.g., hydrocarbons, CO_2 or certain HFCs) and alternative technologies (e.g., fiber insulation materials) and (ii) reducing HFC emissions (e.g., by changing the design of equipment and capturing and destroying HFCs when equipment reaches the end of its useful life). Given the orders-of-magnitude differences in GWPs, it is expected that transitioning to low-climate-impact substitutes with similar life-cycle energy efficiencies as high-GWP HFCs has the potential to provide larger climate benefits than attempts to reduce emissions of HFCs in applications. Low-climate-impact substitutes are already in commercial use in several sectors. These include fiber insulation materials; dry powder asthma inhalers; and non-HFC substances with low or zero GWPs, such as hydrocarbons, ammonia, and CO_2 in some refrigeration systems. Several HFCs with very short atmospheric lifetimes (hence, low GWPs) are now being introduced for foams and aerosols (HFC-1234ze) and mobile air conditioners (HFC-1234yf) (*15*). Also, the Multilateral Fund (MLF) of the Montreal Protocol is funding many projects in developing countries for the transition from ODSs to alternative substances or methods with lower impact on climate. The primary decisions about whether to use high-GWP HFCs or alternatives are currently made by companies and are subject to normal commercial considerations, such as performance; viability; affordability; availability; and health, safety, and environmental factors (*13*). A global framework for regulating future HFC use would provide a clear signal for the commercial sector, guiding the selection of substances for long-term use, as done under the Montreal Protocol for ODSs.

In addition to the direct contribution to climate forcing, indirect climate effects arise from the energy used or saved during the application or product's full life cycle. Ideally, alternative systems would have overall energy efficiencies at least as high as the systems they replace. This is already feasible in a number of sectors, such as domestic, commercial, and industrial refrigeration and some types of air-conditioning systems (*6*, *13*, *15*).

Future Challenge for Policy-Makers

A large number of countries have formally stated their intention to preserve climate benefits of the Montreal Protocol (*1*). A challenge for policy-makers is to identify how this might be accomplished. Given that climate impacts of HFC use can be viewed as unintended side effects of the Montreal Protocol, an option is to expand provisions of this protocol while drawing from parties' experience in formulating successful ODS controls that took scientific, economic, and technical aspects into account. The Montreal Protocol has relevant infrastructure for accomplishing this, including the MLF, expert panels, regional networks, and administrative procedures. This infrastructure and experience suggest that such an approach could effectively and quickly limit continued growth of high-GWP HFCs and preserve the substantial climate benefits that were gained by the Montreal Protocol in phasing out ODSs.

References and Notes

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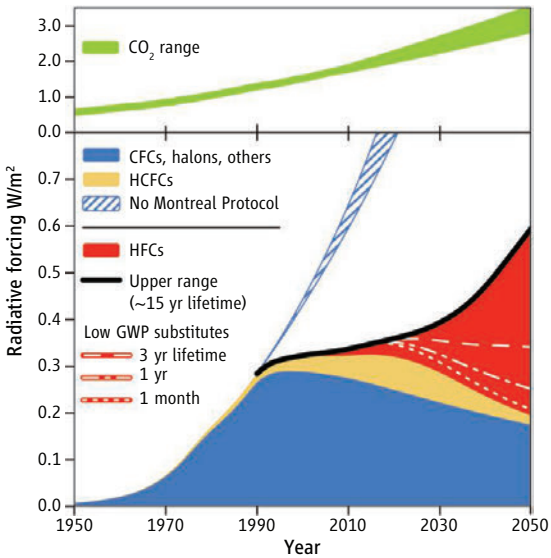

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Drusilla Hufford - BIO

Drusilla Hufford joined the U.S. Environmental Protection Agency (U.S. EPA) in 1984 with an MBA from the Wharton School. At EPA, she has worked on environmental policy issues including water pollution control, solid and hazardous waste management, ozone layer and climate protection, as well as in EPA offices including the Administrator's Office of Policy.

Since 1992, Drusilla has worked to protect the stratospheric ozone layer, initially responsible for identifying and approving alternatives to ozone depleting substances in major industrial sectors through the U.S. Significant New Alternatives Policy (SNAP) Program. In 1997, Ms. Hufford was appointed Director of EPA's Stratospheric Protection Division (SPD). SPD implements Title VI of the Clean Air Act protecting the ozone layer; the division's work has resulted in large reductions in consumption of ozone depleting substances in the U.S. and is the mechanism for domestic implementation of the international treaty to protect the ozone layer, the ***Montreal Protocol on Substances that Deplete the Ozone Layer.***

Because depletion of the ozone layer causes skin cancer, Ms. Hufford has also developed public health campaigns to prevent skin cancer. In 1994, she helped establish the U.S. UV Index, now reported in all major U.S. media markets. In 1997, her work in skin cancer prevention developed a focus on protecting children's health, as she created the SunWise Program, a standards-based curriculum now used to teach sun safety to children at more than 30,000 schools K-8 in all U.S. states. From 2007-2010, she served as Co-Chair of the U.S. National Council on Skin Cancer Prevention.

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November 23, 2011

The Honorable Lisa P. Jackson
Administrator
U.S. Environmental Protection Agency
Ariel Rios Building
1200 Pennsylvania Avenue, N.W.
Washington, DC 20460

Dear Administrator Jackson:

On behalf of the undersigned medical and public health organizations, we strongly urge you to move forward with the December 31, 2011, phase-out of CFC-propelled over-the-counter epinephrine (Primatene Mist CFC) from the U.S. market. We strongly believe that a firm transition date is in the best interest of patients with asthma.

As you know, in response to concerns about the growth of the hole in the ozone layer and its potential global health and environmental effects, the Montreal Protocol treaty was signed by the United States in 1987 and later ratified by the U.S. Senate. The Montreal Protocol created a process to remove non-essential ozone depleting chemicals from the market place. Chloroflourocarbons (CFCs) were one of the many ozone depleting substances covered by the treaty.

As you also know, prior to the Montreal Protocol, CFCs were commonly used as a propellant in household and medical aerosol products. One of the more challenging technical aspects of the transition was developing CFC alternatives for aerosolized respiratory medicines to treat asthma and other lung diseases. Due in large part to industry innovation, the United States has successfully managed the transition from CFC to CFC-free products for drugs used to treat asthma and other respiratory conditions.

We are aware Members of Congress have requested that EPA allow the existing stock of Primatene Mist CFC be sold after the December 31, 2011deadlineand until the stock is depleted. We urge you to reject this request for the following reasons.

Epinephrine is suboptimal care for the treatment of asthma.

Asthma is a common and potentially serious health condition that impacts millions of Americans. Fortunately there are effective medications that can be used to manage patients with asthma. Several expert panels have produced recommendations on the treatment of patients with asthma. None of the expert guidelines recommend the use of over-the-counter medications--like Primatene Mist--to treat asthma. The National Asthma Education and Prevention Program (NAEPP), an expert panel convened by the National Institutes of Health, has issued treatment guidelines for management of asthma. NAEPP recommends against the use of epinephrine for treating asthma exacerbations stating:

> "Drugs of choice for acute bronchospasm. Inhaled route has faster onset, fewer adverse effects, and is more effective than systemic routes. The less beta2-selective agents (isoproterenol, metaproterenol, isoetharine, and **epinephrine***)* are not recommended due to their potential for excessive cardiac stimulation, especially in high doses. (*emphasis added)*(1)

We strongly encourage any patient who uses over the counter medications--like Primatene Mist CFC--to treat his/her asthma to seek a healthcare provider who can help the patient develop an asthma management plan and recommend more effective and safer medications to manage the asthma.

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We note that delay letter requests Primatene Mist CFC be permitted to be sold after the December 31, 2011deadline, until the product stockpile is deleted. Such an imprecise transition deadline will create confusion for patients and undermine efforts for an orderly and effective transition. It will invariably lead to significant variation in product availability. More importantly, a rolling enforcement deadline will prevent pharmacists and other health professionals from being able to deliver a nationally coordinated, timely message to Primatene Mist CFC users on their treatment options.

Consistent Transition Process

This is not the first time industry has petitioned the EPA to be granted an enforcement extension beyond the established deadline. Manufacturers of CFC- containing medical products sought similar exemptions earlier in the transition process. The EPA rejected those earlier petitions. We also note that Armstrong Pharmaceuticals sought and received a one-year extension of the transition date. We believe Armstrong has had sufficient time to prepare for a final transition date of December 31, 2011. FDA determined in 2008 that epinephrine should be phased out. We have been working for more than three years for this orderly transition.

The Ozone Layer

Lastly, we note the hole in the ozone layer still exists. Thankfully, scientists project that due to continuing reductions of on ozone-depleting substances; the hole in the ozone layer is stabilizing and is expected to recover in the coming decades. The success of the Montreal Protocol should be celebrated and give the EPA firm resolve to move

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Asthma and Allergy Foundation of America
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1) National Asthma Education Prevention Program– Expert Report 2 (1997) p. 64 figure 3-2.

November 23, 2011

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U.S. Environmental Protection Agency
Ariel Rios Building
1200 Pennsylvania Avenue, N.W.
Washington, DC 20460

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EPA Stakeholder Meeting, September 8, 2011

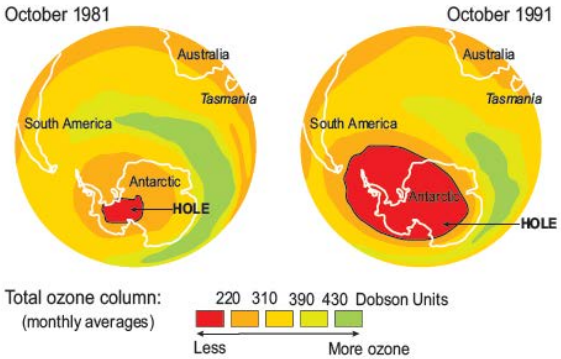
Criteria and Process that Removed the Exemption for CFC-Propelled Epinephrine MDIs

Badrul A. Chowdhury, MD, PhD

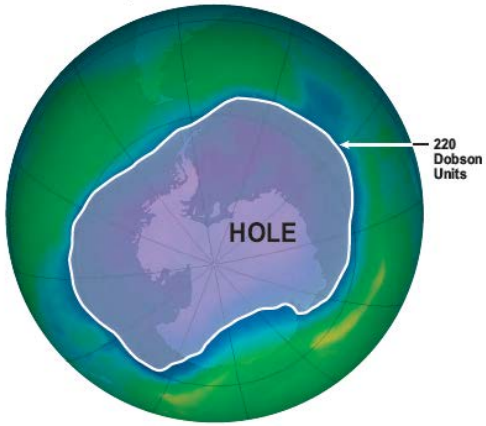
Director, Division of Pulmonary, Allergy, and Rheumatology Products, Center for Drug Evaluation and Research, US Food and Drug Administration

Ozone Depletion

The Antarctic Ozone Hole

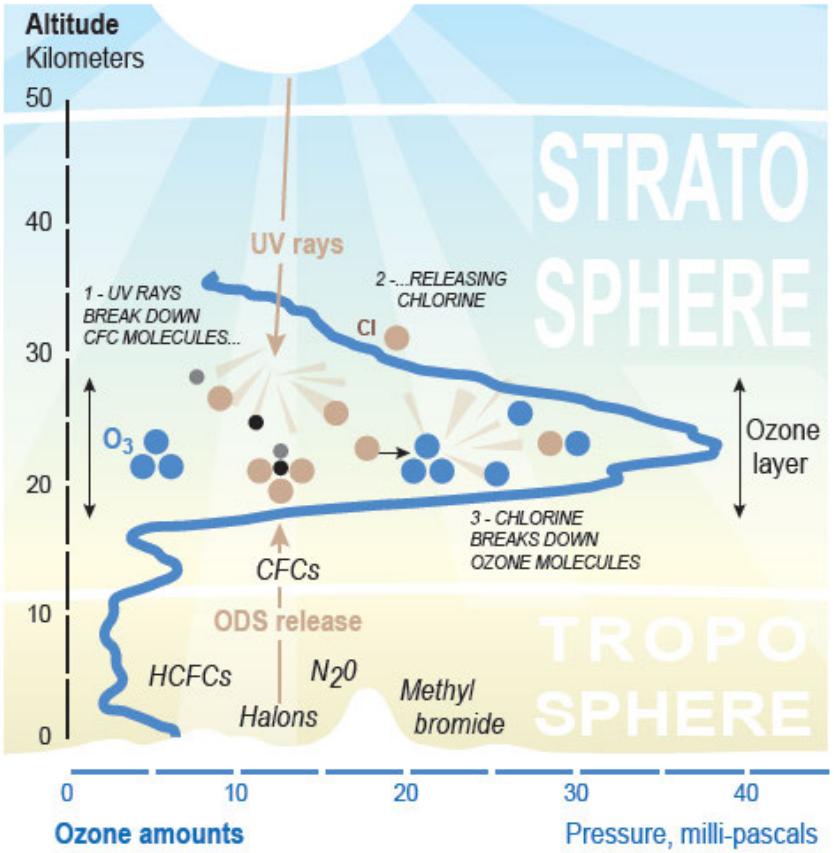


September 24, 2006



From September 21-30, 2006, the average area of the ozone hole was the largest ever observed.

Ozone Destruction in the Stratosphere



UNEP, Vital Ozone Graphics 2.0

Phase-out of CFC Use in MDIs

- Use of CFC banned in industrial countries effective 1996 and rest of the world effective 2010, except for essential uses
- Use of CFC in MDIs for asthma and COPD is conditionally exempted as essential medical use (FDA regulation 21 CFR 2.125, US Clean Air Act, and Montreal Protocol)

Status of CFC Propelled MDIs in the US
- Final Rules Removing Essential Use Designation of CFC Use

- Beclomethasone, dexamethasone, fluticasone, bitolterol, salmeterol, ergotamine tartrate, and ipratropium bromide
  - Effective April 23,2007
  - 71 FR 70870 (December 7, 2006) and 72 FR 20942 (April 27, 2007)
- Albuterol
  - Effective December 31, 2008
  - 70 FR 17168 (April 4, 2005)
- Epinephrine
  - Effective December 31, 2011
  - 73 FR 69532 (November 19, 2008)

http://www.fda.gov/Drugs/DrugSafety/InformationbyDrugClass/ucm063054.htm

Status of CFC Propelled MDIs in the US - Final Rules Removing Essential Use Designation of CFC Use (cont.)

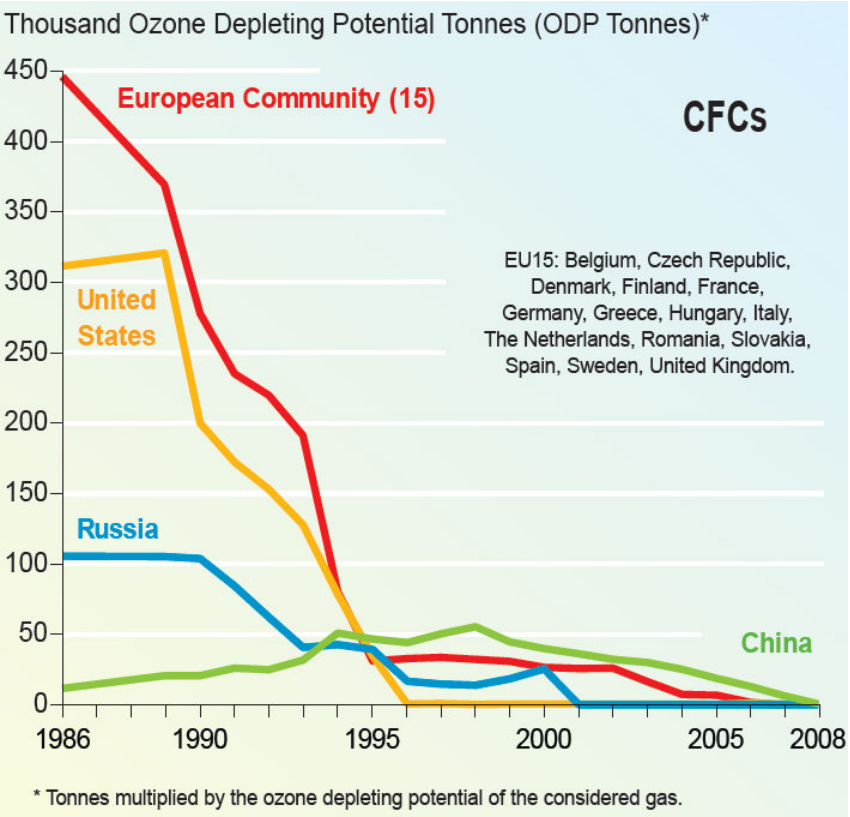
- "Seven moieties" rule
  - Metaproterenol — Effective June 14, 2010
  - Nedocromil — Effective June 14, 2010
  - Triamcinolone — Effective December 31, 2010
  - Cromolyn — Effective December 31, 2010
  - Flunisolide — Effective June 30, 2011
  - Pirbuterol — Effective December 31, 2013
  - Albuterol and Ipratropium — Effective December 31, 2013

  - 75 FR 19213 (April 14, 2010)

http://www.fda.gov/Drugs/DrugSafety/InformationbyDrugClass/ucm193896.htm

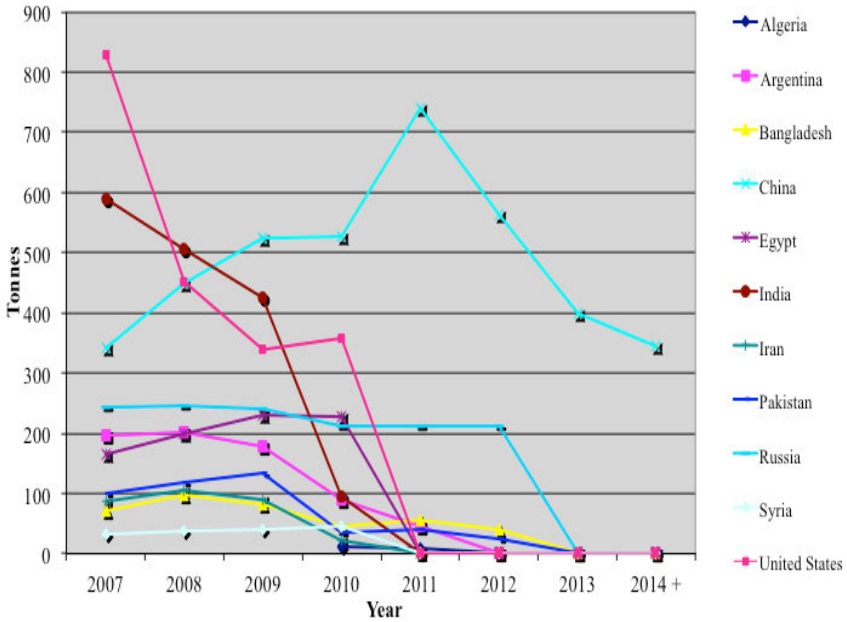
CFC Production and Usage

Production of the Main ODS Gases



UNEP, Vital Ozone Graphics 2.0

Estimated CFC Usage for MDI



UNEP, Report of the TEAP, May 2011

Essential Use
- Montreal protocol, Decision IV/25

- It is necessary for the health, safety or is critical for the functioning of society (encompassing cultural and intellectual aspects); and
- There are no available technically and economically feasible alternatives or substitutes that are acceptable from the standpoint of environment and health;

Essential Use
- United States

- Criteria for Removal of CFC Propelled MDIs after January 1, 2005, codified in 21 CFR 2.125 (g)(2) that cross references 21 CFR 2.125(f)
- Meeting ONE of the following criteria is adequate
  - No technical barriers exist to formulating the product without ozone depleting substances (ODSs)
  - The product will not provide an unavailable important public health benefit
  - Use of the product releases cumulatively significant amounts of ODSs into the atmosphere not warranted by public health benefit
- Allows for removal of products for which there are no alternates with the same active moiety

Regulatory Procedure for Removal of CFC Propelled MDIs

- Codified in 21 CFR 2.125 (g)(2)
  - Consult Advisory Committee
  - Publish Proposed Rule
  - Hold Open Public Meeting
  - Publish Final Rule

Epinephrine MDIs

- Epinephrine is a short-acting adrenergic bronchodilator
- New Drug Application (NDA) for over-the-counter (OTC) epinephrine MDI was approved in 1956
- NDA was held by Wyeth Consumer Healthcare, and currently held by Armstrong Pharmaceuticals Inc.

Removal process for Epinephrine MDIs - Advisory Committee, January 24, 2006

- Joint meeting of the Nonprescription Drug Advisory Committee (NDAC), and the Pulmonary and Allergy Drugs Advisory Committee (PADAC)
  - Wyeth estimated that 2-3 million people use OTC epinephrine MDIs
  - Convenience of having an OTC MDI for asthma discussed
  - Consensus opinion was that epinephrine MDIs present no significant therapeutic benefit and no advantage over albuterol MDIs
  - Majority of the Advisory Committee (11 No, 7 Yes) voted against retaining epinephrine's essential-use designation

http://www.fda.gov/ohrms/dockets/ac/06/transcripts/2006-4200T.pdf

Removal process for Epinephrine MDIs
- Proposed Rule, September 20, 2007

- Published in the Federal Register (72 FR 53711) on September 20, 2007, with the following tentative conclusion
  - There are no substantial technical barriers to formulating epinephrine as a product that does not release ODS, and therefore epinephrine no longer would no longer be an essential use of ODS
  - Proposed effective date was December 31, 2010

http://www.fda.gov/OHRMS/DOCKETS/98fr/07-4663.pdf

Removal process for Epinephrine MDIs
- Open Public Meeting, December 5, 2007

- Armstrong did not oppose the proposal to eliminate the essential-use status for epinephrine, but requested postponing the effective date to December 31, 2011, to allow time for development and approval of an HFA-propelled epinephrine before phase out
- A patients' advocacy organization presented results of surveys finding that OTC epinephrine does not present a public health benefit worthy of continued essential use exemption

http://www.fda.gov/Drugs/DrugSafety/InformationbyDrugClass/ucm080512.htm

Removal process for Epinephrine MDIs
- Final Rule, November 19, 2008

- Published in the Federal Register (73 FR 69532) on November 19, 2008, with the following conclusion
  - There are no substantial technical barriers to formulating epinephrine as a product that does not release ODS, and therefore epinephrine is no longer an essential use of ODS
  - Effective date of December 31, 2011

http://edocket.access.gpo.gov/2008/E8-27436.htm

Epinephrine MDIs
- Public Health Benefit

- At the January 24, 2006, FDA Advisory Committee Meeting, the consensus opinion was that epinephrine MDIs present no significant therapeutic benefit and no advantage over albuterol MDIs
- Asthma Guidelines (NAEPP EPR-3) recommend against epinephrine use due to potential for excessive cardiac stimulation, especially in high doses, and recommends other short-acting beta-adrenergic bronchodilators (albuterol, levalbuterol, pirbuterol) instead
- Epinephrine MDIs do not provide “an unavailable important public health benefit” meaning that it does not
  - save lives
  - reduce or prevent an important morbidity
  - significantly increase patient quality of life

http://www.nhlbi.nih.gov/guidelines/asthma/

Epinephrine MDIs Phase-Out

- Epinephrine is a short-acting adrenergic bronchodilator marketed OTC
- 2-3 million people with asthma use OTC epinephrine (Presented by Wyeth at the FDA Advisory Committee Meeting, January 24, 2006)
- Albuterol MDIs marketed as a prescription product are a suitable alternative for patients currently using epinephrine MDIs

http://www.fda.gov/ohrms/dockets/ac/06/transcripts/2006-4200T.pdf

Epinephrine MDIs Phase-Out

- Epinephrine MDIs cannot be made or sold after December 31, 2011
- Patients using epinephrine MDIs should talk to their health care provider about switching to an alternate, such as albuterol HFA MDIs
- FDA is monitoring the transition closely
  - Regular inventory check with manufacturer
  - Ensuring adequate supply of alternates (e.g., albuterol MDIs)

http://www.fda.gov/Drugs/DrugSafety/InformationbyDrugClass/ucm193304.htm

Epinephrine MDIs Phase-Out

Communication Efforts

- FDA public meeting – Educating the Public About Removal of Essential Use Designation for Epinephrine - September 2009
- FDA webpage
  - Questions and Answers in English and Spanish – November 2008
  - Patient Safety News – July 2010
  - Podcast – April 2011
  - Consumer Update article – March 2011
  - Pharmacy Today article – May 2011
- Presentations at various public meetings
- Epinephrine carton/container with the phase-out message approved - April 2010

Consumer Health Information
www.fda.gov/consumer

Primatene Mist With Chlorofluorocarbons

No Longer Available After Dec. 31, 2011

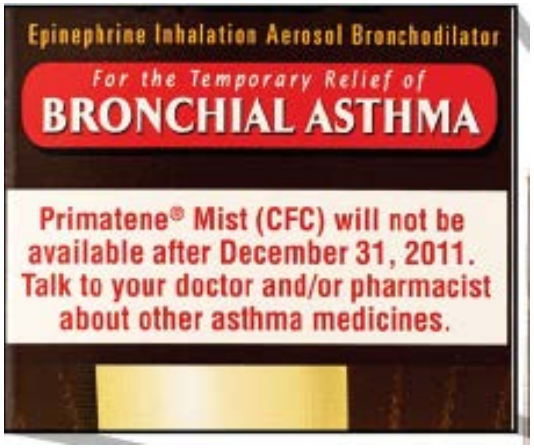
Epinephrine Inhalation Aerosol Bronchodilator
For the Temporary Relief of
BRONCHIAL ASTHMA
Primatene® Mist (CFC) will not be available after December 31, 2011. Talk to your doctor and/or pharmacist about other asthma medicines.

The only over-the-counter asthma inhaler sold in the United States will no longer be available next year as part of an international agreement to stop the use of substances that damage the environment.

Primatene Mist (epinephrine) is approved by the Food and Drug Administration (FDA) for the temporary relief of occasional symptoms of mild asthma. FDA urges those who use Primatene Mist to see a health care professional soon to switch to another asthma medicine.

Primatene Mist inhalers are being discontinued because they use chlorofluorocarbons (CFCs) as a propellant (spray) to move the medicine out of the inhaler so patients can breathe the medicine into their lungs.

CFCs harm the environment by decreasing the earth's ozone layer. This layer of the atmosphere protects us from some of the sun's harmful ultraviolet radiation, which can increase the risk of skin cancers and cataracts. The United States and most other countries have signed an international agreement to phase out CFCs and other ozone-depleting substances.



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Epinephrine MDIs Phase-Out

Communication Efforts

- EPA Stakeholder Meeting on U.S. Transition of Ozone-Safe Metered Dose Inhalers – September 8, 2011
- FDA plans for additional stakeholder outreach – September 2011
- Armstrong encouraged to educate and reach out to patients to make the transition smooth for patients
- Albuterol manufacturers
  - ensure adequate supply of alternative of albuterol HFA products
  - encouraged to educate and provide assistance programs for patients during transition
- Stakeholder involvement on all aspects of the transition

http://www.fda.gov/Drugs/DrugSafety/InformationbyDrugClass/ucm193304.htm

Epinephrine MDIs Phase-Out

Communication Efforts

U.S. Department of Health & Human Services

U.S. Food and Drug Administration

Home > Drugs > Drug Safety and Availability > Information by Drug Class

Drugs

Phase-Out of Epinephrine CFC Metered-Dose Inhalers

Epinephrine metered dose inhalers (MDIs) that contain chlorofluorocarbons (CFC) are being phased out and cannot be sold in the United States after December 31, 2011. Patients who use epinephrine CFC inhalers need to talk to their health care professionals and switch to another medicine before that date.

Epinephrine Phase-Out

- Inhaler phaseout approaching [1][2]
  FDA article in Pharmacy Today, 5/2011
- FDA Drug Safety Podcast: Primatene Mist With Chlorofluorocarbons No Longer Available After Dec. 31, 2011 [3]
  4/18/2011
- Primatene Mist With Chlorofluorocarbons No Longer Available After Dec. 31, 2011 [4]
  FDA Consumer Update article (3/16/2011)
- Epinephrine CFC Metered-dose Inhalers - Questions and Answers [5]
- Epinephrine CFC Metered-Dose Inhalers - Questions and Answers (PDF - 182KB) [6]
- Epinephrine CFC Metered-dose Inhalers - Questions and Answers - Podcast - Full Version mp3 (MP3 - 5495KB) [7]
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  4/4/2005
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- Educating the Public About Removal of Essential-Use Designation for Epinephrine [17]
  Public workshop (9/25/2009)
- Public Meeting on Essential Uses of Ozone Depleting Substances, December 5, 2007 [18]

http://www.fda.gov/Drugs/DrugSafety/InformationbyDrugClass/ucm193304.htm

EPA Stakeholder Meeting, September 8, 2011

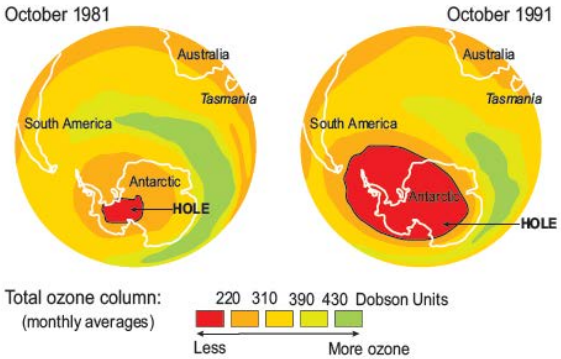
Criteria and Process that Removed the Exemption for CFC-Propelled Epinephrine MDIs

Badrul A. Chowdhury, MD, PhD

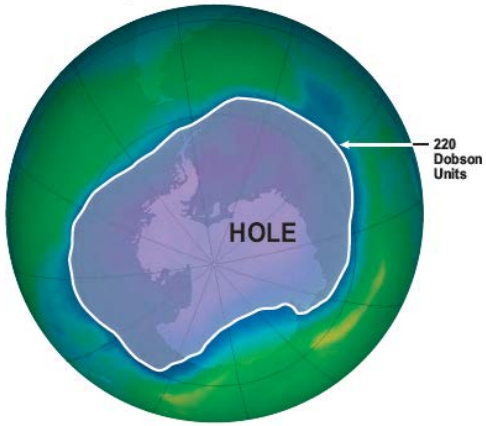
Director, Division of Pulmonary, Allergy, and Rheumatology Products, Center for Drug Evaluation and Research, US Food and Drug Administration

Ozone Depletion

The Antarctic Ozone Hole

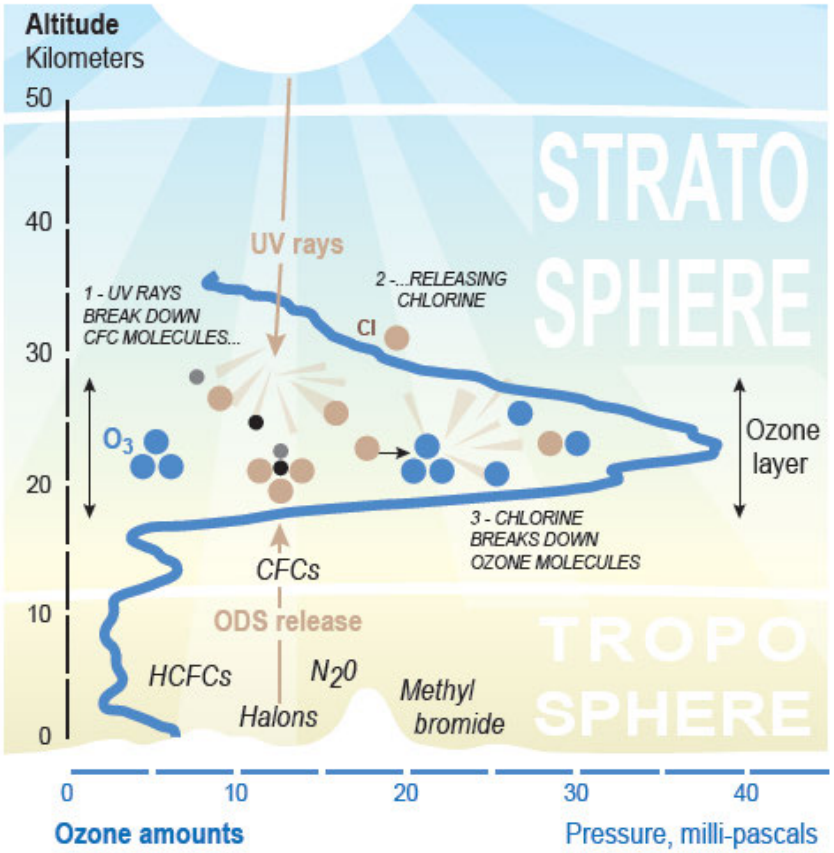


September 24, 2006



From September 21-30, 2006, the average area of the ozone hole was the largest ever observed.

Ozone Destruction in the Stratosphere



UNEP, Vital Ozone Graphics 2.0

Phase-out of CFC Use in MDIs

- Use of CFC banned in industrial countries effective 1996 and rest of the world effective 2010, except for essential uses
- Use of CFC in MDIs for asthma and COPD is conditionally exempted as essential medical use (FDA regulation 21 CFR 2.125, US Clean Air Act, and Montreal Protocol)

Status of CFC Propelled MDIs in the US
- Final Rules Removing Essential Use Designation of CFC Use

- Beclomethasone, dexamethasone, fluticasone, bitolterol, salmeterol, ergotamine tartrate, and ipratropium bromide
  - Effective April 23,2007
  - 71 FR 70870 (December 7, 2006) and 72 FR 20942 (April 27, 2007)
- Albuterol
  - Effective December 31, 2008
  - 70 FR 17168 (April 4, 2005)
- Epinephrine
  - Effective December 31, 2011
  - 73 FR 69532 (November 19, 2008)

http://www.fda.gov/Drugs/DrugSafety/InformationbyDrugClass/ucm063054.htm

Status of CFC Propelled MDIs in the US - Final Rules Removing Essential Use Designation of CFC Use (cont.)

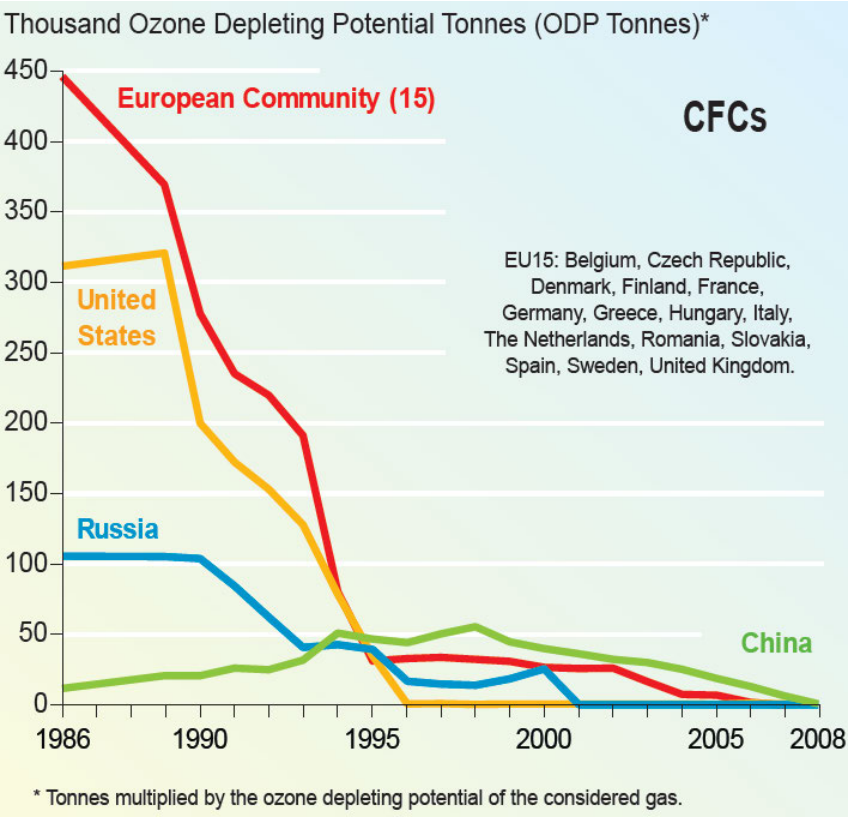
- "Seven moieties" rule
  - Metaproterenol — Effective June 14, 2010
  - Nedocromil — Effective June 14, 2010
  - Triamcinolone — Effective December 31, 2010
  - Cromolyn — Effective December 31, 2010
  - Flunisolide — Effective June 30, 2011
  - Pirbuterol — Effective December 31, 2013
  - Albuterol and Ipratropium — Effective December 31, 2013

  - 75 FR 19213 (April 14, 2010)

http://www.fda.gov/Drugs/DrugSafety/InformationbyDrugClass/ucm193896.htm

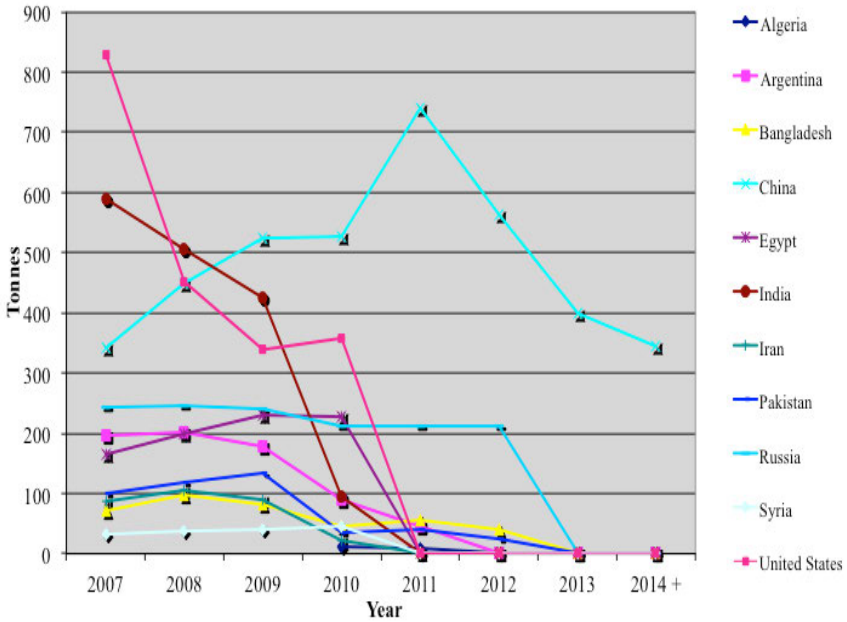
CFC Production and Usage

Production of the Main ODS Gases



UNEP, Vital Ozone Graphics 2.0

Estimated CFC Usage for MDI



UNEP, Report of the TEAP, May 2011

Essential Use
- Montreal protocol, Decision IV/25

- It is necessary for the health, safety or is critical for the functioning of society (encompassing cultural and intellectual aspects); and
- There are no available technically and economically feasible alternatives or substitutes that are acceptable from the standpoint of environment and health;

Essential Use
- United States

- Criteria for Removal of CFC Propelled MDIs after January 1, 2005, codified in 21 CFR 2.125 (g)(2) that cross references 21 CFR 2.125(f)
- Meeting ONE of the following criteria is adequate
  - No technical barriers exist to formulating the product without ozone depleting substances (ODSs)
  - The product will not provide an unavailable important public health benefit
  - Use of the product releases cumulatively significant amounts of ODSs into the atmosphere not warranted by public health benefit
- Allows for removal of products for which there are no alternates with the same active moiety

Regulatory Procedure for Removal of CFC Propelled MDIs

- Codified in 21 CFR 2.125 (g)(2)
  - Consult Advisory Committee
  - Publish Proposed Rule
  - Hold Open Public Meeting
  - Publish Final Rule

Epinephrine MDIs

- Epinephrine is a short-acting adrenergic bronchodilator
- New Drug Application (NDA) for over-the-counter (OTC) epinephrine MDI was approved in 1956
- NDA was held by Wyeth Consumer Healthcare, and currently held by Armstrong Pharmaceuticals Inc.

Removal process for Epinephrine MDIs - Advisory Committee, January 24, 2006

- Joint meeting of the Nonprescription Drug Advisory Committee (NDAC), and the Pulmonary and Allergy Drugs Advisory Committee (PADAC)
  - Wyeth estimated that 2-3 million people use OTC epinephrine MDIs
  - Convenience of having an OTC MDI for asthma discussed
  - Consensus opinion was that epinephrine MDIs present no significant therapeutic benefit and no advantage over albuterol MDIs
  - Majority of the Advisory Committee (11 No, 7 Yes) voted against retaining epinephrine's essential-use designation

http://www.fda.gov/ohrms/dockets/ac/06/transcripts/2006-4200T.pdf

Removal process for Epinephrine MDIs
- Proposed Rule, September 20, 2007

- Published in the Federal Register (72 FR 53711) on September 20, 2007, with the following tentative conclusion
  - There are no substantial technical barriers to formulating epinephrine as a product that does not release ODS, and therefore epinephrine no longer would no longer be an essential use of ODS
  - Proposed effective date was December 31, 2010

http://www.fda.gov/OHRMS/DOCKETS/98fr/07-4663.pdf

Removal process for Epinephrine MDIs
- Open Public Meeting, December 5, 2007

- Armstrong did not oppose the proposal to eliminate the essential-use status for epinephrine, but requested postponing the effective date to December 31, 2011, to allow time for development and approval of an HFA-propelled epinephrine before phase out
- A patients' advocacy organization presented results of surveys finding that OTC epinephrine does not present a public health benefit worthy of continued essential use exemption

http://www.fda.gov/Drugs/DrugSafety/InformationbyDrugClass/ucm080512.htm

Removal process for Epinephrine MDIs
- Final Rule, November 19, 2008

- Published in the Federal Register (73 FR 69532) on November 19, 2008, with the following conclusion
  - There are no substantial technical barriers to formulating epinephrine as a product that does not release ODS, and therefore epinephrine is no longer an essential use of ODS
  - Effective date of December 31, 2011

http://edocket.access.gpo.gov/2008/E8-27436.htm

Epinephrine MDIs
- Public Health Benefit

- At the January 24, 2006, FDA Advisory Committee Meeting, the consensus opinion was that epinephrine MDIs present no significant therapeutic benefit and no advantage over albuterol MDIs
- Asthma Guidelines (NAEPP EPR-3) recommend against epinephrine use due to potential for excessive cardiac stimulation, especially in high doses, and recommends other short-acting beta-adrenergic bronchodilators (albuterol, levalbuterol, pirbuterol) instead
- Epinephrine MDIs do not provide “an unavailable important public health benefit” meaning that it does not
  - save lives
  - reduce or prevent an important morbidity
  - significantly increase patient quality of life

http://www.nhlbi.nih.gov/guidelines/asthma/

Epinephrine MDIs Phase-Out

- Epinephrine is a short-acting adrenergic bronchodilator marketed OTC
- 2-3 million people with asthma use OTC epinephrine (Presented by Wyeth at the FDA Advisory Committee Meeting, January 24, 2006)
- Albuterol MDIs marketed as a prescription product are a suitable alternative for patients currently using epinephrine MDIs

http://www.fda.gov/ohrms/dockets/ac/06/transcripts/2006-4200T.pdf

Epinephrine MDIs Phase-Out

- Epinephrine MDIs cannot be made or sold after December 31, 2011
- Patients using epinephrine MDIs should talk to their health care provider about switching to an alternate, such as albuterol HFA MDIs
- FDA is monitoring the transition closely
  - Regular inventory check with manufacturer
  - Ensuring adequate supply of alternates (e.g., albuterol MDIs)

http://www.fda.gov/Drugs/DrugSafety/InformationbyDrugClass/ucm193304.htm

Epinephrine MDIs Phase-Out

Communication Efforts

- FDA public meeting – Educating the Public About Removal of Essential Use Designation for Epinephrine - September 2009
- FDA webpage
  - Questions and Answers in English and Spanish – November 2008
  - Patient Safety News – July 2010
  - Podcast – April 2011
  - Consumer Update article – March 2011
  - Pharmacy Today article – May 2011
- Presentations at various public meetings
- Epinephrine carton/container with the phase-out message approved - April 2010

Consumer Health Information
www.fda.gov/consumer

Primatene Mist With Chlorofluorocarbons

No Longer Available After Dec. 31, 2011

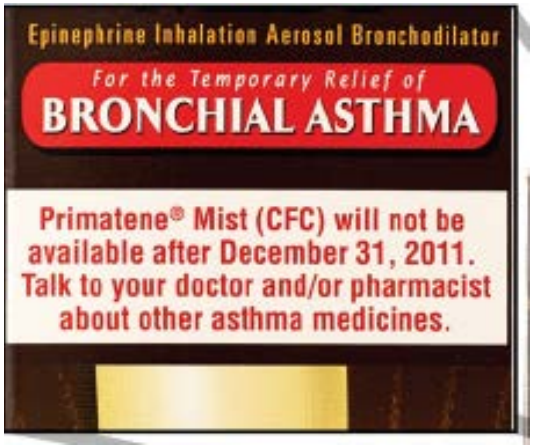
Epinephrine Inhalation Aerosol Bronchodilator
For the Temporary Relief of
BRONCHIAL ASTHMA
Primatene® Mist (CFC) will not be available after December 31, 2011. Talk to your doctor and/or pharmacist about other asthma medicines.

The only over-the-counter asthma inhaler sold in the United States will no longer be available next year as part of an international agreement to stop the use of substances that damage the environment.

Primatene Mist (epinephrine) is approved by the Food and Drug Administration (FDA) for the temporary relief of occasional symptoms of mild asthma. FDA urges those who use Primatene Mist to see a health care professional soon to switch to another asthma medicine.

Primatene Mist inhalers are being discontinued because they use chlorofluorocarbons (CFCs) as a propellant (spray) to move the medicine out of the inhaler so patients can breathe the medicine into their lungs.

CFCs harm the environment by decreasing the earth's ozone layer. This layer of the atmosphere protects us from some of the sun's harmful ultraviolet radiation, which can increase the risk of skin cancers and cataracts. The United States and most other countries have signed an international agreement to phase out CFCs and other ozone-depleting substances.



http://www.fda.gov/Drugs/DrugSafety/InformationbyDrugClass/ucm193304.htm

Epinephrine MDIs Phase-Out

Communication Efforts

- EPA Stakeholder Meeting on U.S. Transition of Ozone-Safe Metered Dose Inhalers – September 8, 2011
- FDA plans for additional stakeholder outreach – September 2011
- Armstrong encouraged to educate and reach out to patients to make the transition smooth for patients
- Albuterol manufacturers
  - ensure adequate supply of alternative of albuterol HFA products
  - encouraged to educate and provide assistance programs for patients during transition
- Stakeholder involvement on all aspects of the transition

http://www.fda.gov/Drugs/DrugSafety/InformationbyDrugClass/ucm193304.htm

Epinephrine MDIs Phase-Out

Communication Efforts

U.S. Department of Health & Human Services

U.S. Food and Drug Administration

Home > Drugs > Drug Safety and Availability > Information by Drug Class

Drugs

Phase-Out of Epinephrine CFC Metered-Dose Inhalers

Epinephrine metered dose inhalers (MDIs) that contain chlorofluorocarbons (CFC) are being phased out and cannot be sold in the United States after December 31, 2011. Patients who use epinephrine CFC inhalers need to talk to their health care professionals and switch to another medicine before that date.

Epinephrine Phase-Out

- Inhaler phaseout approaching [1][2]
  FDA article in Pharmacy Today, 5/2011
- FDA Drug Safety Podcast: Primatene Mist With Chlorofluorocarbons No Longer Available After Dec. 31, 2011 [3]
  4/18/2011
- Primatene Mist With Chlorofluorocarbons No Longer Available After Dec. 31, 2011 [4]
  FDA Consumer Update article (3/16/2011)
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Statement for the Record of Regina McCarthy
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Hearing on the "U.S. Agricultural Relief Act of 2012" and the "Asthma Inhalers Relief Act of 2012"

Subcommittee on Energy and Power
Committee on Energy and Commerce
July 18, 2012

Chairman Whitfield, Ranking Member Rush, and members of the Committee, I appreciate the opportunity to provide a written statement for the record on the draft bills entitled the "U.S. Agricultural Relief Act of 2012" and the "Asthma Inhalers Relief Act of 2012", which are presently before the Committee. These bills address the treatment of methyl bromide and Primatene Mist, respectively, which are or contain ozone-depleting substances that the United States has agreed to phase out of domestic production under the Montreal Protocol, subject to specified critical and essential use exemptions.

Although the Administration does not yet have a position on these draft bills, I would like to make several points that I hope will assist the Committee in its consideration of them. First, EPA does not believe that these bills are necessary. Through ongoing exemption programs under the Montreal Protocol and Title VI of the Clean Air Act, the Executive Branch already has sufficient tools to address issues related to continuing essential and critical needs for otherwise phased-out ozone depleting substances. Collaboration between relevant Executive Branch agencies in this area is strong. This collaboration was envisioned by Congress in the drafting of Title VI, and it has been instrumental in giving practical meaning to the flexibility built into the Montreal Protocol. Second, as explained in greater detail below, the bills could have a number

of unintended adverse consequences. Since each legislative draft deals with a very different exemption process and has differing potential consequences, I will deal with each separately.

Background on the Montreal Protocol

The Montreal Protocol on Substances that Deplete the Ozone Layer was ratified by the United States in 1987, with the personal support of President Ronald Reagan. The treaty, which has undergone multiple revisions over successive years, phases out the production of ozone depleting substances. Because the stratospheric ozone layer absorbs ultraviolet-B radiation that would otherwise reach the surface of the planet, emission of ozone depleting substances results in increased incidence of skin cancer and other health and environmental impacts. The Montreal Protocol has been ratified by 197 countries and is widely recognized as one of the most successful international treaties in force.

As part of the 1990 amendments to the Clean Air Act, Congress enacted Title VI of the Act, which directs EPA to work with other federal agencies to carry out U.S. Montreal Protocol commitments for phasing out ozone depleting substances. Title VI specifies mechanisms to increase the smoothness and clarity of this phase-out, including a ban on nonessential products and flexibility to allow continued production of ozone depleting substances in areas where additional time might be required to identify effective alternatives.

The United States has met Montreal Protocol requirements more rapidly, and at lower cost, than anticipated. By 1996, U.S. phaseouts were occurring four years faster, and covering more chemicals than initially planned, while estimated costs dropped by nearly a third. Ending damage to the ozone layer is expected to prevent millions of future U.S. deaths that would otherwise have occurred from skin cancer. EPA's 1999 study under Section 812 of the Clean Air Act concluded that the benefits of this program substantially exceed the costs.

The "U.S. Agricultural Sector Relief Act of 2012"

Methyl bromide is an odorless, colorless gas that has been used as a soil fumigant and structural fumigant to control pests across a wide range of agricultural sectors. Because methyl bromide depletes the stratospheric ozone layer, the amount of methyl bromide produced and imported in the United States was reduced incrementally until it was phased out in January 1, 2005, pursuant to our obligations under the Montreal Protocol and Title VI of the Clean Air Act.

Under the Protocol, the Parties to the Protocol have authority to permit exemptions from the phaseout for "critical" uses of methyl bromide that are nominated by a given country. The Protocol includes Decision IX/6, which states that:

> "use of methyl bromide should qualify as 'critical' only if the nominating Party determines that:
>
> (i) The specific use is critical because the lack of availability of methyl bromide for that use would result in a significant market disruption; and
>
> (ii) There are no technically and economically feasible alternatives or substitutes available to the user that are acceptable from the standpoint of environment and health and are suitable to the crops and circumstances of the nomination;"

EPA in 2003 established the Critical Use Exemption process for methyl bromide in anticipation of the 2005 phaseout, to provide for growers with critical needs for continued use of the fumigant beyond the phaseout. The U.S. Government develops each annual critical use nomination through a rigorous technical process involving the careful efforts of several agencies, and in close collaboration with the grower community.

Each year, EPA solicits applications from growers and grower groups. Staff of the EPA Office of Pesticide Programs and the U.S. Department of Agriculture (USDA) Office of Pest Management Policy review applications and work with growers to compile the best available information on current critical uses. We recognize the vital importance of extensive interaction with the user community. Accordingly, EPA and USDA work actively with applicants to identify information gaps, hold multiple calls and meetings to discuss specific agronomic conditions and to enhance supporting information, and provide support to, and attend, the annual Methyl Bromide Alternatives Outreach Conference. In addition, between 1995 and 2012, USDA – through the Agricultural Research Service (ARS), the Cooperative State Research Education and Extension Service (CSREES), and the Inter-regional Project 4 (IR-4) programs – has spent over $300 million on research and outreach related to alternatives for crops that used methyl bromide.

All these efforts have the common goal of allowing the U.S. government to develop technically supportable estimates for U.S. critical needs for methyl bromide. The value of the careful process has been demonstrated in our success to date in Montreal Protocol negotiations. The U.S. government has successfully defended our nominations for critical uses of methyl bromide, securing approval of an average of 88 percent of our nominated amount in each year from 2005 through 2013.

While the current Critical Use Exemption process has been effective and successful, the bill could disrupt that process in a number of respects. Most notably, the bill effectively requires EPA to pursue a critical use exemption under the Protocol – for each and every applicant in the full amount requested by the applicant – unless EPA can demonstrate to the applicant that the exemption in that amount would *not* be justified. As explained above, however, for a critical use

exemption to be approved, the Parties to the Protocol ultimately must determine that the requirements of the treaty are satisfied. The bill effectively shift the burden of proof for justifying a critical use exemption from the broad current group of stakeholders, including the critical users who are best positioned to understand the particulars of their needs, to EPA alone. This shift may have the unintended result of nominations that are not as fully technically supported as may be needed to secure international agreement.

Another concern raised by the bill is that, by codifying the list of critical uses set forth in the Code of Federal Regulations on January 1, 2005, it effectively resets the universe of critical users to those that existed in 2005. In so doing, it excludes an array of critical users that were identified after that date. At the same time, this provision of the bill will add back some uses that need not be on the list, as many once-critical users since 2005 have adopted alternatives and no longer rely on methyl bromide.

The bill enumerates "emergency uses" for methyl bromide, and in doing so, raises two potential concerns. At present, the treaty offers some flexibility in this area; if the United States enacts legislation setting forth a specific list, this may encourage the Parties to the Protocol to pursue greater specificity with regard to allowable emergency uses, potentially limiting important existing flexibility. Further, the bill's list excludes certain very high value, national security applications – for example, homeland security uses that may be needed, such as use of methyl bromide to decontaminate a building after Anthrax exposure.

Finally, EPA is concerned about how the proposed legislation might affect EPA's authority to regulate the use of methyl bromide under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). FIFRA authorizes EPA to require the registration of pesticides sold or distributed in commerce and, as part of the registration process, to approve the labeling of the

pesticide product. The draft legislation might preclude EPA from using FIFRA authorities to impose requirements on the manner in which methyl bromide may be used when authorized for emergency events. If the bill requires EPA to accept, without change, the terms of a request to use methyl bromide in an emergency event, EPA arguably would not be able to continue to decide how the use of methyl bromide, a pesticide, would be regulated under FIFRA. At present, and since methyl bromide was first approved for use as a pesticide, EPA has reviewed all proposals to use the compound and evaluated potential risks to public health and the environment. When necessary, EPA has required methyl bromide products to bear enforceable labeling that specifies how it can be used. Such requirements include, for example, limits on maximum rates of application, required protective equipment for applicators, and buffers to protect workers and bystanders. EPA regards the ability to continue to regulate the use of methyl bromide under FIFRA as critical to protecting public health and the environment.

The "Asthma Inhaler Relief Act of 2012"

Epinephrine is a short-acting beta-adrenergic bronchodilator used to treat wheezing and shortness of breath in patients with asthma. Marketed as Primatene Mist, epinephrine metered-dose inhalers (MDIs) that contain chlorofluorocarbons (CFCs) are over-the-counter inhalation aerosol products used to treat the symptoms of asthma. CFCs are ozone-depleting substances that, pursuant to the Montreal Protocol, were banned from domestic production in the United States in 1996.

Both the Montreal Protocol and Title VI allow for continued production of CFC-based metered dose inhalers through an essential use exemption provision. The Montreal Protocol includes Decision IV/25, which provides that an essential use exemption is available provided the following criteria are met:

"It is necessary for the health, safety or is critical for the functioning of society (encompassing cultural and intellectual aspects); and

There are no available technically and economically feasible alternatives or substitutes that are acceptable from the standpoint of environment and health;"

Congress, through Title VI of the Clean Air Act, effectively established a partnership between EPA and the U.S. Food and Drug Administration (FDA) to guide a gradual, patient-safe transition to non-CFC propellants for asthma treatments. Since the prior CFC propellants were banned in 1996, EPA has managed the essential use exemption process for these products. Under this process, EPA solicited information from pharmaceutical makers about annual CFC needs, developed essential use exemption requests in close consultation with FDA, and worked with FDA and the Department of State to secure U.S. nomination amounts before the Parties to the Montreal Protocol. EPA then completed rulemakings to allow for additional production of otherwise banned CFCs in amounts authorized by the Parties to the Montreal Protocol. These amounts were determined by careful review and coordination with FDA, the agency with the responsibility for determining the medical necessity for continued essential use status for each individual active agent used to treat asthma.

This interagency partnership has been highly successful. Since the CFC phaseout in 1996, FDA has approved 19 safe and effective alternative asthma treatments. In the case of Primatene Mist, FDA conducted a thorough public process involving stakeholders, pharmaceutical manufacturers, medical and patient advocacy groups, a 2008 FDA rule set a date for removing epinephrine from the Clean Air Act list of essential CFC uses, stating that continued availability of epinephrine is not necessary to save lives, to reduce or prevent asthma morbidity, or to significantly increase patient quality of life. In response to a request from the

manufacturer to allow the additional time needed to bring to market a non-CFC ephinephrine alternative, FDA delayed the rule's effective date to January 1, 2012, when Primatene Mist became subject to the CAA ban on sale and distribution.

The withdrawal of epinephrine metered dose inhalers was one of many successful transitions to newer safe and effective asthma therapies. The certainty and transparency of this process allowed pharmaceutical manufacturers ample time – 20 years in the case of epinephrine – to research, develop and secure regulatory approval for patient-friendly effective alternatives. We are concerned that a bill to require EPA to allow the sale of remaining stocks of epinephrine inhalers would confuse patients, reduce confidence in the transition process, and send a strong signal to other pharmaceutical manufacturers that orderly engagement in public policy processes may not be rewarded. Further, the bill's language is directed at restricting EPA enforcement authority. Among other concerns, the Committee should be aware that, since the bill does not amend the underlying Clean Air Act ban on sale of nonessential products, this means there is no barrier to possible citizen suits associated with continued sales of otherwise banned materials.

Conclusion

In summary, existing flexibilities under the Montreal Protocol and the Clean Air Act have proven adequate to address critical use issues associated with ozone-depleting substances. Using these flexibilities, EPA and its federal agency partners have worked cooperatively with stakeholders to safely and effectively address issues associated with methyl bromide and Primatene Mist. EPA does not believe that the draft bills before the Committee are necessary and is concerned that their enactment could lead to a number of unintended and adverse consequences. Accordingly, I respectfully urge the Committee to carefully consider these issues as it proceeds.

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Assistant Administrator of Air and Radiation
U.S. Environmental Protection Agency

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The Montreal Protocol on Substances that Deplete the Ozone Layer was ratified by the United States in 1987, with the personal support of President Ronald Reagan. The treaty, which has undergone multiple revisions over successive years, phases out the production of ozone depleting substances. Because the stratospheric ozone layer absorbs ultraviolet-B radiation that would otherwise reach the surface of the planet, emission of ozone depleting substances results in increased incidence of skin cancer and other health and environmental impacts. The Montreal Protocol has been ratified by 197 countries and is widely recognized as one of the most successful international treaties in force.

As part of the 1990 amendments to the Clean Air Act, Congress enacted Title VI of the Act, which directs EPA to work with other federal agencies to carry out U.S. Montreal Protocol commitments for phasing out ozone depleting substances. Title VI specifies mechanisms to increase the smoothness and clarity of this phase-out, including a ban on nonessential products and flexibility to allow continued production of ozone depleting substances in areas where additional time might be required to identify effective alternatives.

The United States has met Montreal Protocol requirements more rapidly, and at lower cost, than anticipated. By 1996, U.S. phaseouts were occurring four years faster, and covering more chemicals than initially planned, while estimated costs dropped by nearly a third. Ending damage to the ozone layer is expected to prevent millions of future U.S. deaths that would otherwise have occurred from skin cancer. EPA's 1999 study under Section 812 of the Clean Air Act concluded that the benefits of this program substantially exceed the costs.

The "U.S. Agricultural Sector Relief Act of 2012"

Methyl bromide is an odorless, colorless gas that has been used as a soil fumigant and structural fumigant to control pests across a wide range of agricultural sectors. Because methyl bromide depletes the stratospheric ozone layer, the amount of methyl bromide produced and imported in the United States was reduced incrementally until it was phased out in January 1, 2005, pursuant to our obligations under the Montreal Protocol and Title VI of the Clean Air Act.

Under the Protocol, the Parties to the Protocol have authority to permit exemptions from the phaseout for "critical" uses of methyl bromide that are nominated by a given country. The Protocol includes Decision IX/6, which states that:

> "use of methyl bromide should qualify as 'critical' only if the nominating Party determines that:
>
> (i) The specific use is critical because the lack of availability of methyl bromide for that use would result in a significant market disruption; and
>
> (ii) There are no technically and economically feasible alternatives or substitutes available to the user that are acceptable from the standpoint of environment and health and are suitable to the crops and circumstances of the nomination;"

EPA in 2003 established the Critical Use Exemption process for methyl bromide in anticipation of the 2005 phaseout, to provide for growers with critical needs for continued use of the fumigant beyond the phaseout. The U.S. Government develops each annual critical use nomination through a rigorous technical process involving the careful efforts of several agencies, and in close collaboration with the grower community.

Each year, EPA solicits applications from growers and grower groups. Staff of the EPA Office of Pesticide Programs and the U.S. Department of Agriculture (USDA) Office of Pest Management Policy review applications and work with growers to compile the best available information on current critical uses. We recognize the vital importance of extensive interaction with the user community. Accordingly, EPA and USDA work actively with applicants to identify information gaps, hold multiple calls and meetings to discuss specific agronomic conditions and to enhance supporting information, and provide support to, and attend, the annual Methyl Bromide Alternatives Outreach Conference. In addition, between 1995 and 2012, USDA – through the Agricultural Research Service (ARS), the Cooperative State Research Education and Extension Service (CSREES), and the Inter-regional Project 4 (IR-4) programs – has spent over $300 million on research and outreach related to alternatives for crops that used methyl bromide.

All these efforts have the common goal of allowing the U.S. government to develop technically supportable estimates for U.S. critical needs for methyl bromide. The value of the careful process has been demonstrated in our success to date in Montreal Protocol negotiations. The U.S. government has successfully defended our nominations for critical uses of methyl bromide, securing approval of an average of 88 percent of our nominated amount in each year from 2005 through 2013.

While the current Critical Use Exemption process has been effective and successful, the bill could disrupt that process in a number of respects. Most notably, the bill effectively requires EPA to pursue a critical use exemption under the Protocol – for each and every applicant in the full amount requested by the applicant – unless EPA can demonstrate to the applicant that the exemption in that amount would *not* be justified. As explained above, however, for a critical use

exemption to be approved, the Parties to the Protocol ultimately must determine that the requirements of the treaty are satisfied. The bill effectively shift the burden of proof for justifying a critical use exemption from the broad current group of stakeholders, including the critical users who are best positioned to understand the particulars of their needs, to EPA alone. This shift may have the unintended result of nominations that are not as fully technically supported as may be needed to secure international agreement.

Another concern raised by the bill is that, by codifying the list of critical uses set forth in the Code of Federal Regulations on January 1, 2005, it effectively resets the universe of critical users to those that existed in 2005. In so doing, it excludes an array of critical users that were identified after that date. At the same time, this provision of the bill will add back some uses that need not be on the list, as many once-critical users since 2005 have adopted alternatives and no longer rely on methyl bromide.

The bill enumerates "emergency uses" for methyl bromide, and in doing so, raises two potential concerns. At present, the treaty offers some flexibility in this area; if the United States enacts legislation setting forth a specific list, this may encourage the Parties to the Protocol to pursue greater specificity with regard to allowable emergency uses, potentially limiting important existing flexibility. Further, the bill's list excludes certain very high value, national security applications – for example, homeland security uses that may be needed, such as use of methyl bromide to decontaminate a building after Anthrax exposure.

Finally, EPA is concerned about how the proposed legislation might affect EPA's authority to regulate the use of methyl bromide under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). FIFRA authorizes EPA to require the registration of pesticides sold or distributed in commerce and, as part of the registration process, to approve the labeling of the

pesticide product. The draft legislation might preclude EPA from using FIFRA authorities to impose requirements on the manner in which methyl bromide may be used when authorized for emergency events. If the bill requires EPA to accept, without change, the terms of a request to use methyl bromide in an emergency event, EPA arguably would not be able to continue to decide how the use of methyl bromide, a pesticide, would be regulated under FIFRA. At present, and since methyl bromide was first approved for use as a pesticide, EPA has reviewed all proposals to use the compound and evaluated potential risks to public health and the environment. When necessary, EPA has required methyl bromide products to bear enforceable labeling that specifies how it can be used. Such requirements include, for example, limits on maximum rates of application, required protective equipment for applicators, and buffers to protect workers and bystanders. EPA regards the ability to continue to regulate the use of methyl bromide under FIFRA as critical to protecting public health and the environment.

The "Asthma Inhaler Relief Act of 2012"

Epinephrine is a short-acting beta-adrenergic bronchodilator used to treat wheezing and shortness of breath in patients with asthma. Marketed as Primatene Mist, epinephrine metered-dose inhalers (MDIs) that contain chlorofluorocarbons (CFCs) are over-the-counter inhalation aerosol products used to treat the symptoms of asthma. CFCs are ozone-depleting substances that, pursuant to the Montreal Protocol, were banned from domestic production in the United States in 1996.

Both the Montreal Protocol and Title VI allow for continued production of CFC-based metered dose inhalers through an essential use exemption provision. The Montreal Protocol includes Decision IV/25, which provides that an essential use exemption is available provided the following criteria are met:

"It is necessary for the health, safety or is critical for the functioning of society (encompassing cultural and intellectual aspects); and

There are no available technically and economically feasible alternatives or substitutes that are acceptable from the standpoint of environment and health;"

Congress, through Title VI of the Clean Air Act, effectively established a partnership between EPA and the U.S. Food and Drug Administration (FDA) to guide a gradual, patient-safe transition to non-CFC propellants for asthma treatments. Since the prior CFC propellants were banned in 1996, EPA has managed the essential use exemption process for these products. Under this process, EPA solicited information from pharmaceutical makers about annual CFC needs, developed essential use exemption requests in close consultation with FDA, and worked with FDA and the Department of State to secure U.S. nomination amounts before the Parties to the Montreal Protocol. EPA then completed rulemakings to allow for additional production of otherwise banned CFCs in amounts authorized by the Parties to the Montreal Protocol. These amounts were determined by careful review and coordination with FDA, the agency with the responsibility for determining the medical necessity for continued essential use status for each individual active agent used to treat asthma.

This interagency partnership has been highly successful. Since the CFC phaseout in 1996, FDA has approved 19 safe and effective alternative asthma treatments. In the case of Primatene Mist, FDA conducted a thorough public process involving stakeholders, pharmaceutical manufacturers, medical and patient advocacy groups, a 2008 FDA rule set a date for removing epinephrine from the Clean Air Act list of essential CFC uses, stating that continued availability of epinephrine is not necessary to save lives, to reduce or prevent asthma morbidity, or to significantly increase patient quality of life. In response to a request from the

manufacturer to allow the additional time needed to bring to market a non-CFC ephinephrine alternative, FDA delayed the rule's effective date to January 1, 2012, when Primatene Mist became subject to the CAA ban on sale and distribution.

The withdrawal of epinephrine metered dose inhalers was one of many successful transitions to newer safe and effective asthma therapies. The certainty and transparency of this process allowed pharmaceutical manufacturers ample time – 20 years in the case of epinephrine – to research, develop and secure regulatory approval for patient-friendly effective alternatives. We are concerned that a bill to require EPA to allow the sale of remaining stocks of epinephrine inhalers would confuse patients, reduce confidence in the transition process, and send a strong signal to other pharmaceutical manufacturers that orderly engagement in public policy processes may not be rewarded. Further, the bill's language is directed at restricting EPA enforcement authority. Among other concerns, the Committee should be aware that, since the bill does not amend the underlying Clean Air Act ban on sale of nonessential products, this means there is no barrier to possible citizen suits associated with continued sales of otherwise banned materials.

Conclusion

In summary, existing flexibilities under the Montreal Protocol and the Clean Air Act have proven adequate to address critical use issues associated with ozone-depleting substances. Using these flexibilities, EPA and its federal agency partners have worked cooperatively with stakeholders to safely and effectively address issues associated with methyl bromide and Primatene Mist. EPA does not believe that the draft bills before the Committee are necessary and is concerned that their enactment could lead to a number of unintended and adverse consequences. Accordingly, I respectfully urge the Committee to carefully consider these issues as it proceeds.

SUN SAFETY PROGRAMS

Environmental Protection Agency

Drusilla Hufford, Director
Stratospheric Protection Division, U.S. EPA

Briefing for the Florida Society of Dermatology and Dermatologic Surgery

May 2012

Scope of Briefing

- Problem: rising skin cancer rates
- Causes: behavior, genetics, ozone depletion
- EPA's Response: protect the ozone layer and share information about sun safety
  - SunWise program
  - UV Index
  - Don't Fry Day
- Summary

Rising Skin Cancer Rates

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- High cost of skin cancer
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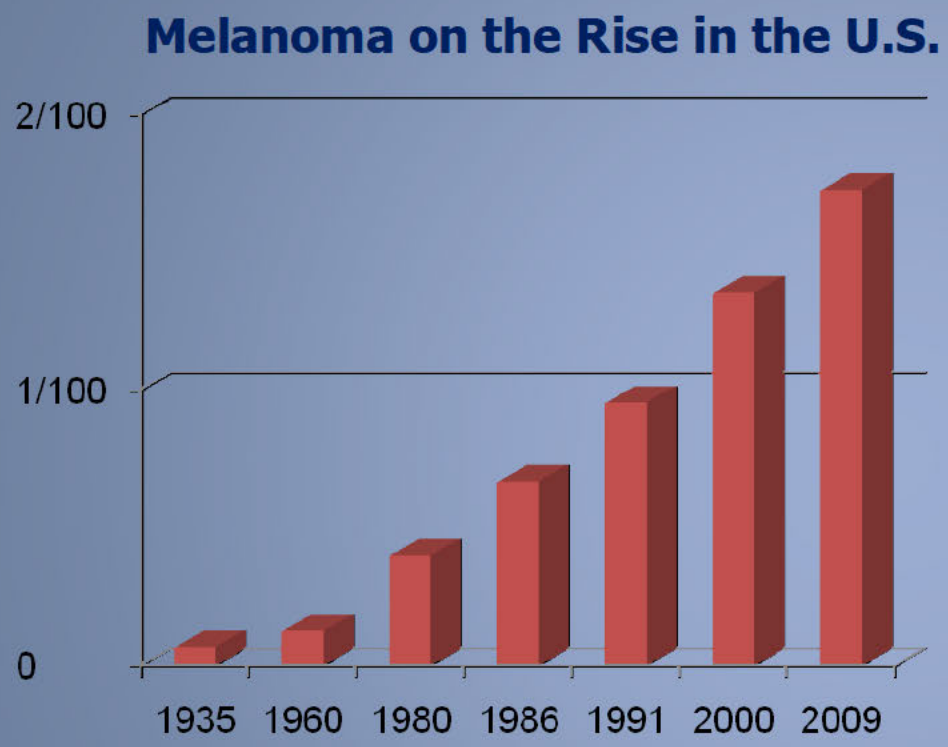

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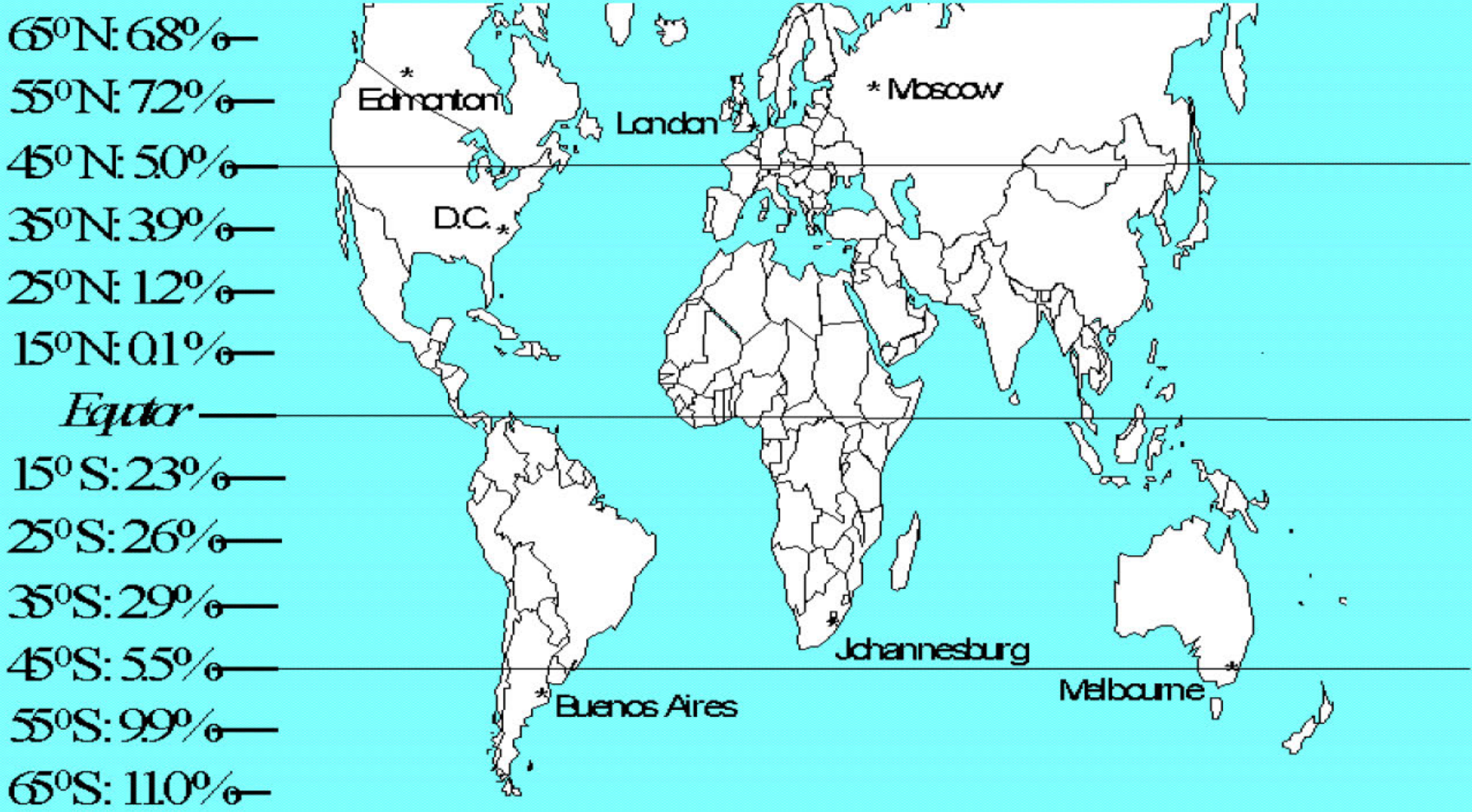

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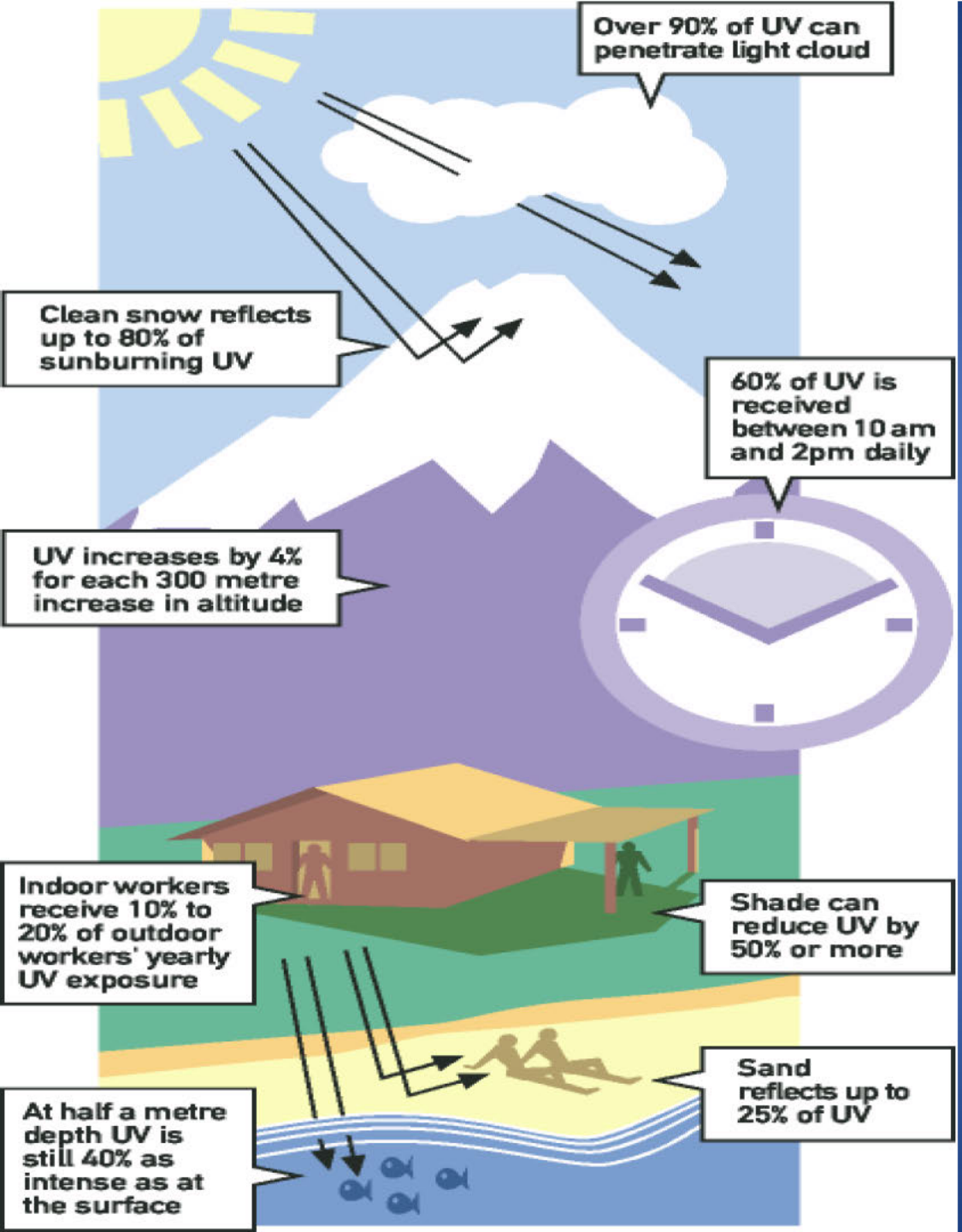

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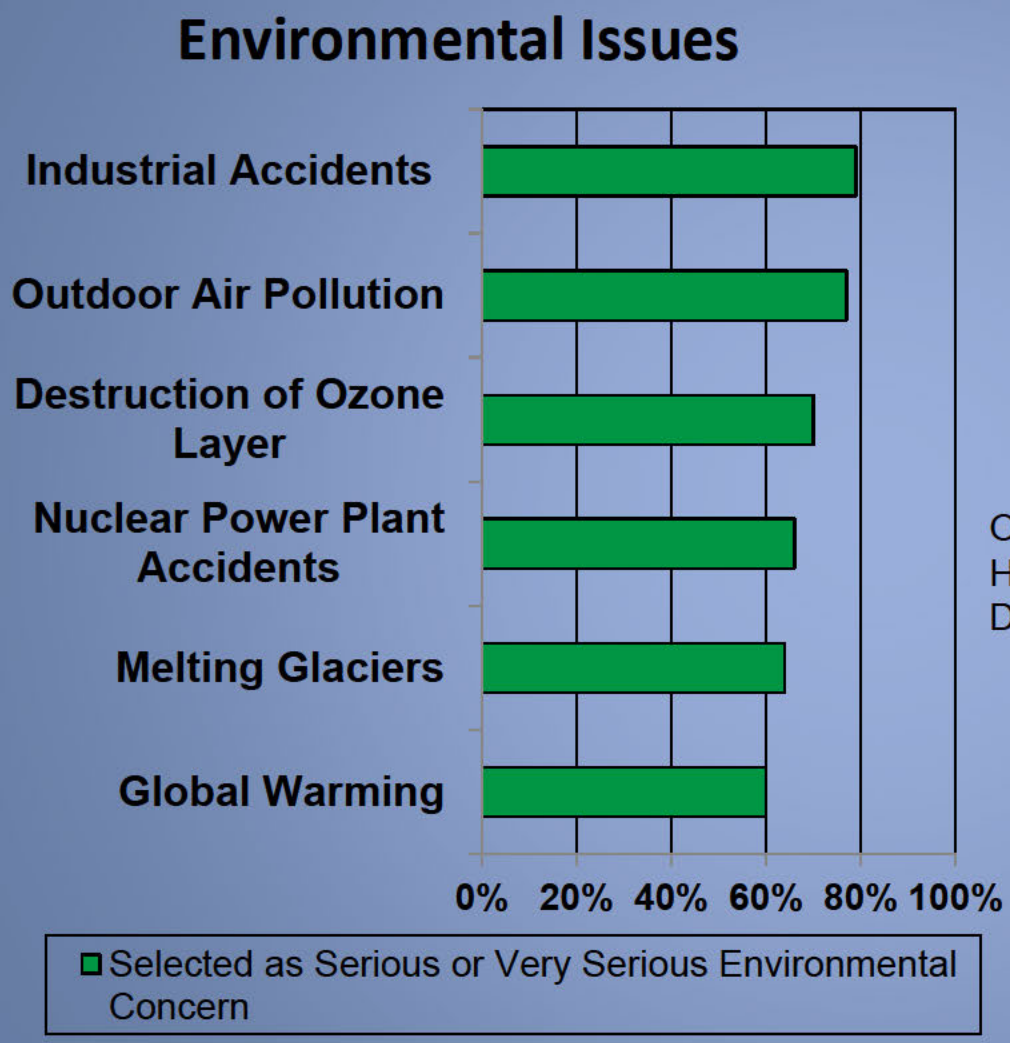

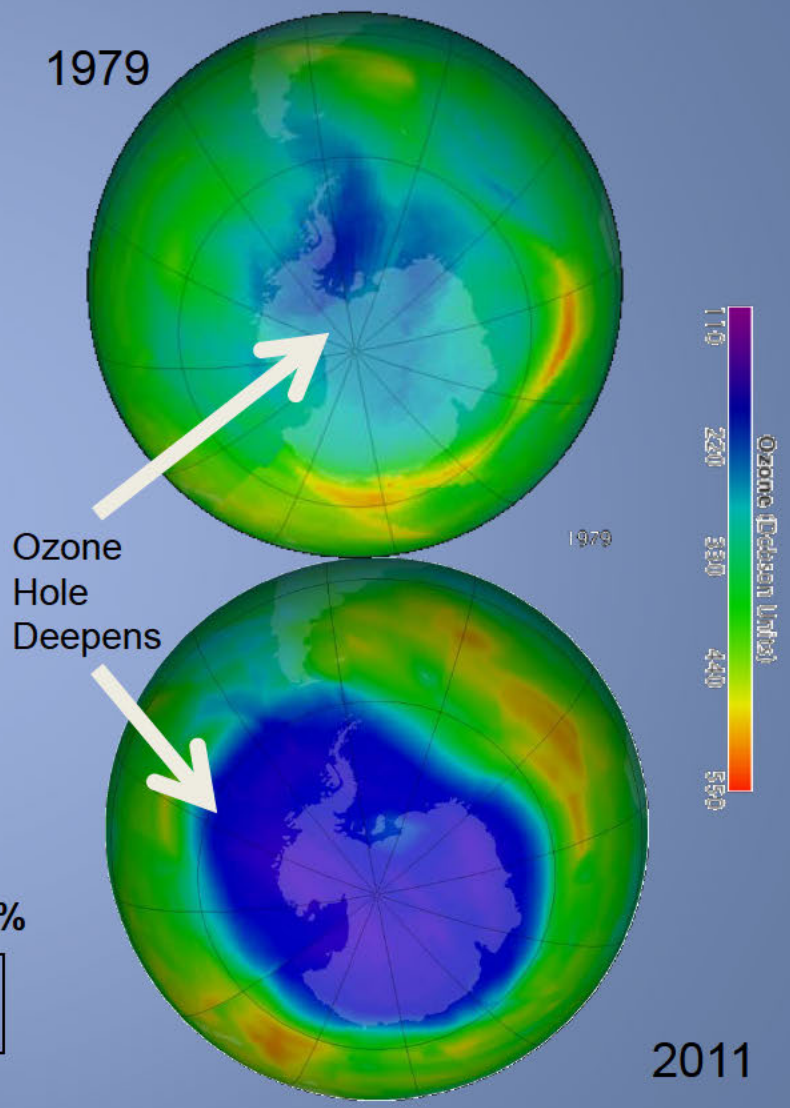

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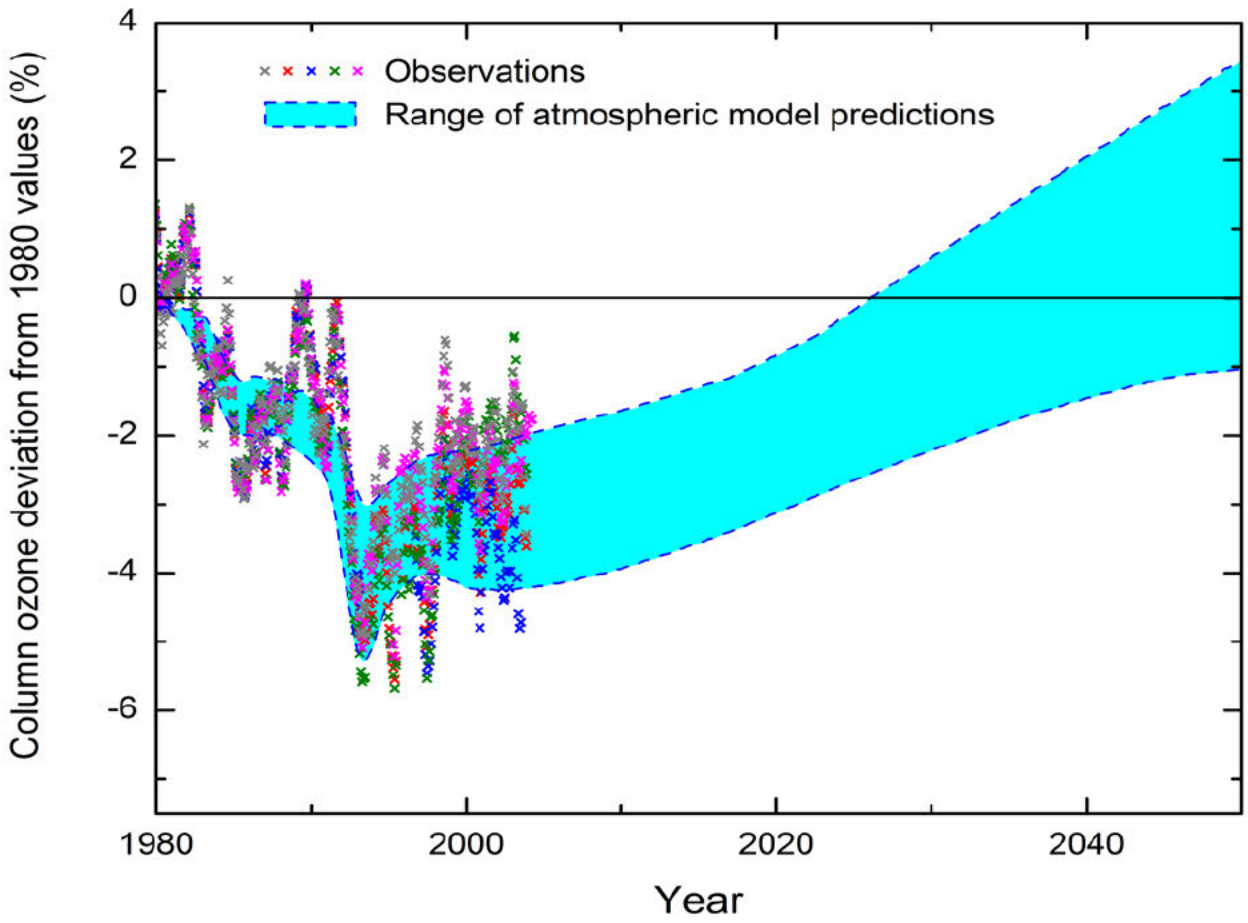

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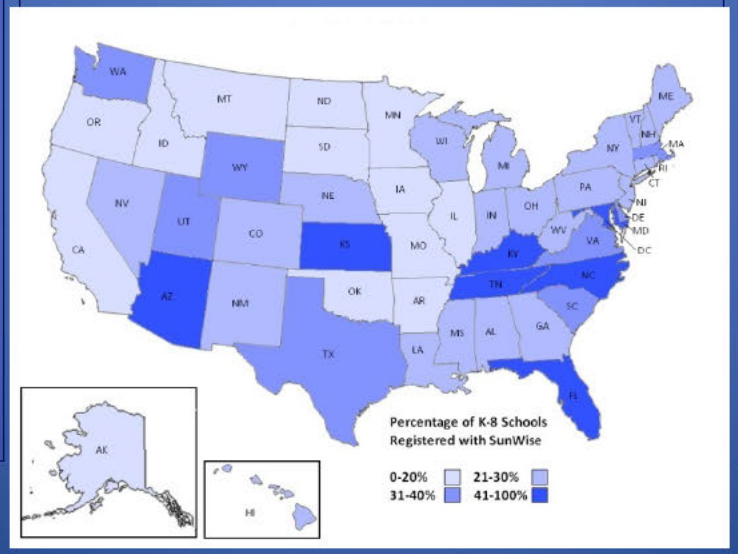

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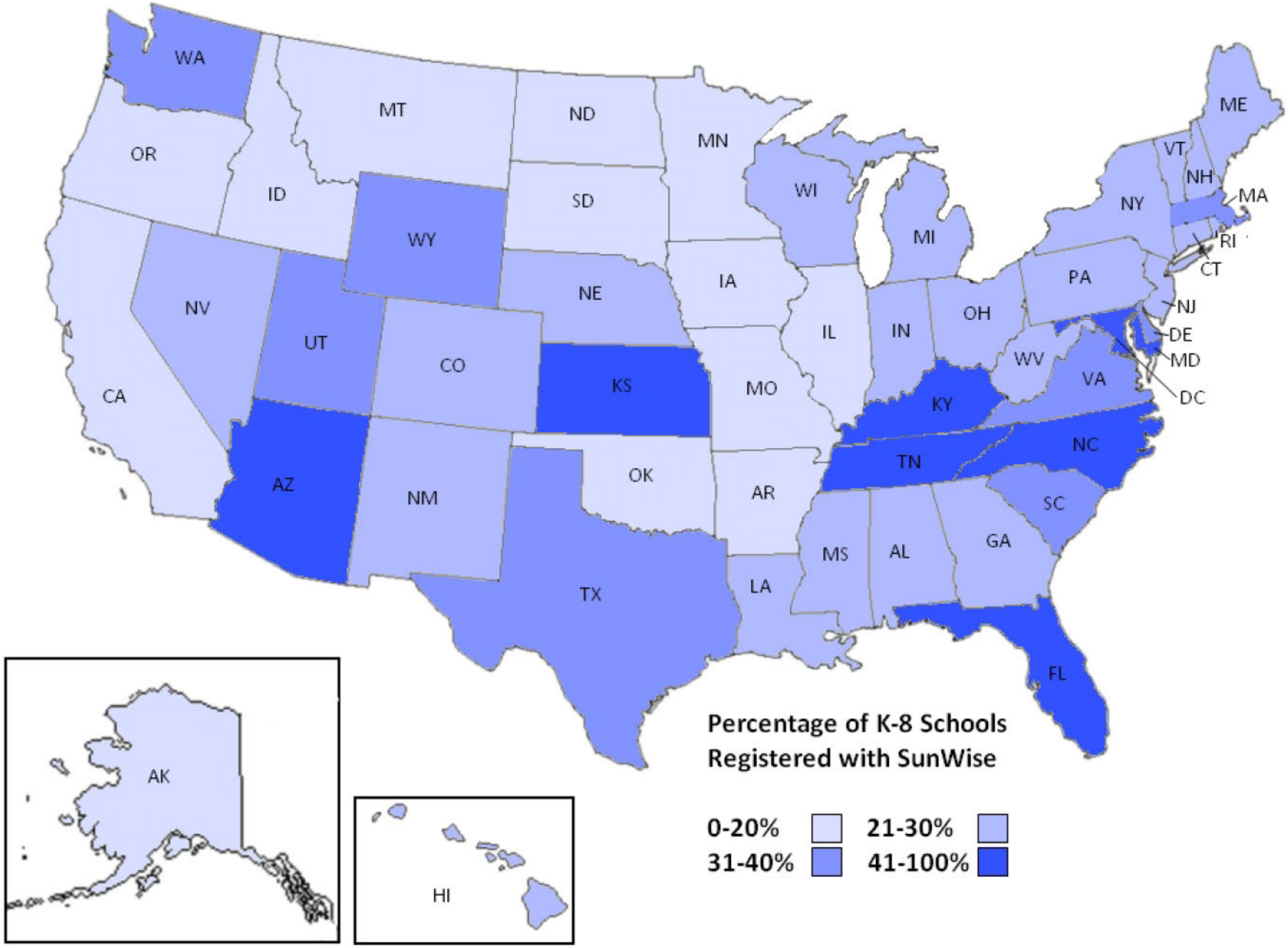
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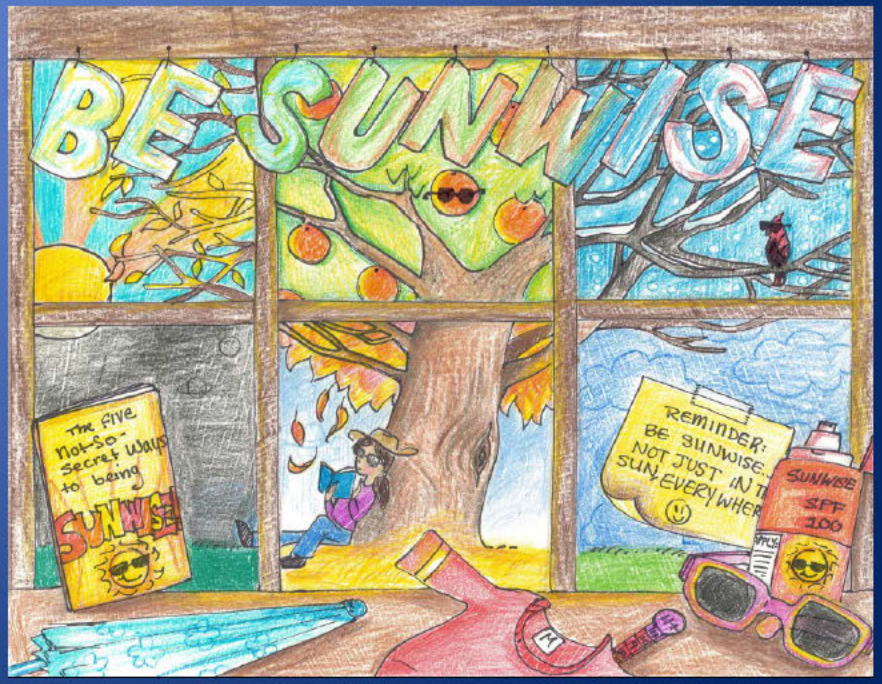

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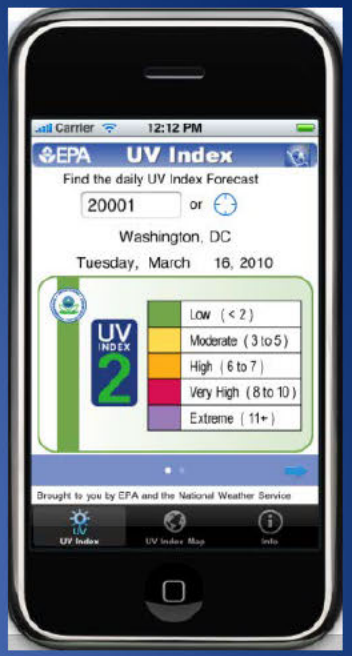

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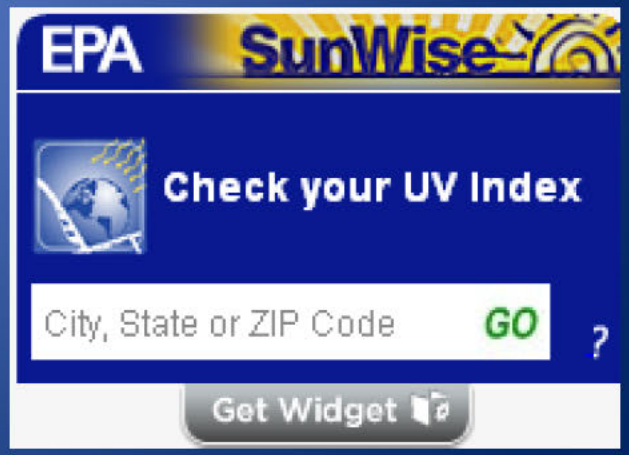

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For more information, please contact:

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Hufford.Drusilla@epa.gov

SunWise Program
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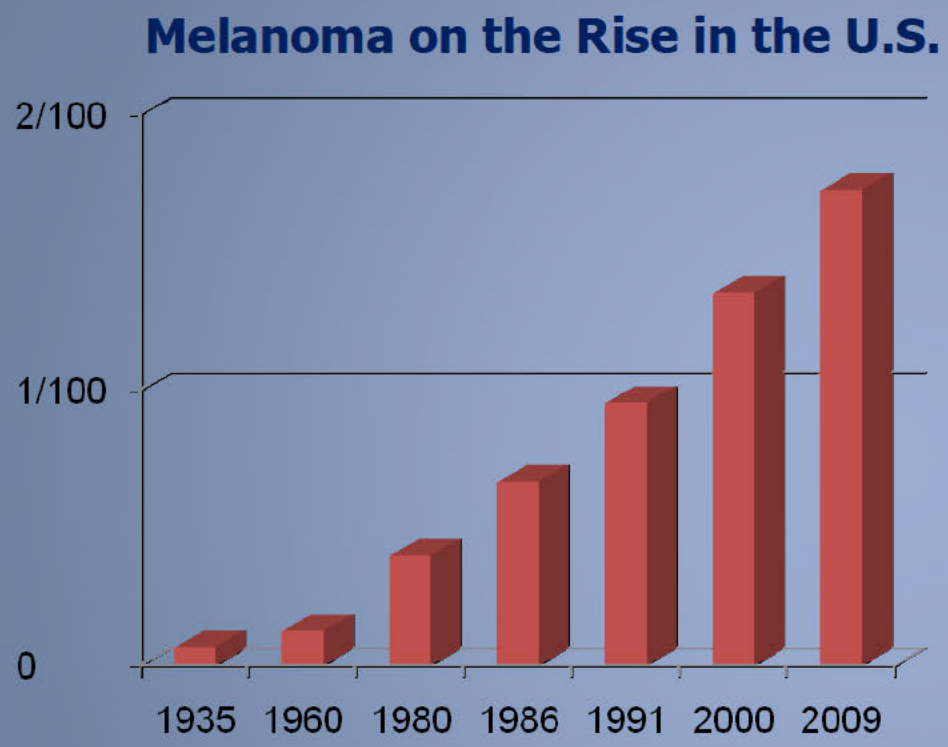

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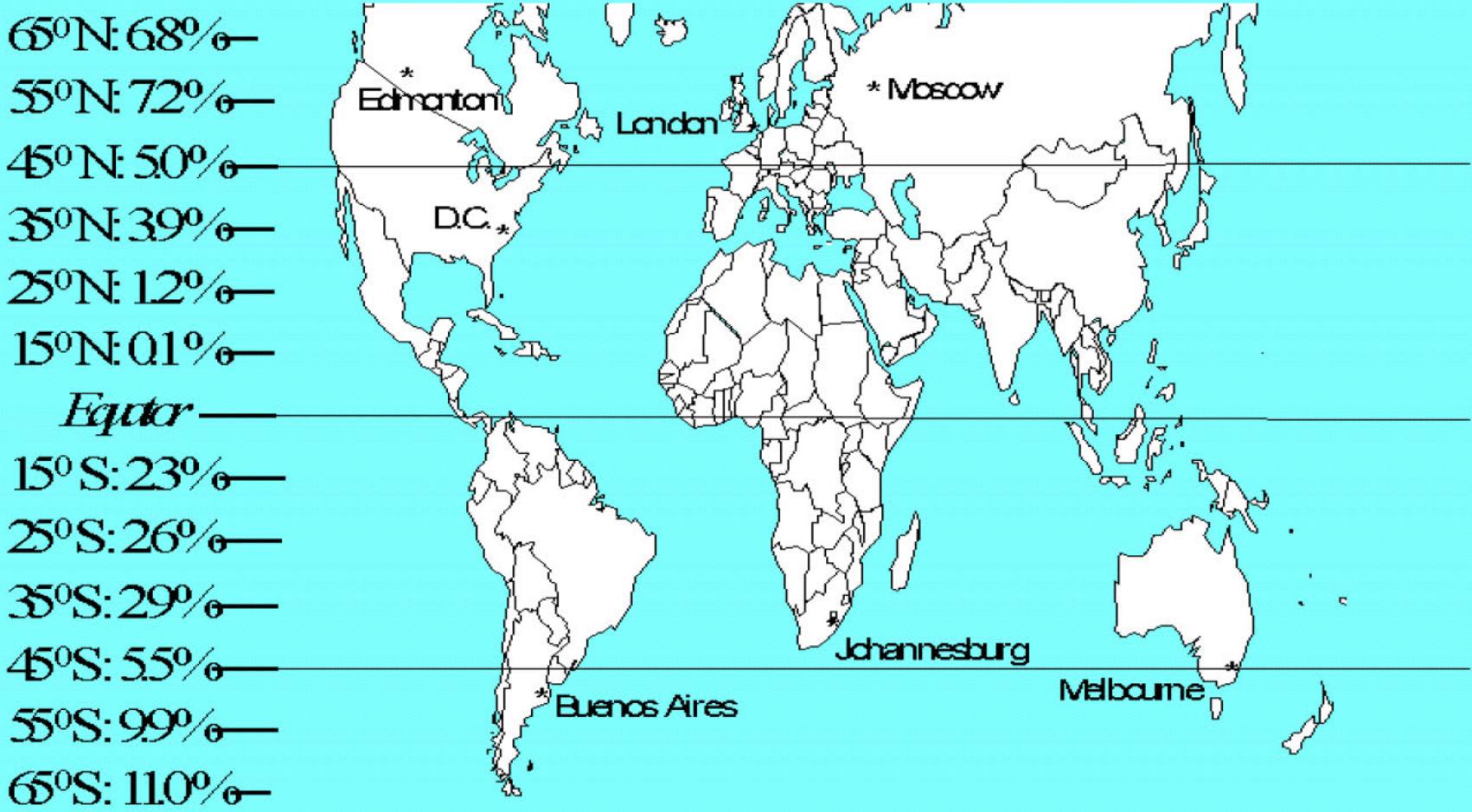

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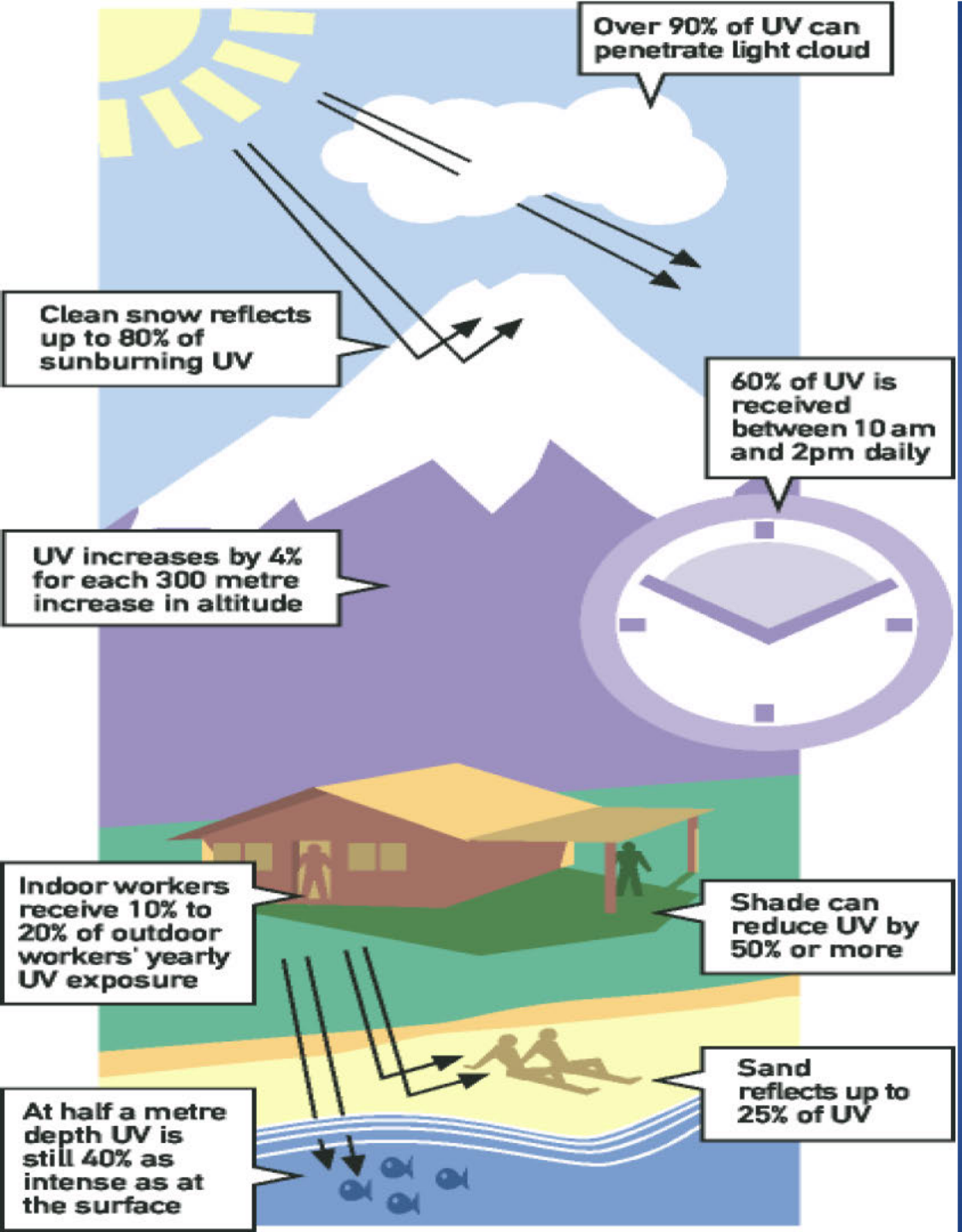

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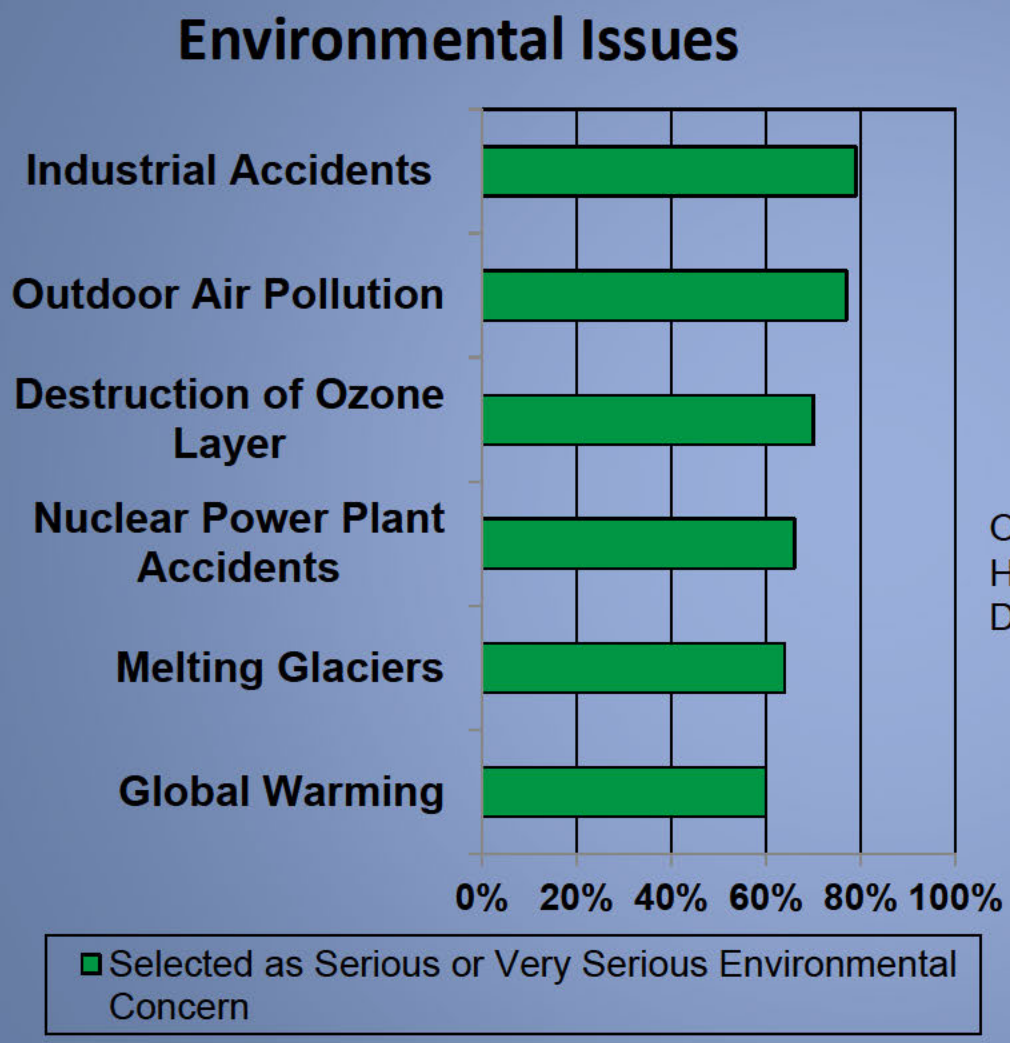

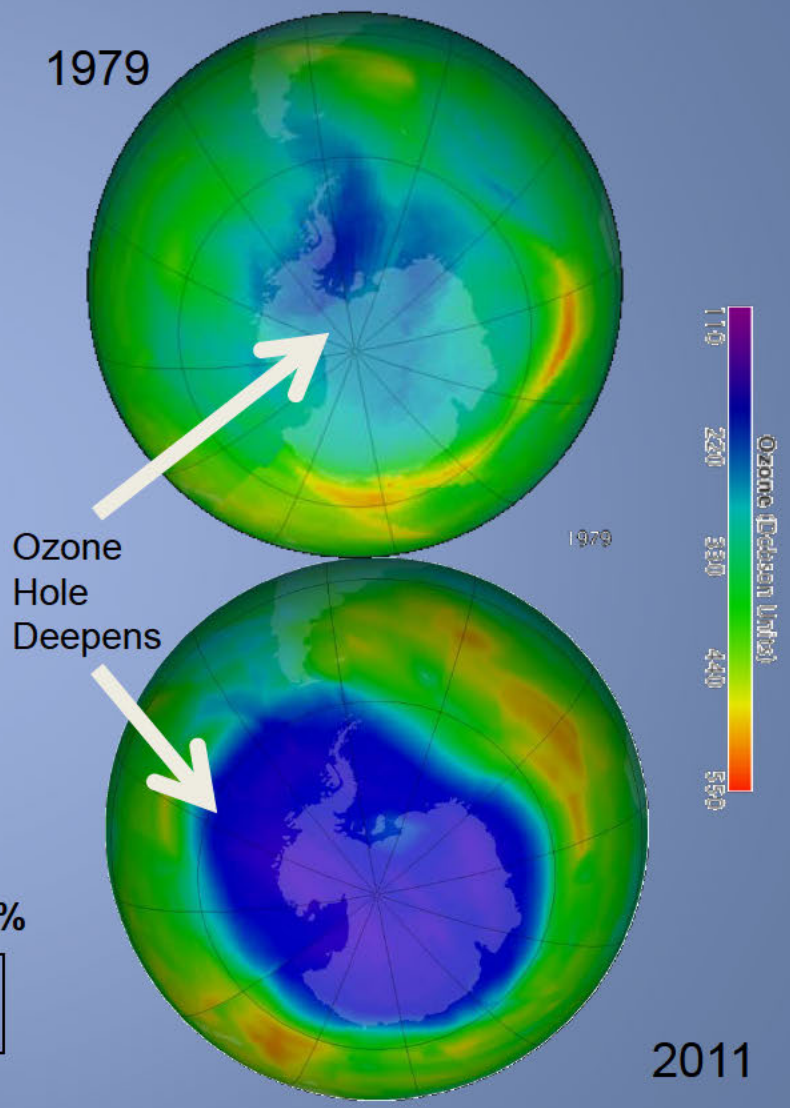

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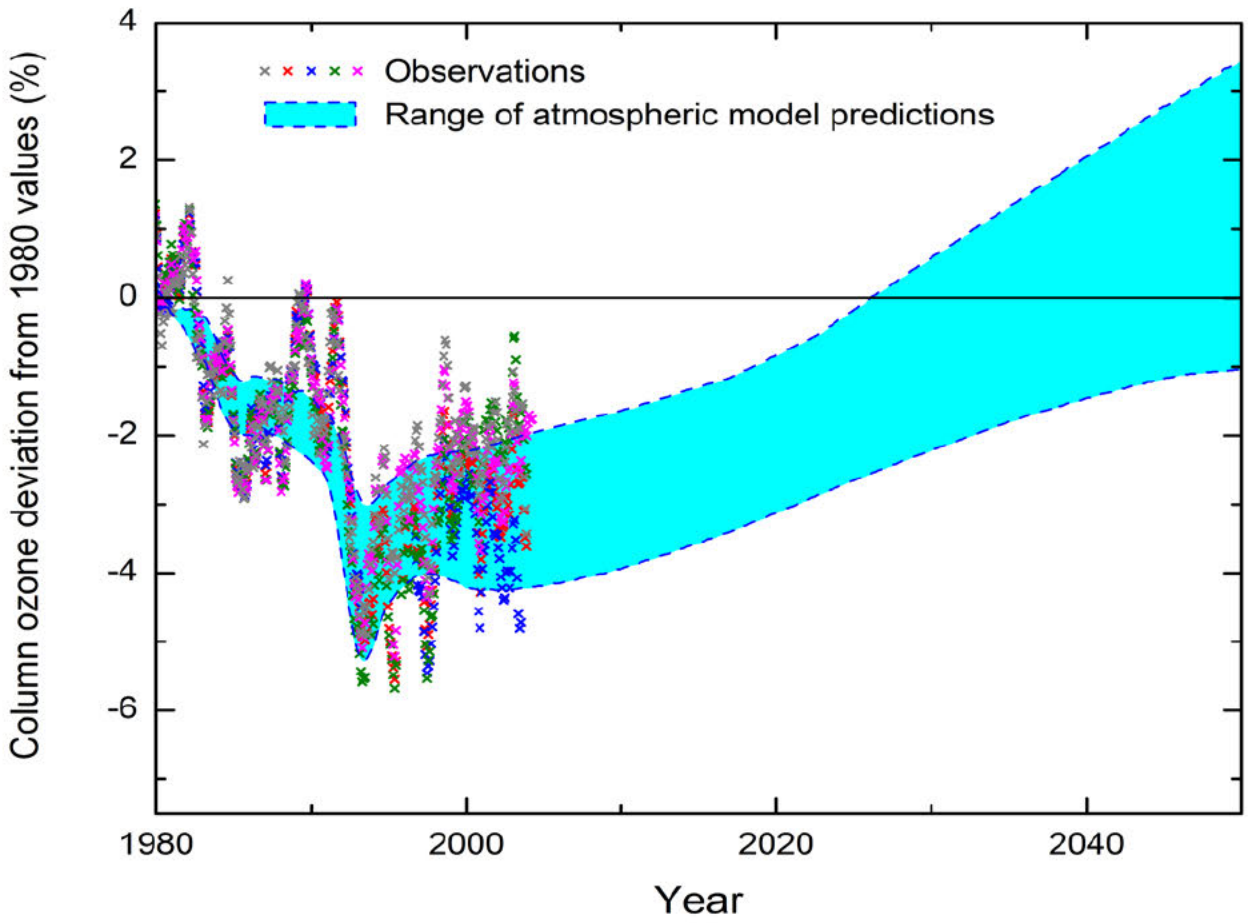

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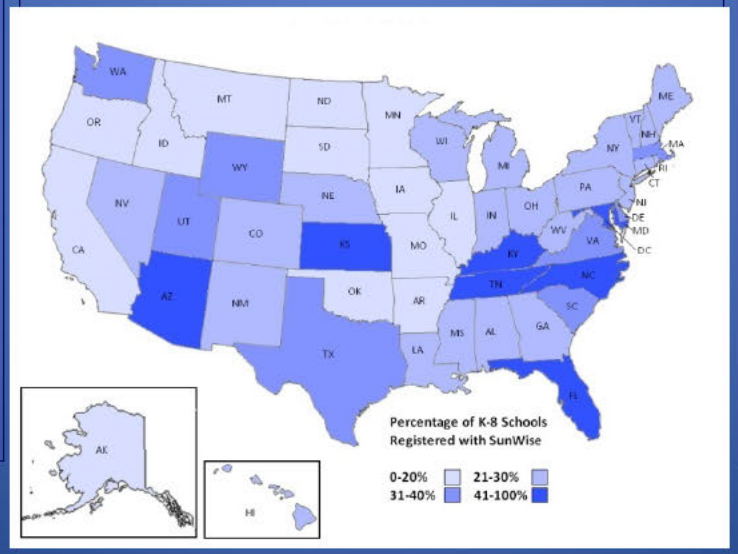

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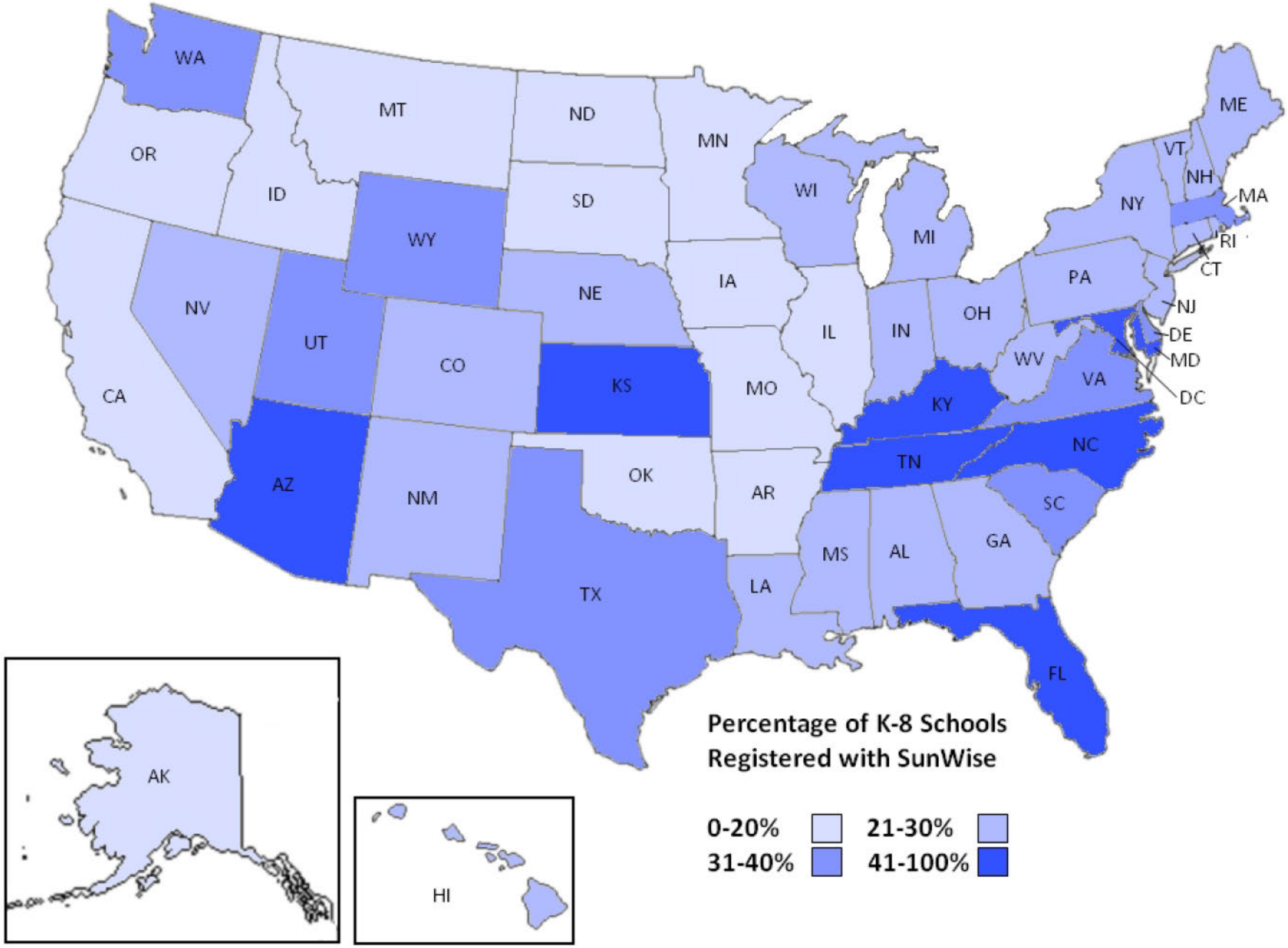
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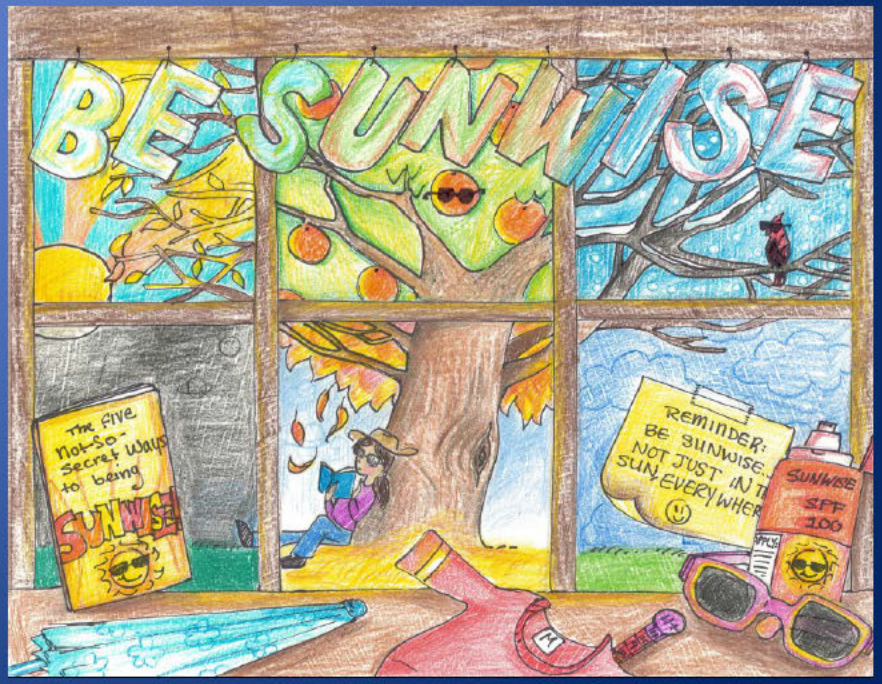

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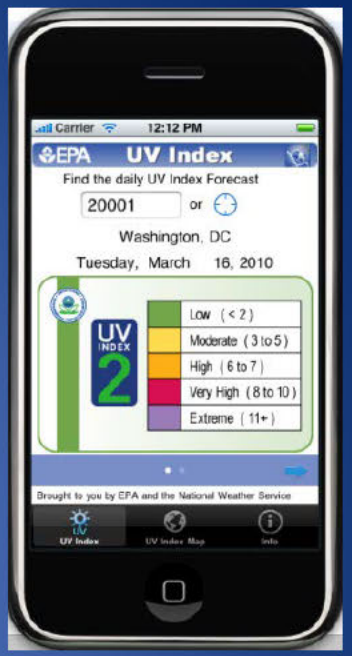

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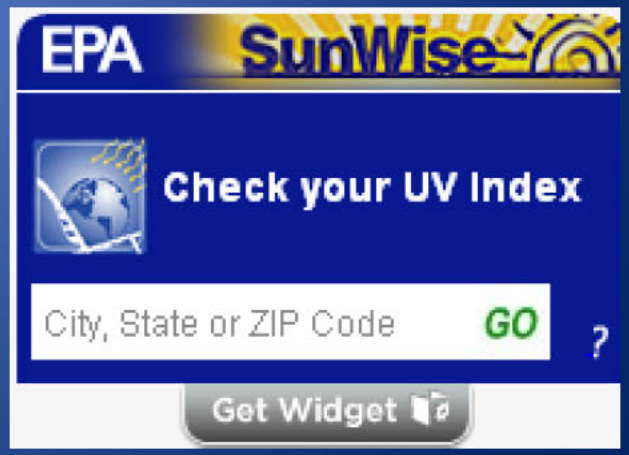

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Protecting the Stratospheric Ozone Layer

Presentation to the Florida Society of Dermatology and Dermatologic Surgery, May 2012

Drusilla Hufford, U.S. Environmental Protection Agency

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- World, U.S. Response: Montreal Protocol on Substances that Deplete Ozone in the Stratosphere, Clean Air Act Amendments of 1990, U.S. Domestic Program
- Summary of 2010 Scientific Assessment Panel Report: State of the Ozone Layer
- Next Steps: Preserve Montreal Protocol Climate Benefits
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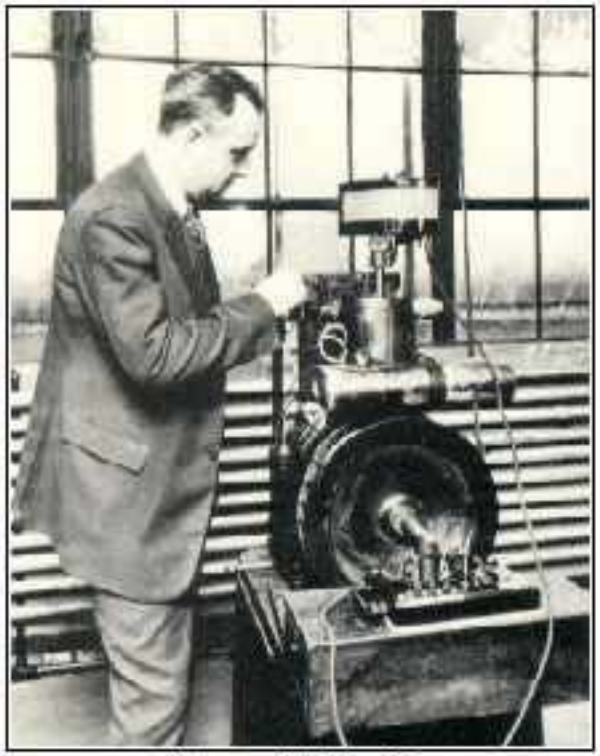

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Refrigerants, blowing agents, aerosol propellants, sterilants, solvents, MDI, fire extinguishers

CFCs: Long-lived, Deplete Stratospheric Ozone (CFC Chemistry)

Molina and Rowland (Nature, 1974)

Stratospheric sink for chlorofluoromethanes : chlorine atomc-atalysed destruction of ozone

Mario J. Molina & F. S. Rowland

Department of Chemistry, University of California, Irvine, California 92664

Chlorofluoromethanes are being added to the environment in steadily increasing amounts. These compounds are chemically inert and may remain in the atmosphere for 40–150 years, and concentrations can be expected to reach 10 to 30 times present levels. Photodissociation of the chlorofluoromethanes in the stratosphere produces significant amounts of chlorine atoms, and leads to the destruction of atmospheric ozone.

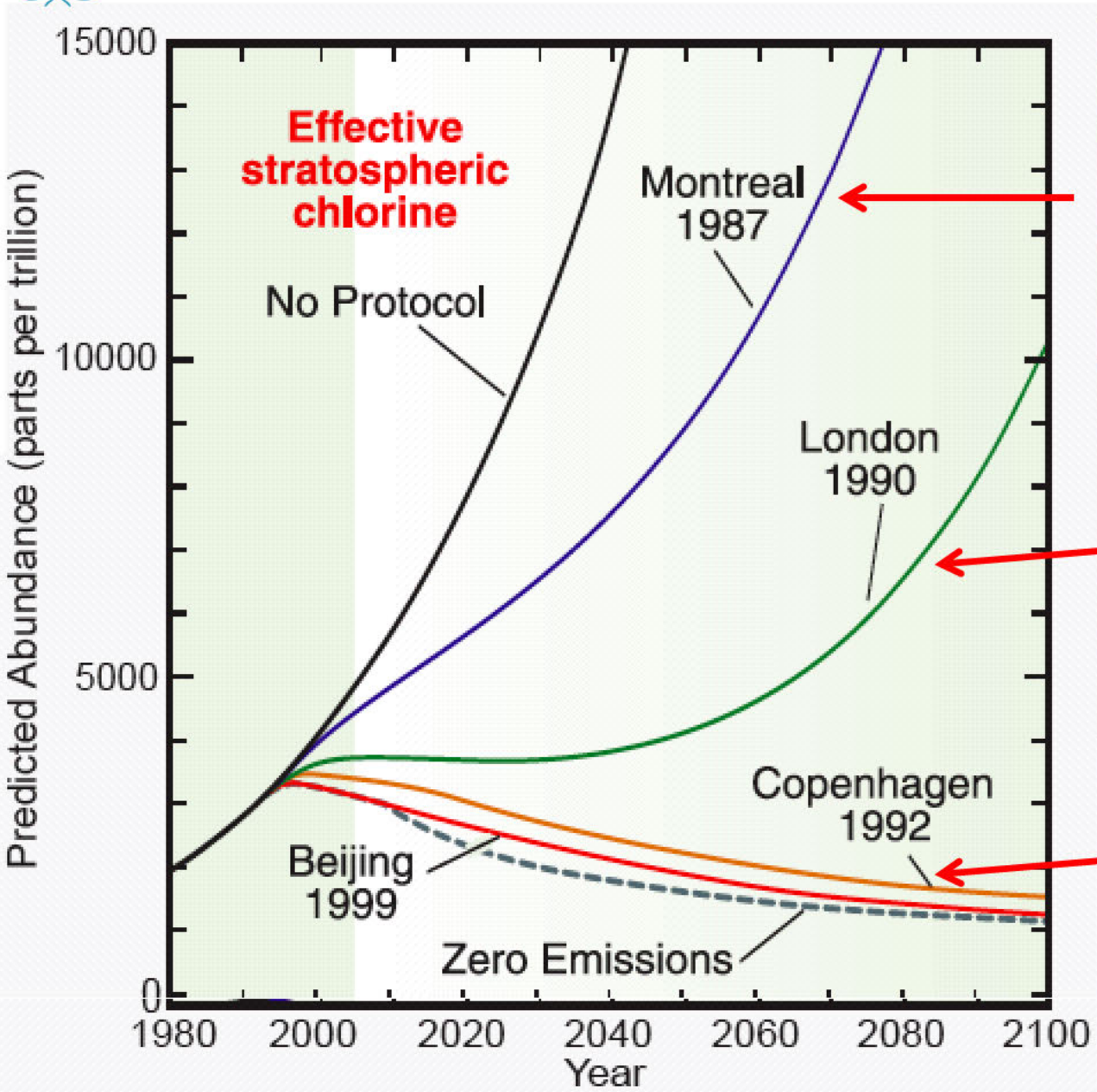
$$Cl + O_3 \rightarrow ClO + O_2$$

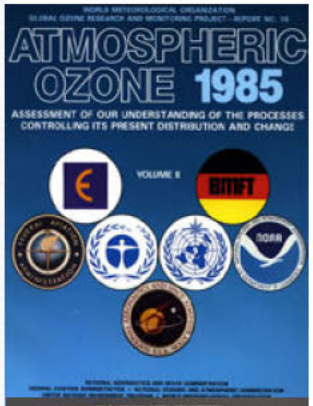
$$O + ClO \rightarrow Cl + O_2$$

$$\text{Net: } O + O_3 \rightarrow 2\,O_2$$

1985 British Antarctic Survey (Joe Farman) created first iconic view of the hole in the ozone layer at the South Pole

Ozone Science Assessments





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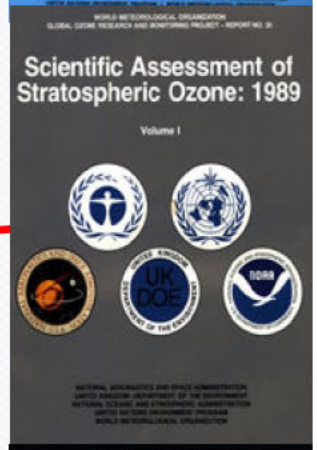
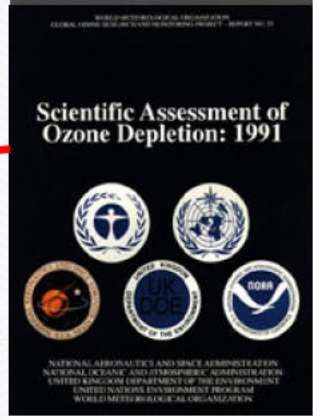


Ozone hole explained; ozone depletion outside the polar regions recognized



Further evidence of adverse effects of ODS

U.S. Domestic Response: Clean Air Act Title VI

Three Primary Regulatory Tasks of CAA Title VI:

- Meet U.S. international compliance obligations under Montreal Protocol --
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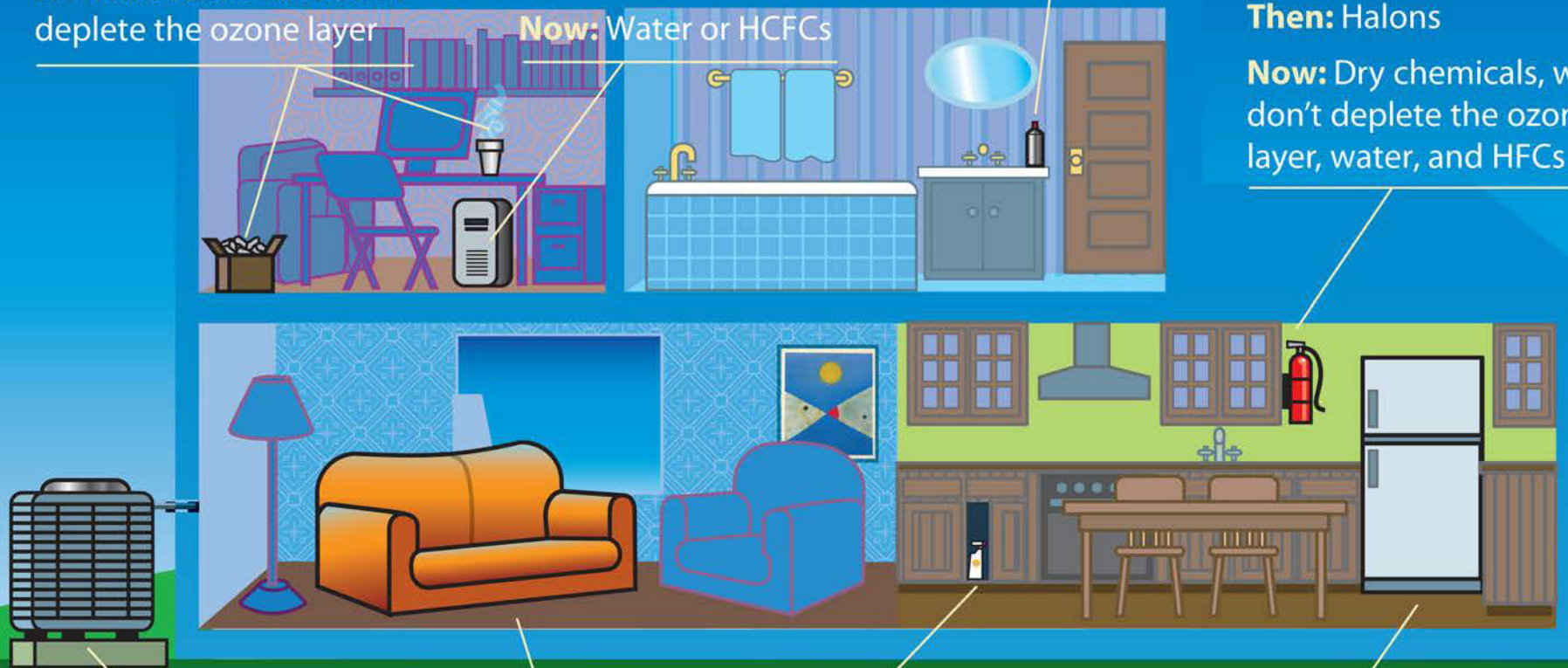
Then and Now: Progress in Ozone Protection



Polystyrene Cups and Packing Peanuts

Then: CFCs

Now: Materials that don't deplete the ozone layer

Computer Circuit Boards

Then: CFCs or methyl chloroform

Now: Water or HCFCs

Aerosol Cans

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Now: Dry chemicals, which don't deplete the ozone layer, water, and HFCs

Home and Car Air Conditioners

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Now: HCFCs and HFCs

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Then: CFCs

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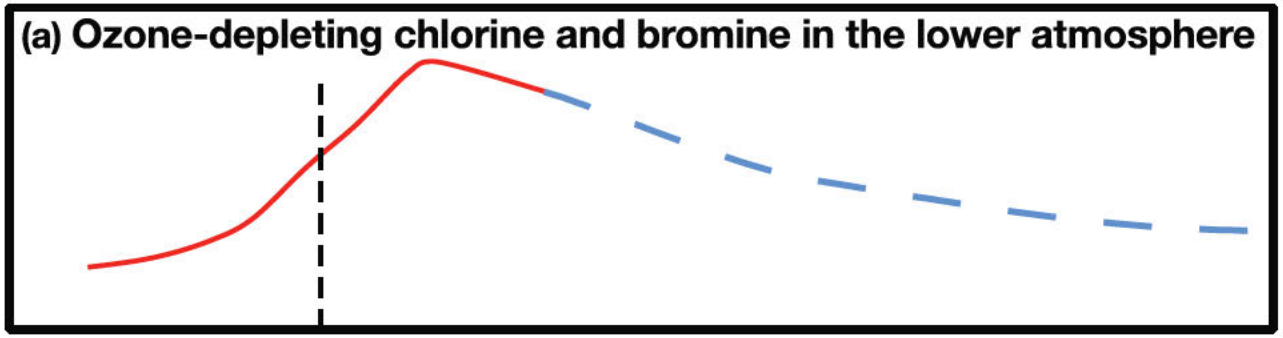
Key finding of the Science Assessment Panel (2010)

Let us look at these individually…..

Ozone-Depleting Substances (ODS)



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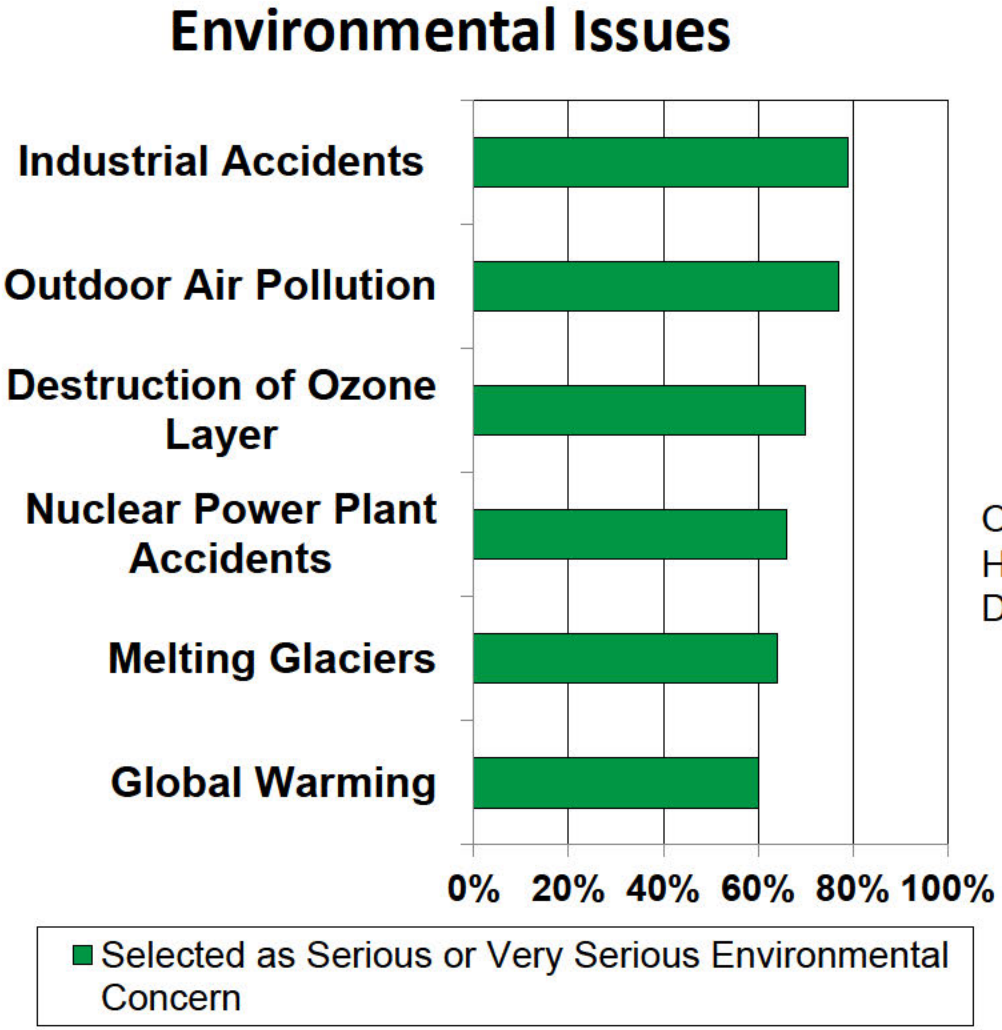

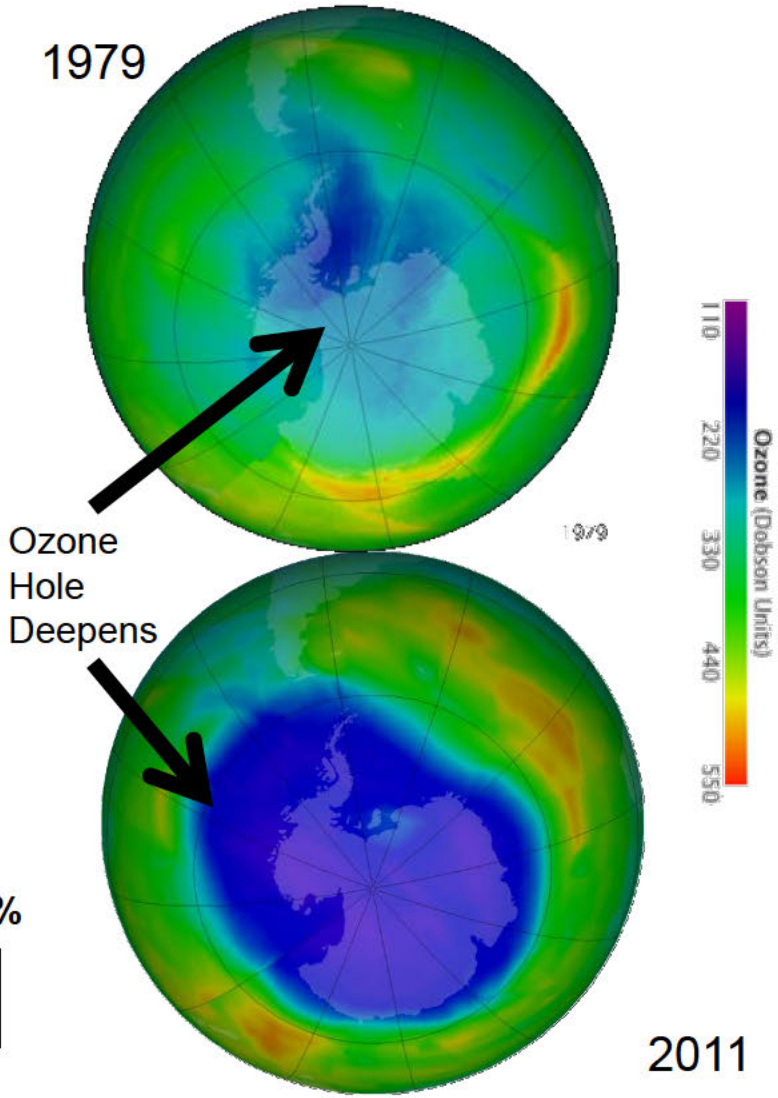

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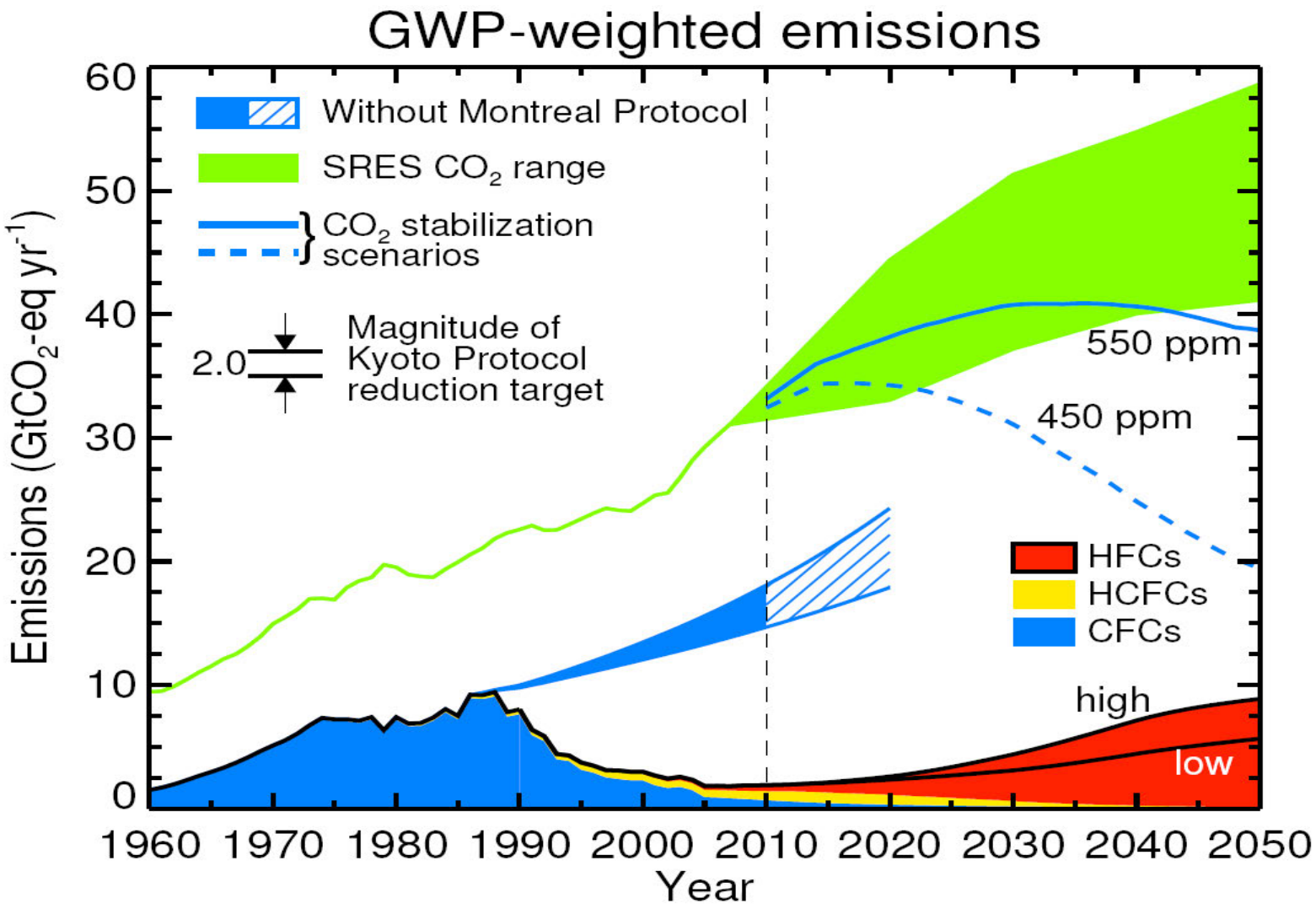

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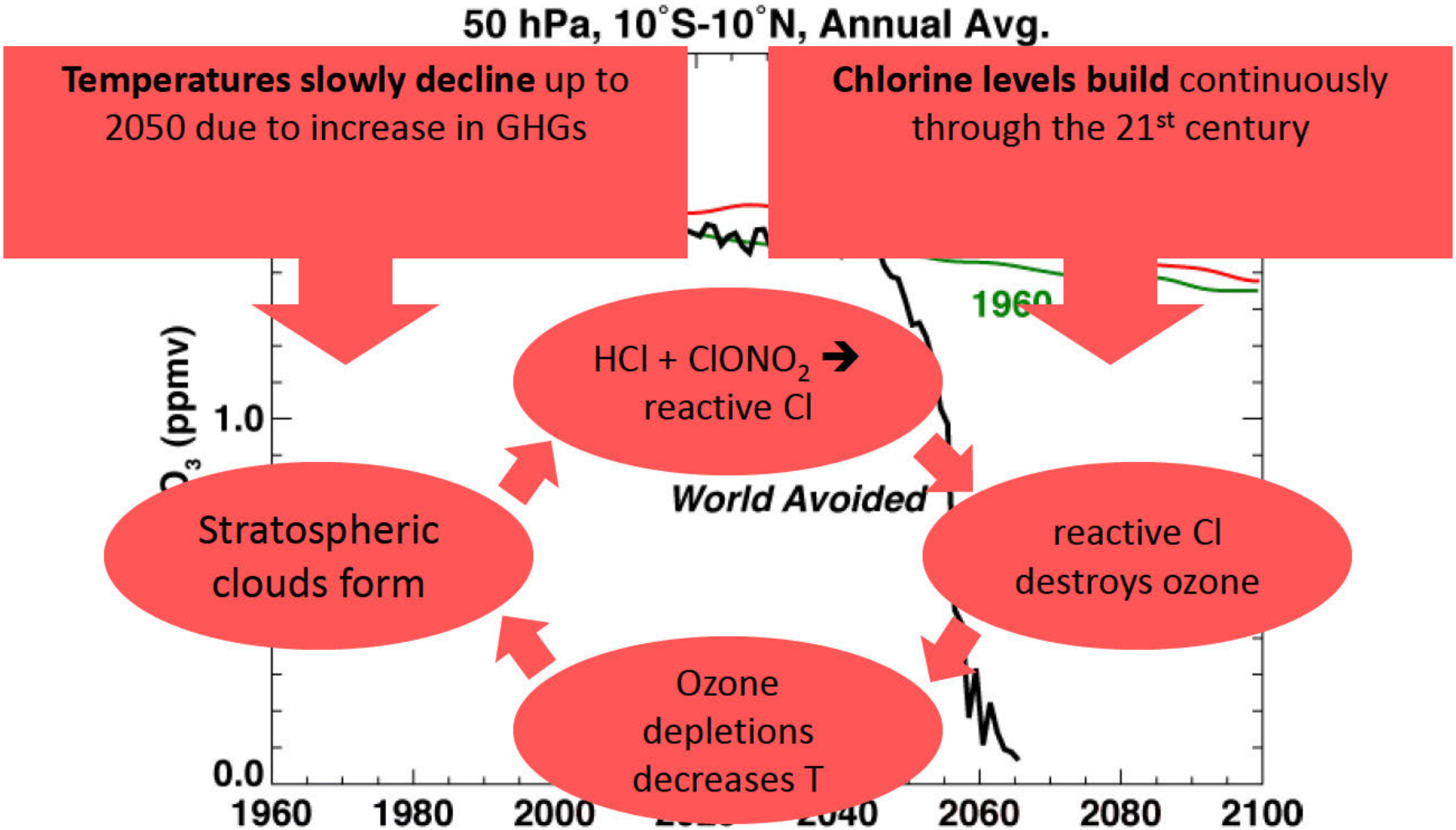

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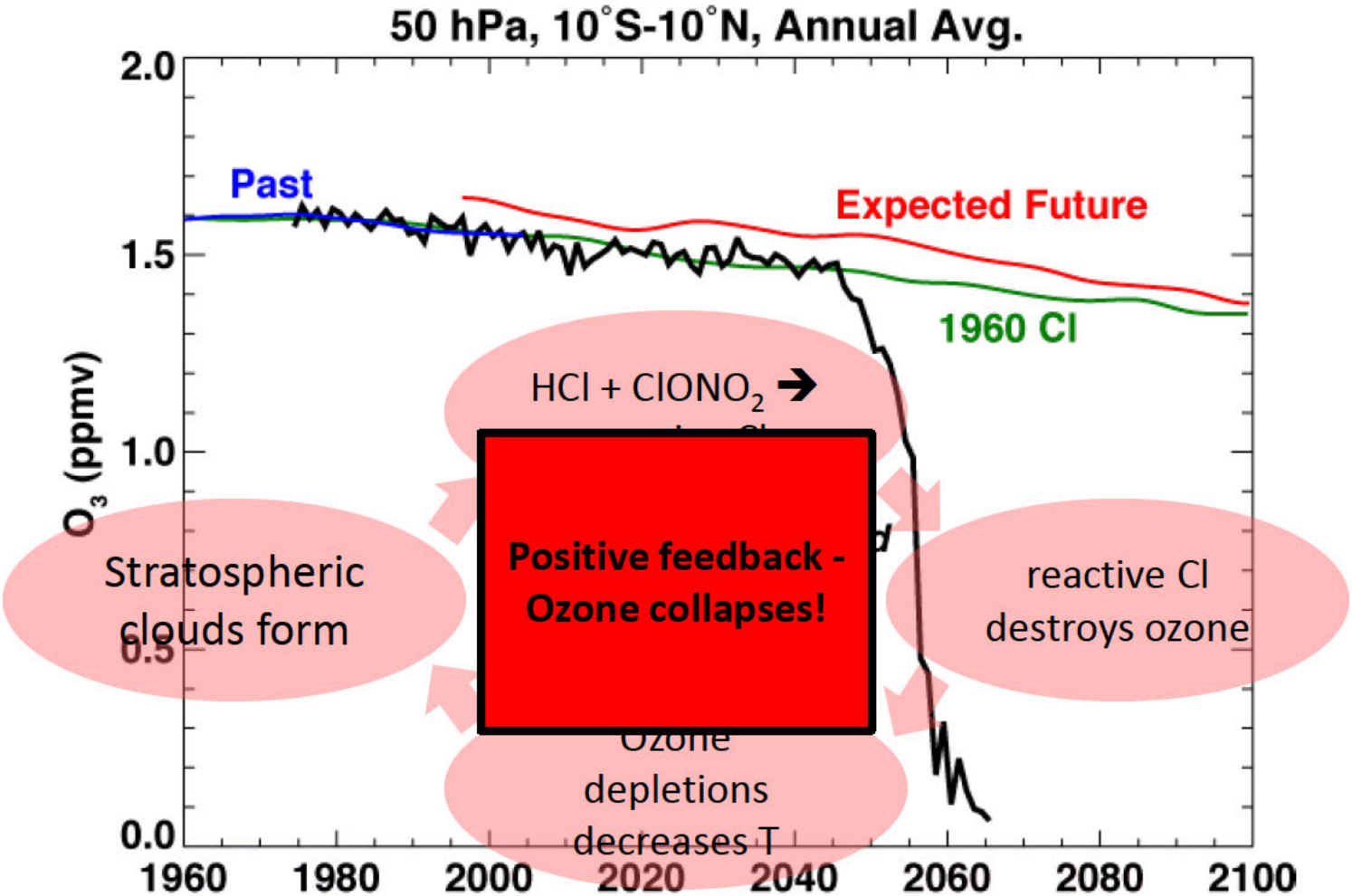

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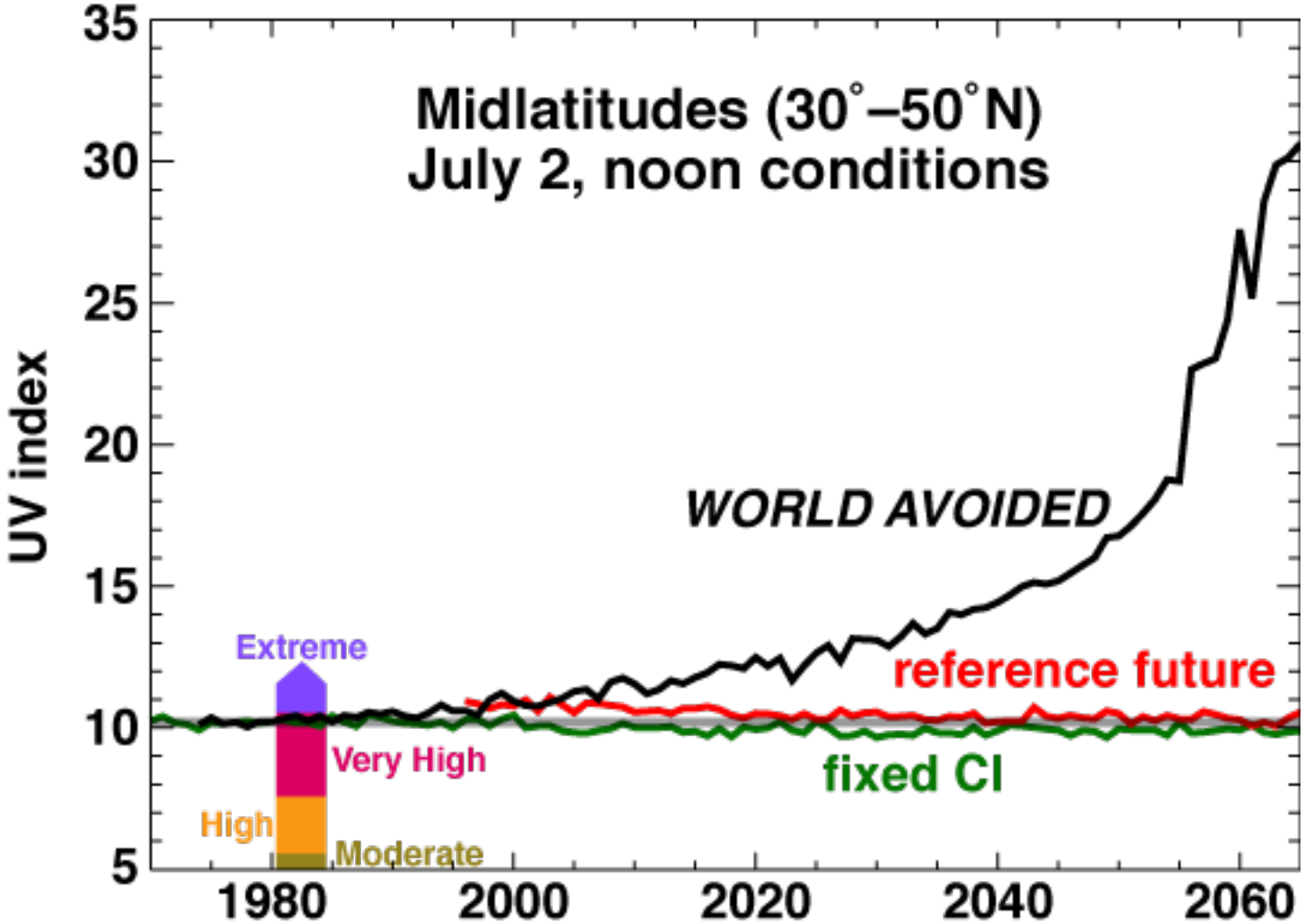

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Protecting the Stratospheric Ozone Layer

Presentation to the Florida Society of Dermatology and Dermatologic Surgery, May 2012

Drusilla Hufford, U.S. Environmental Protection Agency

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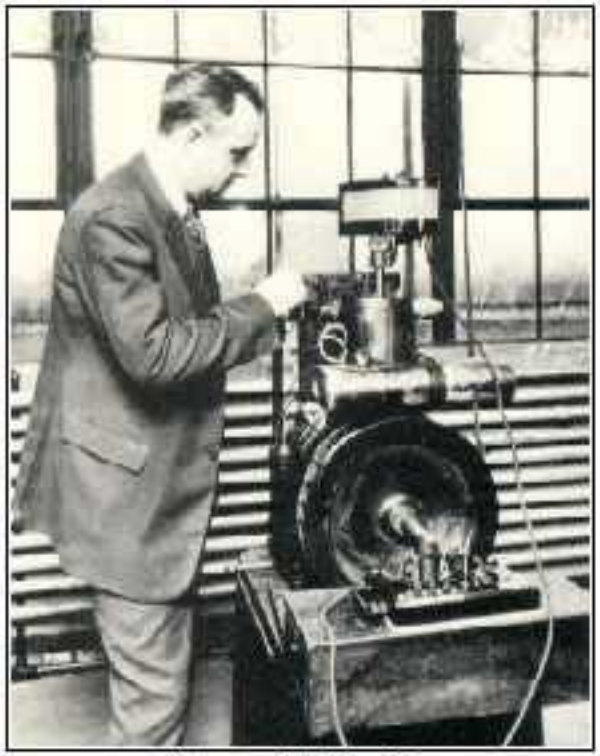

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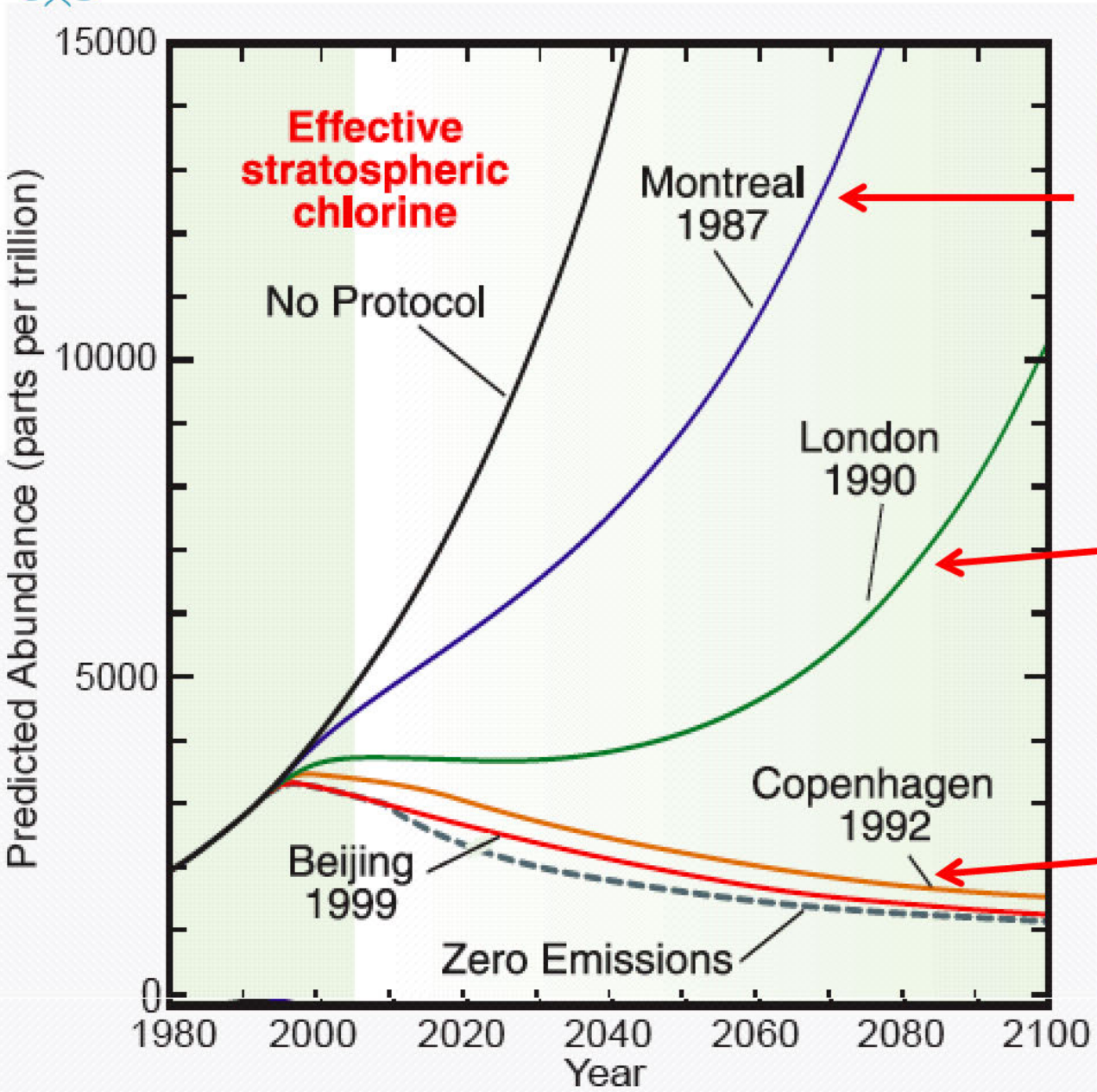

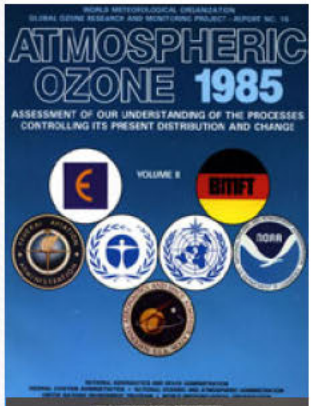

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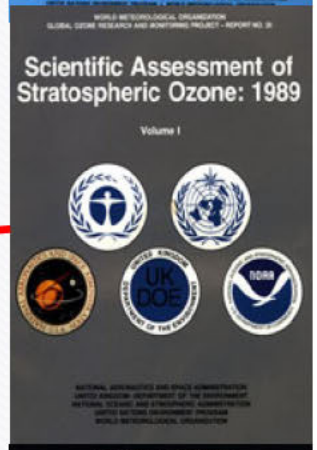

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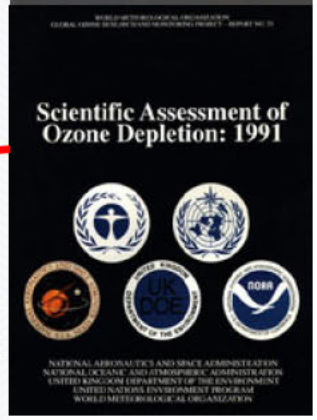

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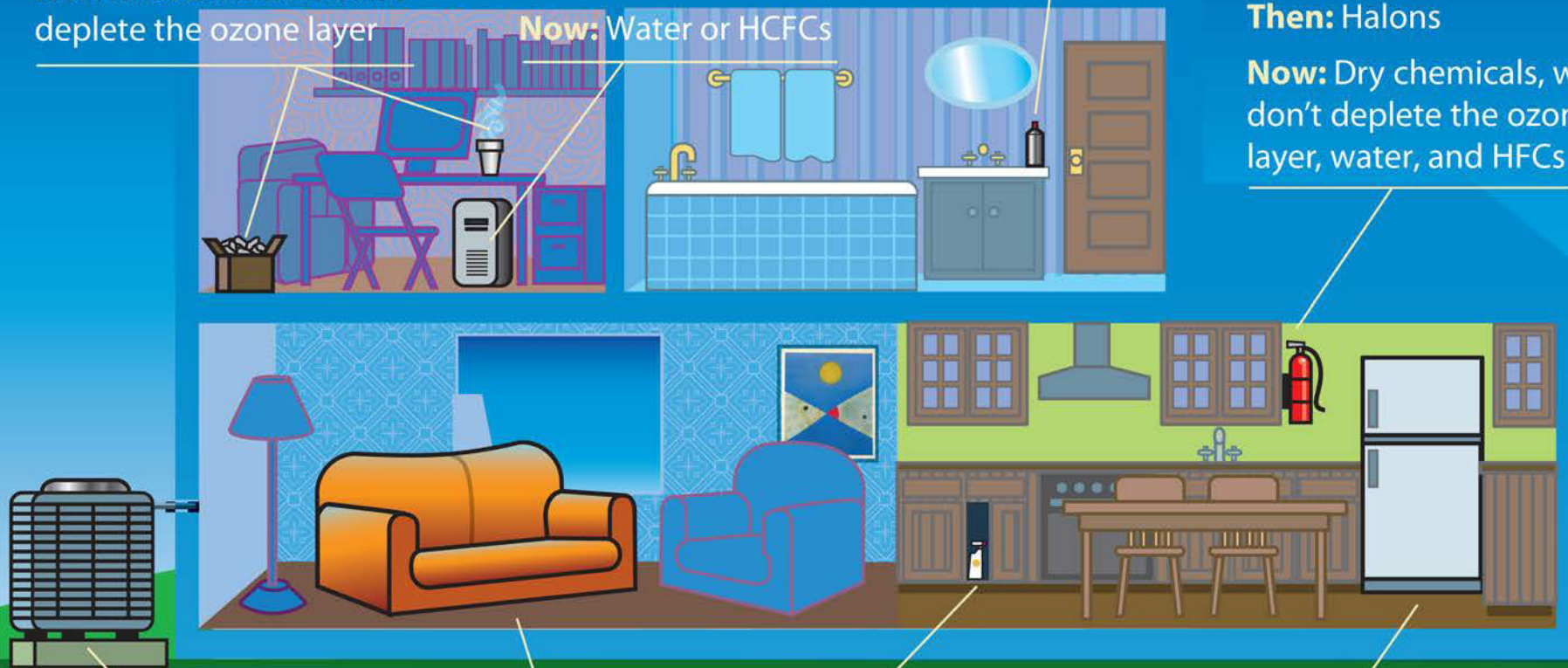

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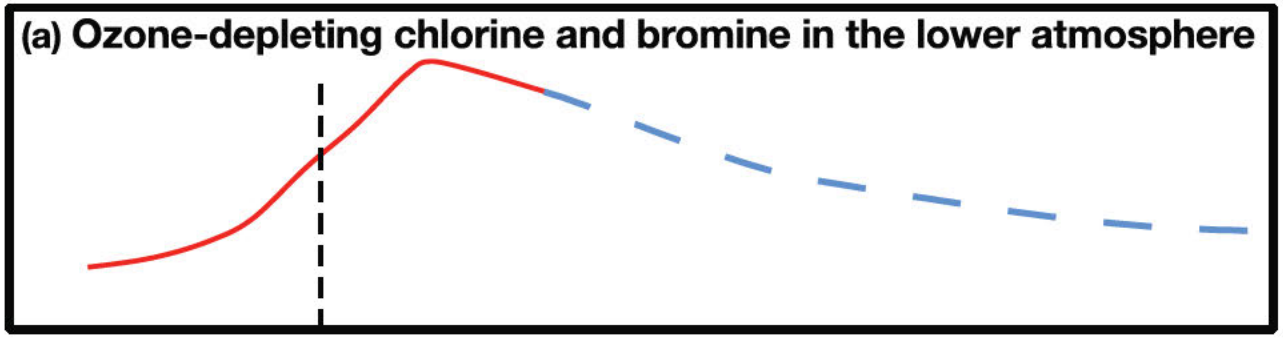

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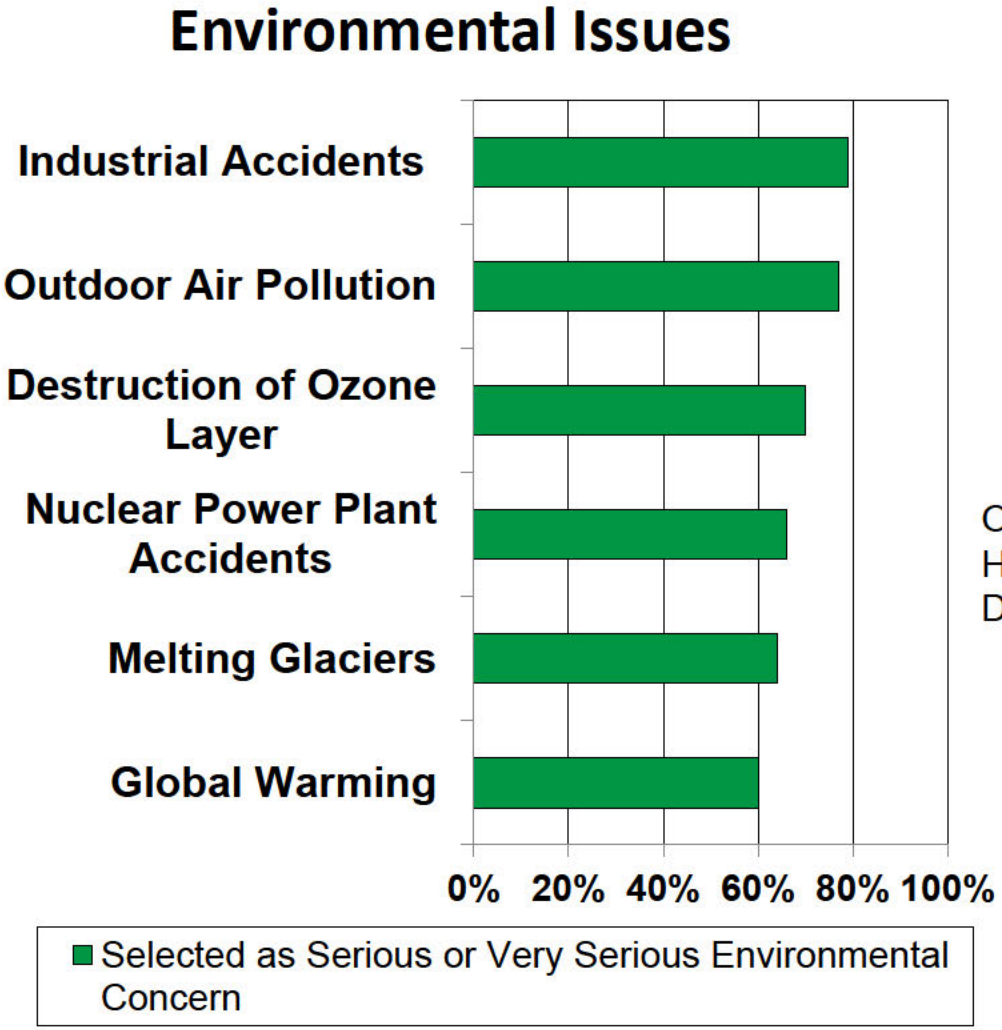

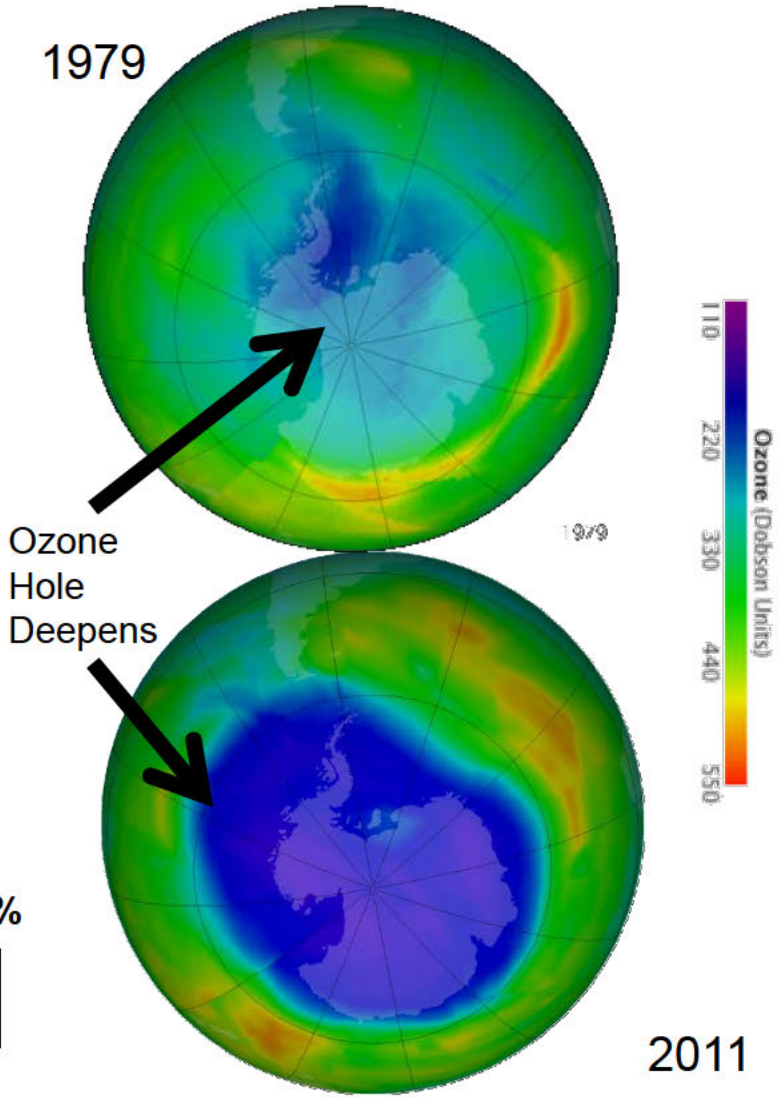

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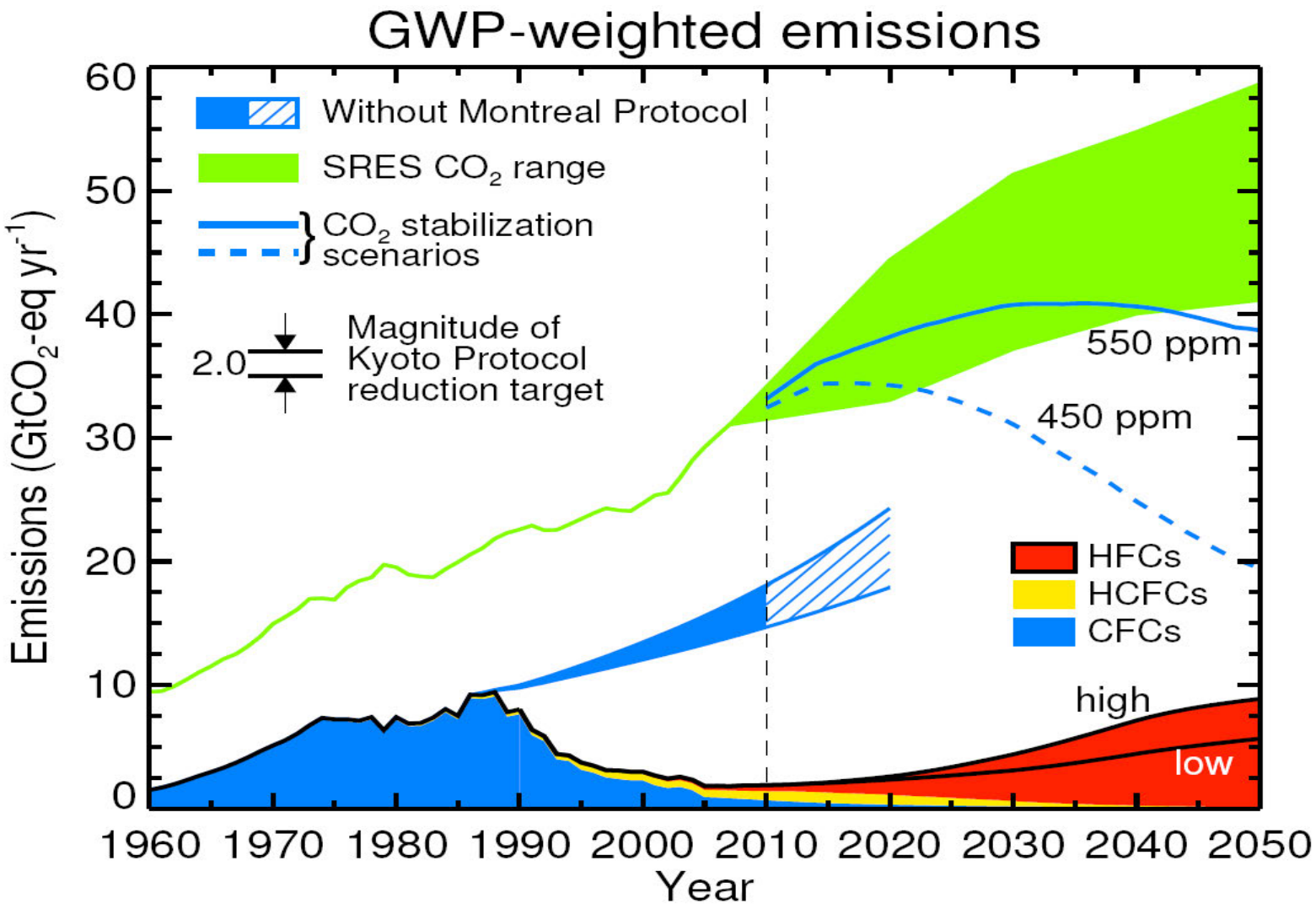

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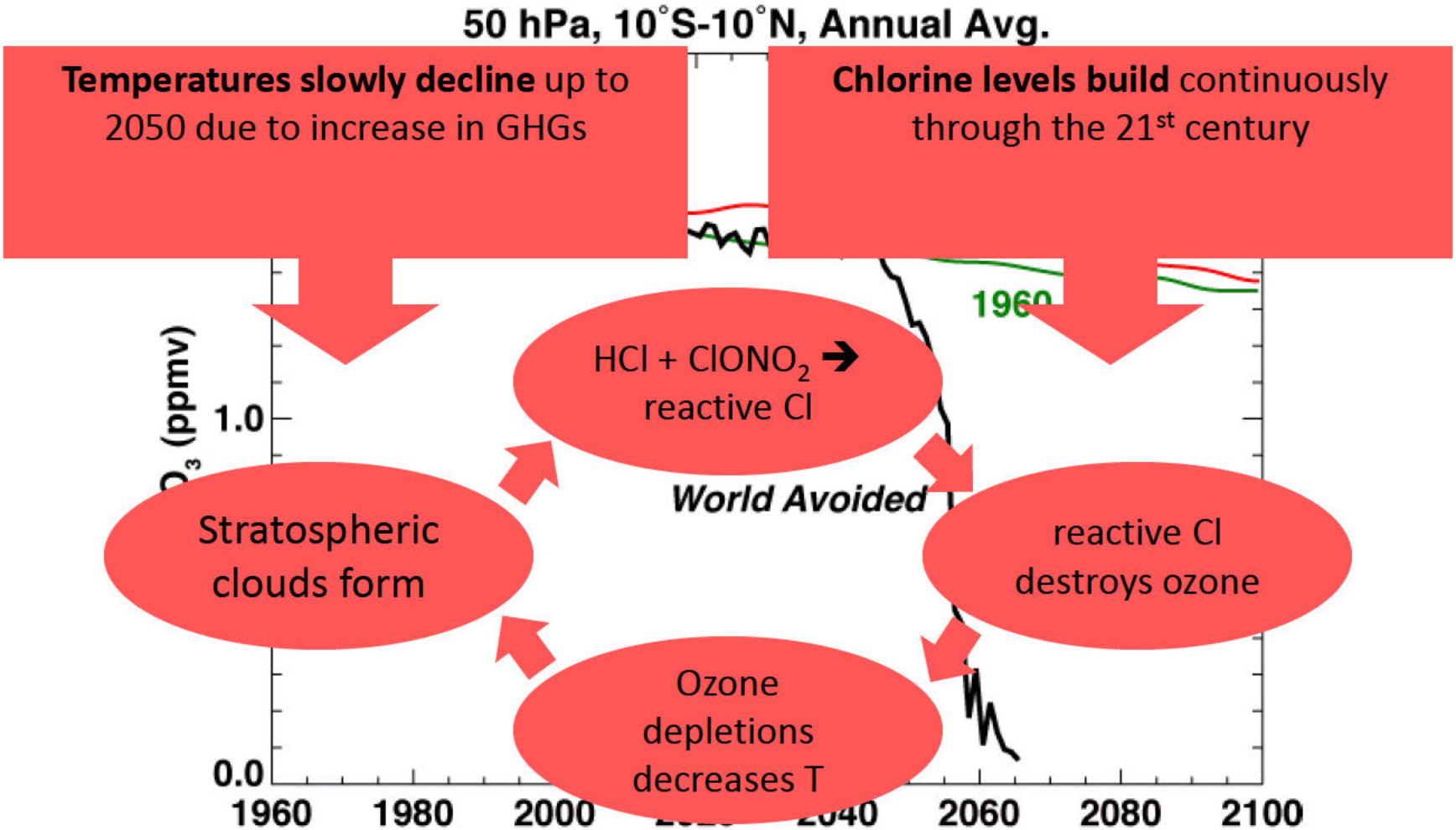

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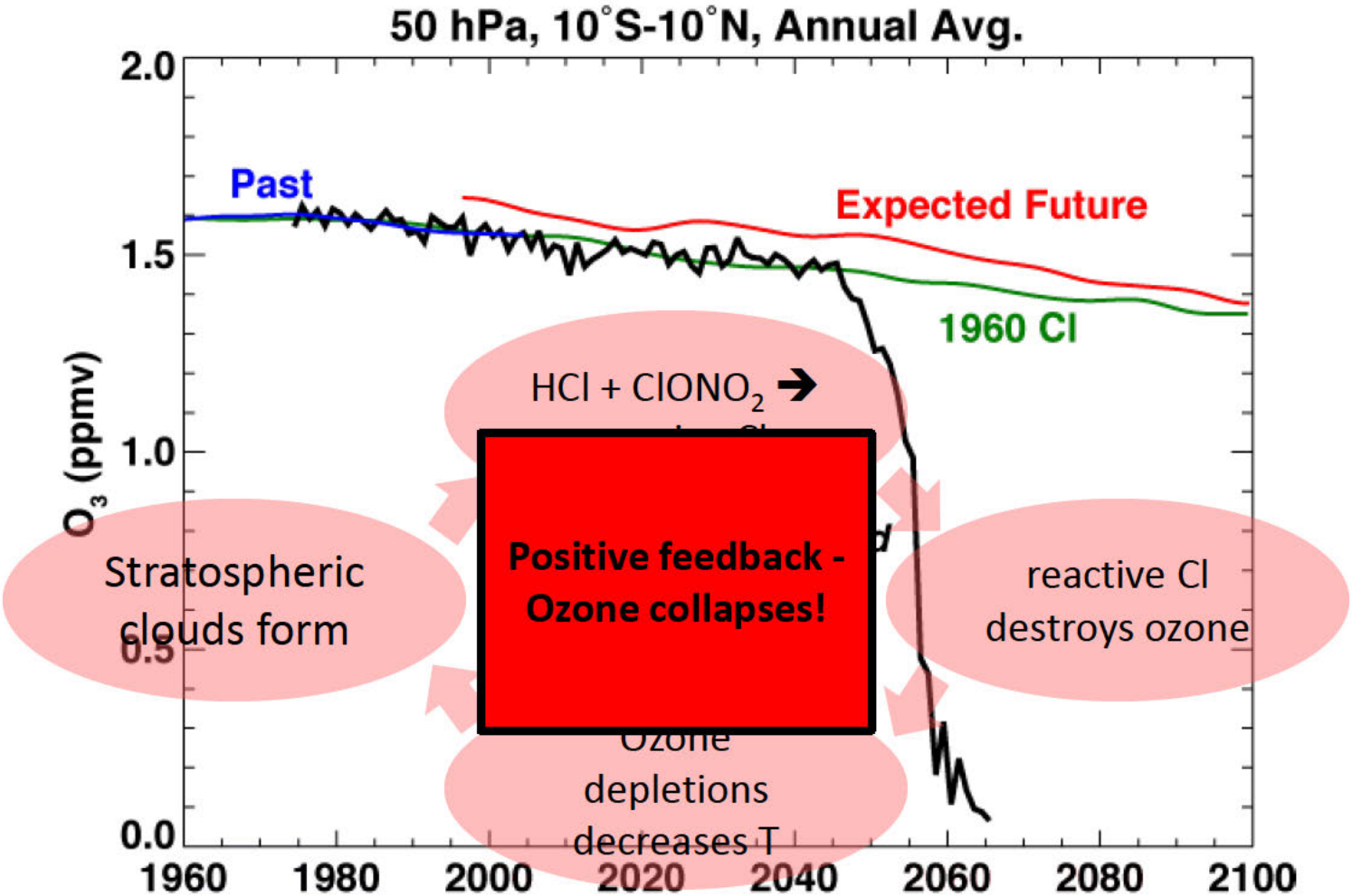

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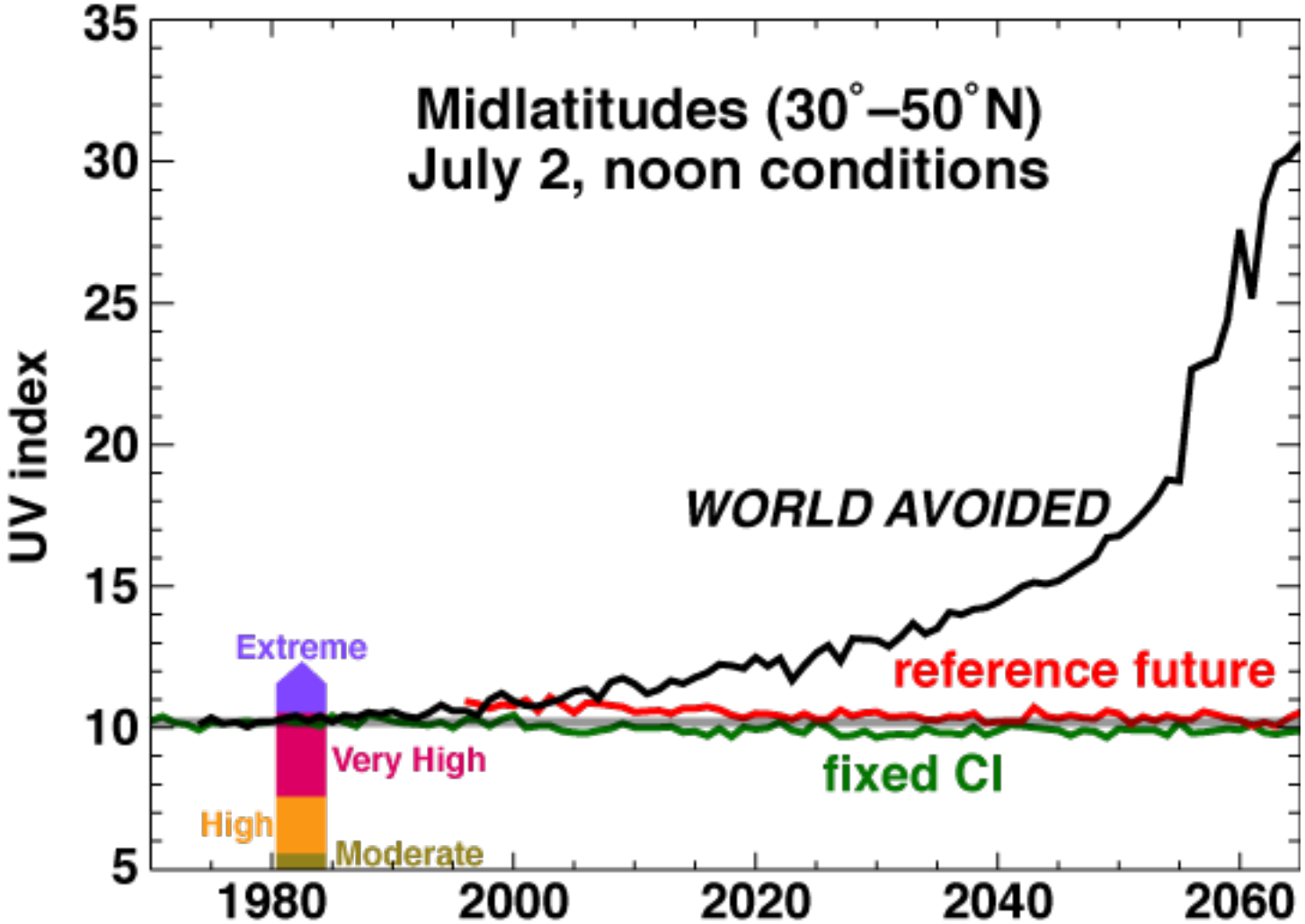

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Education, Outreach, and Communication:

Reducing UV- Related Skin Cancer Risk Through Public Education

Drusilla Hufford, U.S. EPA

2011 IYC Symposium on Stratospheric Ozone and Climate Change

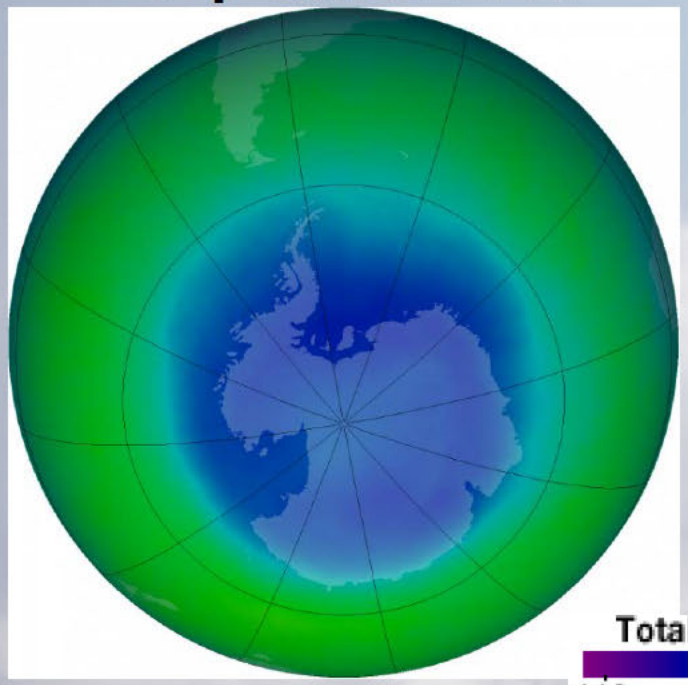
November 10, 2011

Scope of Briefing

- Why EPA and Sun Safety?
- History of EPA Sun Safety Programs
- UV Index
- SunWise
- Communications and Media
- Path Forward

Earth's Sunscreen Will Recover - Slowly

Ozone hole over Antarctica in
September 1987



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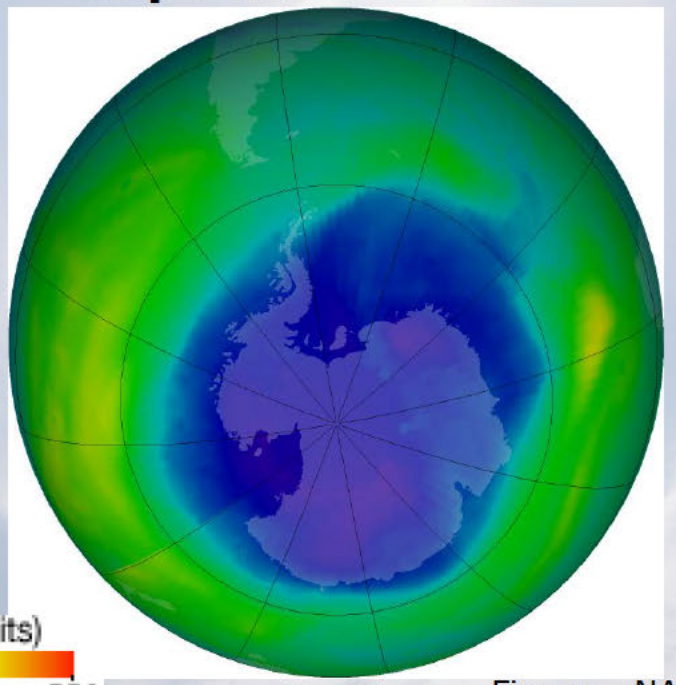
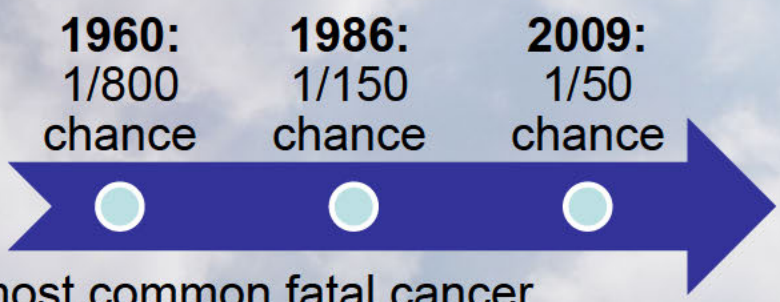


Figures: NASA

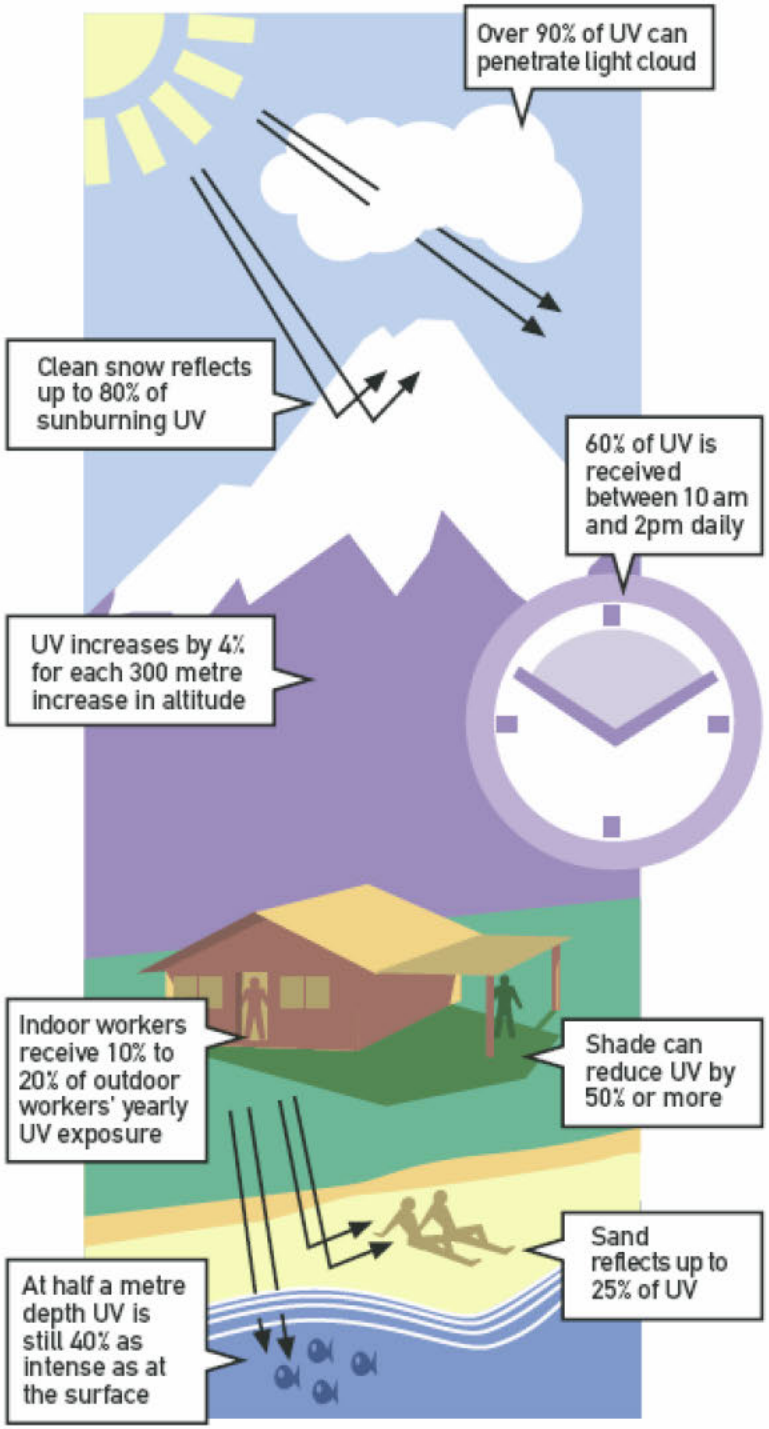
- *Ozone layer is Earth's "sunscreen" – protects people, plants and animals from too much ultraviolet radiation*
- *Because ozone depleting chemicals persist for long periods in the ozone layer, damage cannot be reversed rapidly - but should recover by about 2065*

Sun Safety: Essential but Challenging

- Skin cancer is the most common U.S. cancer
  - more common than breast, prostate, colon & lung cancer ***combined***
- Cost of skin cancer
  - $1.5 billion for non-melanoma skin cancer treatment costs in 2004
  - $3.5 billion in annual lost productivity due to melanoma deaths
- Lifetime risk of developing melanoma is increasing



- Melanoma is 6th most common fatal cancer
  - Most common cancer among 20-30 year olds
- Skin cancer is preventable, but messaging presents special challenges



- UV Index Goal: Without alarmism, share information to help American families plan outdoor activities to minimize harmful UV exposures
- Barriers:
  - "Chance of too much UV for the next 50 years"
  - Daily UV Index same in July in Phoenix….why report it?
  - Immediate vs. longer-term consequences:
    - Drive during weather emergency - get stuck today
    - Unprotected time in high noon sun – get skin cancer in 20 years

EPA's Sun Safety Programs

SunWise
a program that radiates good ideas
A Partnership Program of the U.S. Environmental Protection Agency
www.epa.gov/sunwise

The Friday before Memorial Day is
Don't Fry Day
www.skincancerprevention.org

UV INDEX

UV Index
1994

SunWise
School
Program
1999

Don't Fry
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New/Social
Media
Campaign
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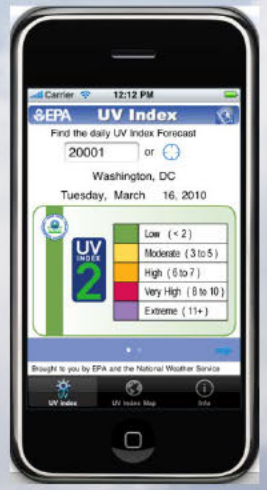


SunWise Goal:

Prevent Skin Cancer by Building Sun Safety Habits in Kids

Proven Effective

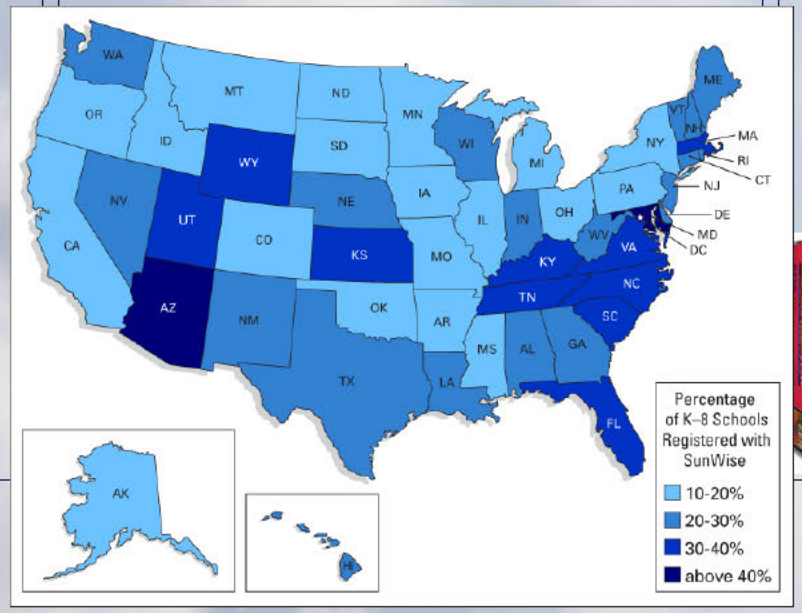
SunWise students show an 11% decrease in sunburns.

Every $1 invested in SunWise earns $2 to $4 in public health savings.

OncoLink EditorsChoice

GOLD TRIANGLE Awards

In All 50 States



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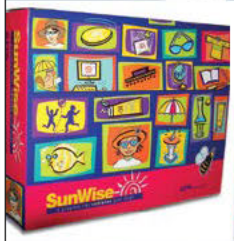

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www.skincancerprevention.org

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Education, Outreach, and Communication:

Reducing UV- Related Skin Cancer Risk Through Public Education

Drusilla Hufford, U.S. EPA

2011 IYC Symposium on Stratospheric Ozone and Climate Change

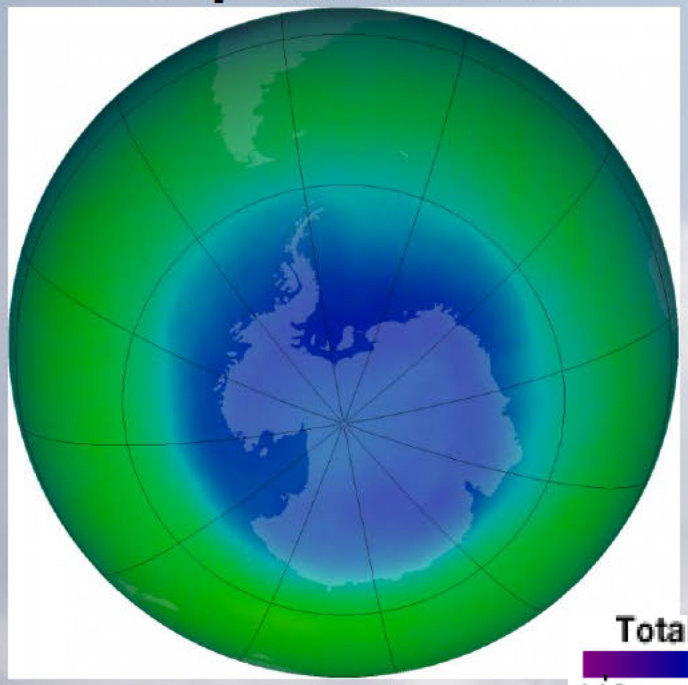
November 10, 2011

Scope of Briefing

- Why EPA and Sun Safety?
- History of EPA Sun Safety Programs
- UV Index
- SunWise
- Communications and Media
- Path Forward

Earth's Sunscreen Will Recover - Slowly

Ozone hole over Antarctica in
September 1987



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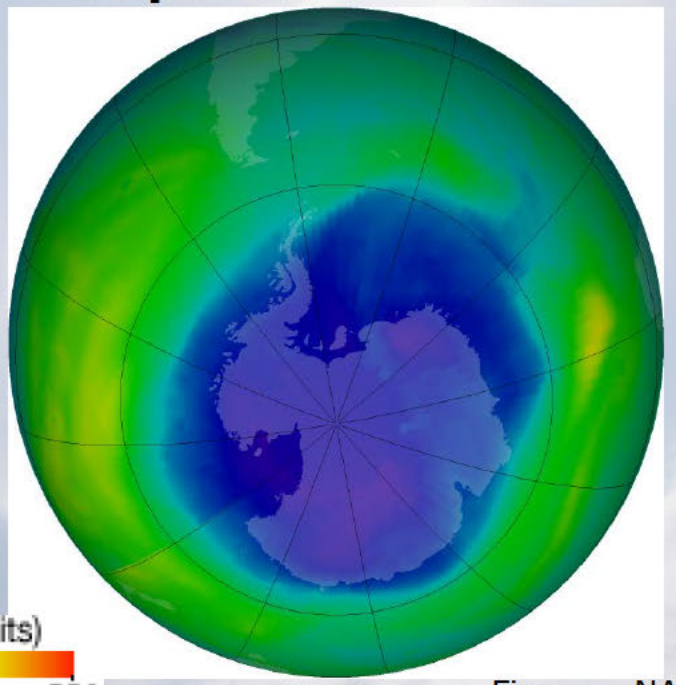

Figures: NASA

- *Ozone layer is Earth's "sunscreen" – protects people, plants and animals from too much ultraviolet radiation*
- *Because ozone depleting chemicals persist for long periods in the ozone layer, damage cannot be reversed rapidly - but should recover by about 2065*

Sun Safety: Essential but Challenging

- Skin cancer is the most common U.S. cancer
  - more common than breast, prostate, colon & lung cancer ***combined***
- Cost of skin cancer
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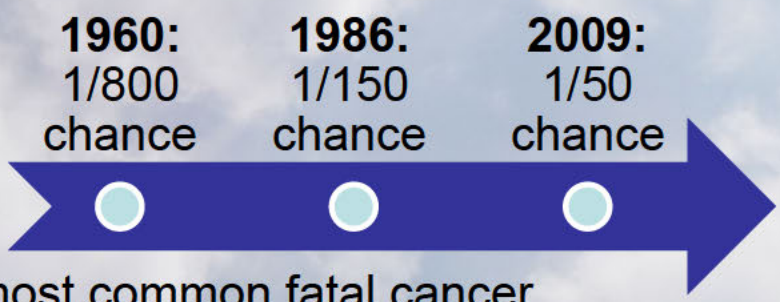

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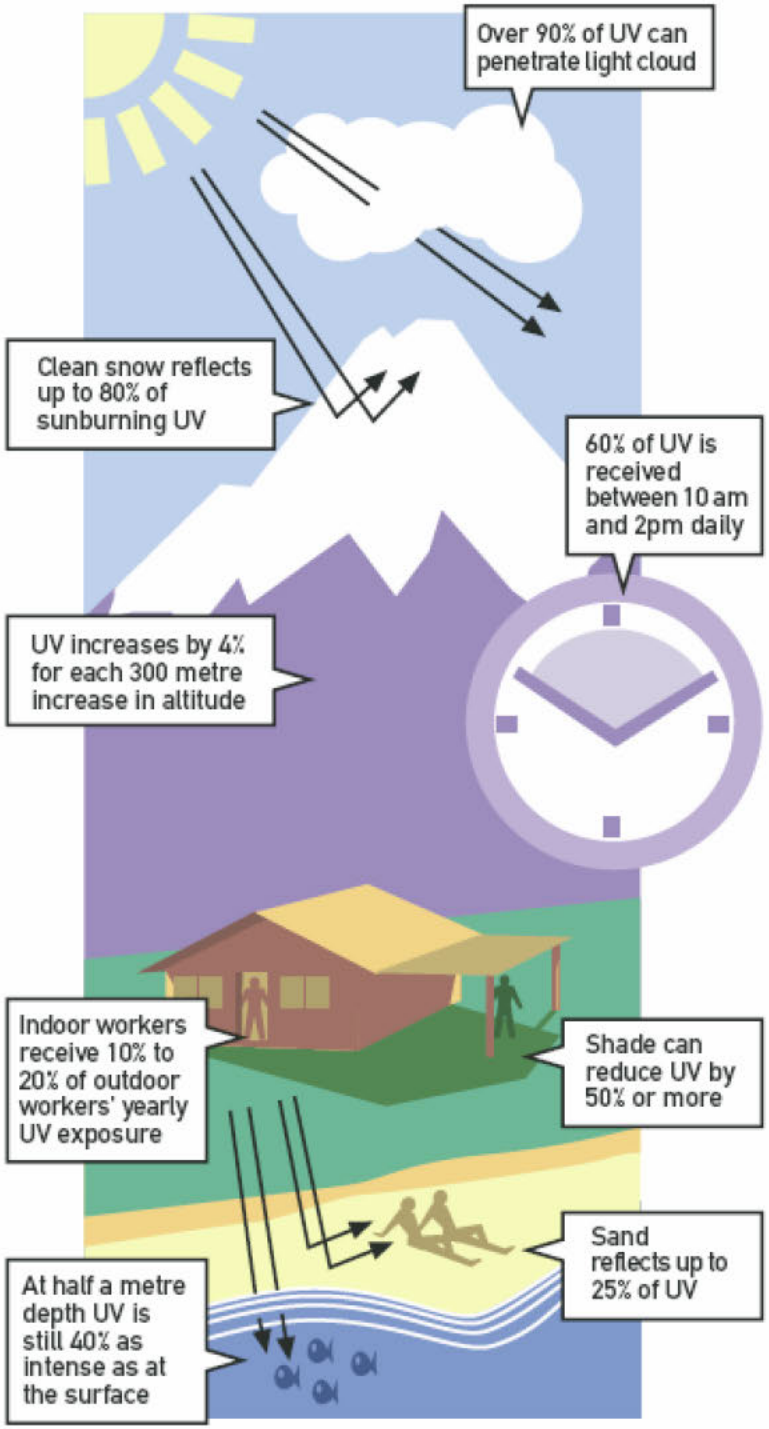
- Skin cancer is preventable, but messaging presents special challenges



- UV Index Goal: Without alarmism, share information to help American families plan outdoor activities to minimize harmful UV exposures
- Barriers:
  - "Chance of too much UV for the next 50 years"
  - Daily UV Index same in July in Phoenix….why report it?
  - Immediate vs. longer-term consequences:
    - Drive during weather emergency - get stuck today
    - Unprotected time in high noon sun – get skin cancer in 20 years

EPA's Sun Safety Programs

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UV Index
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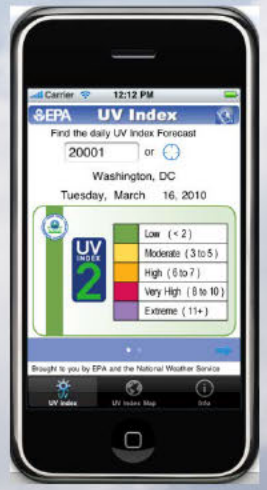
SunWise
School
Program
1999

Don't Fry
Day
2009

New/Social
Media
Campaign
2010



SunWise Goal:

Prevent Skin Cancer by Building Sun Safety Habits in Kids

Proven Effective

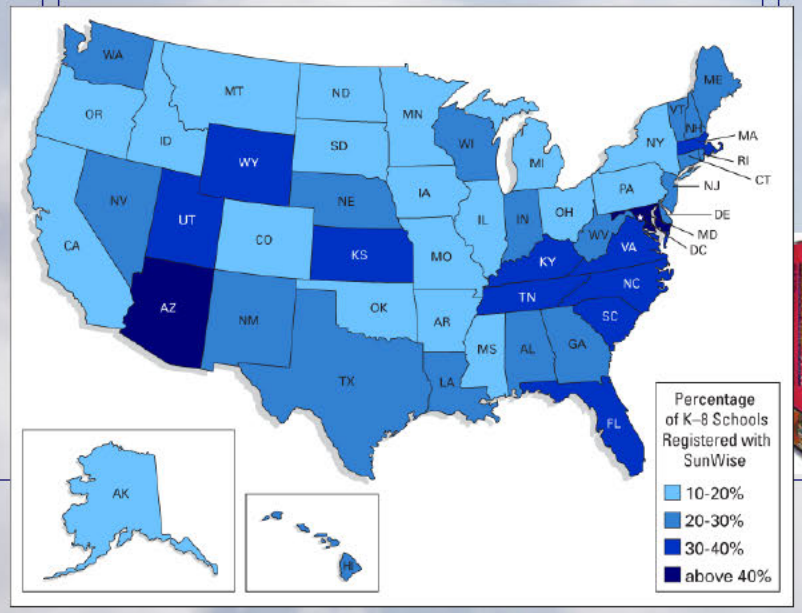
SunWise students show an 11% decrease in sunburns.

Every $1 invested in SunWise earns $2 to $4 in public health savings.

OncoLink EditorsChoice

GOLD TRIANGLE Awards

In All 50 States



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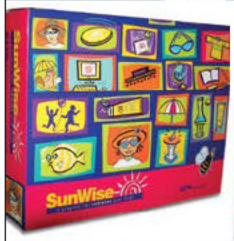

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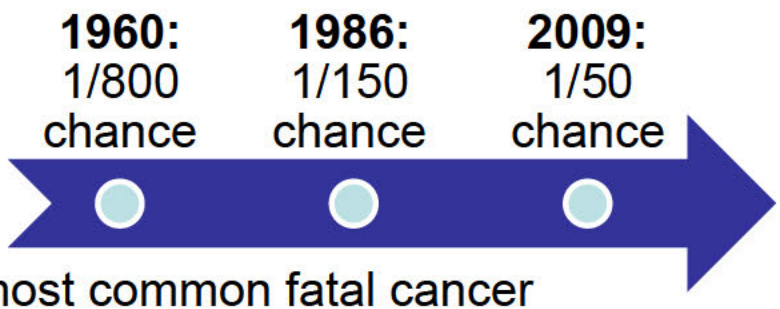

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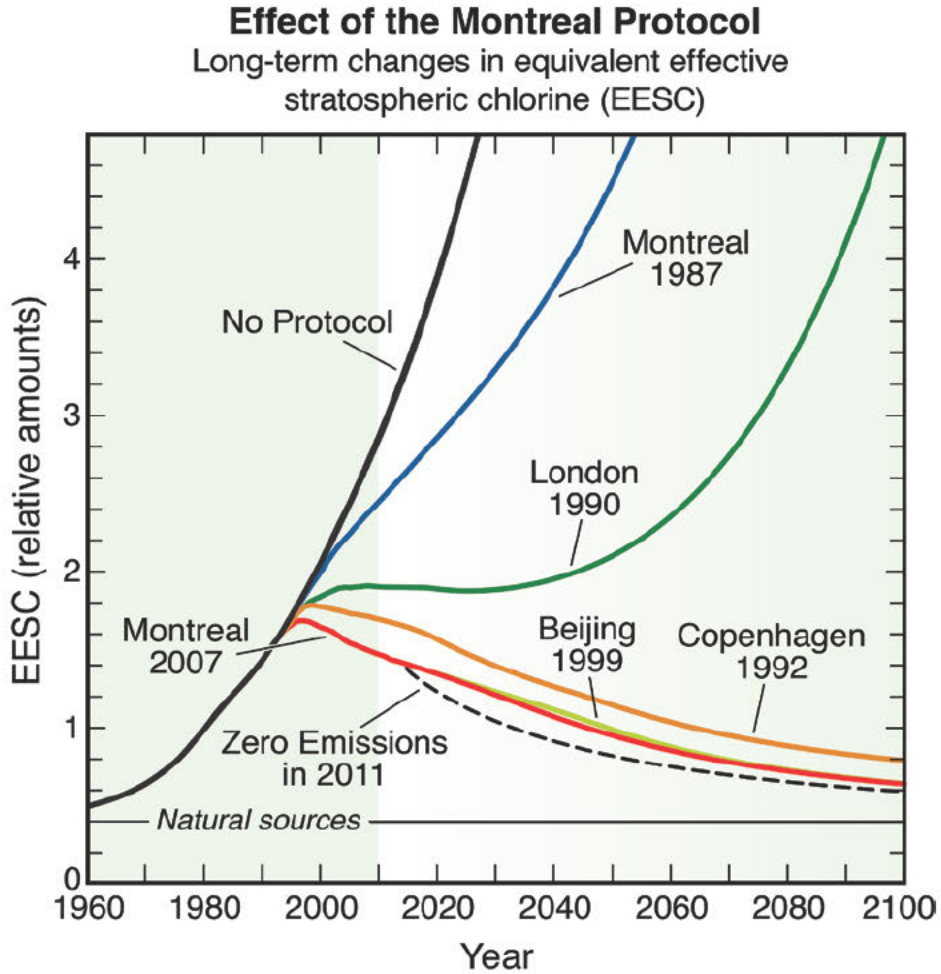

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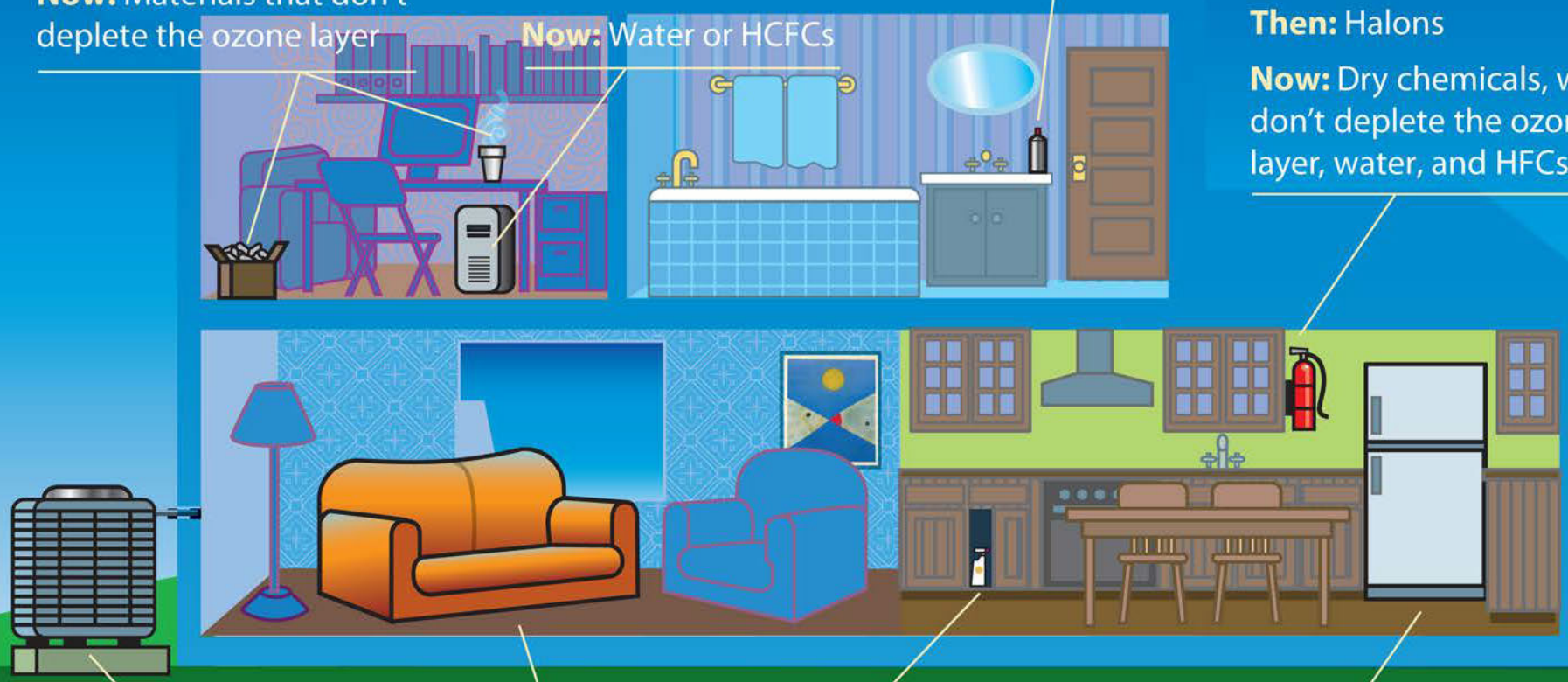

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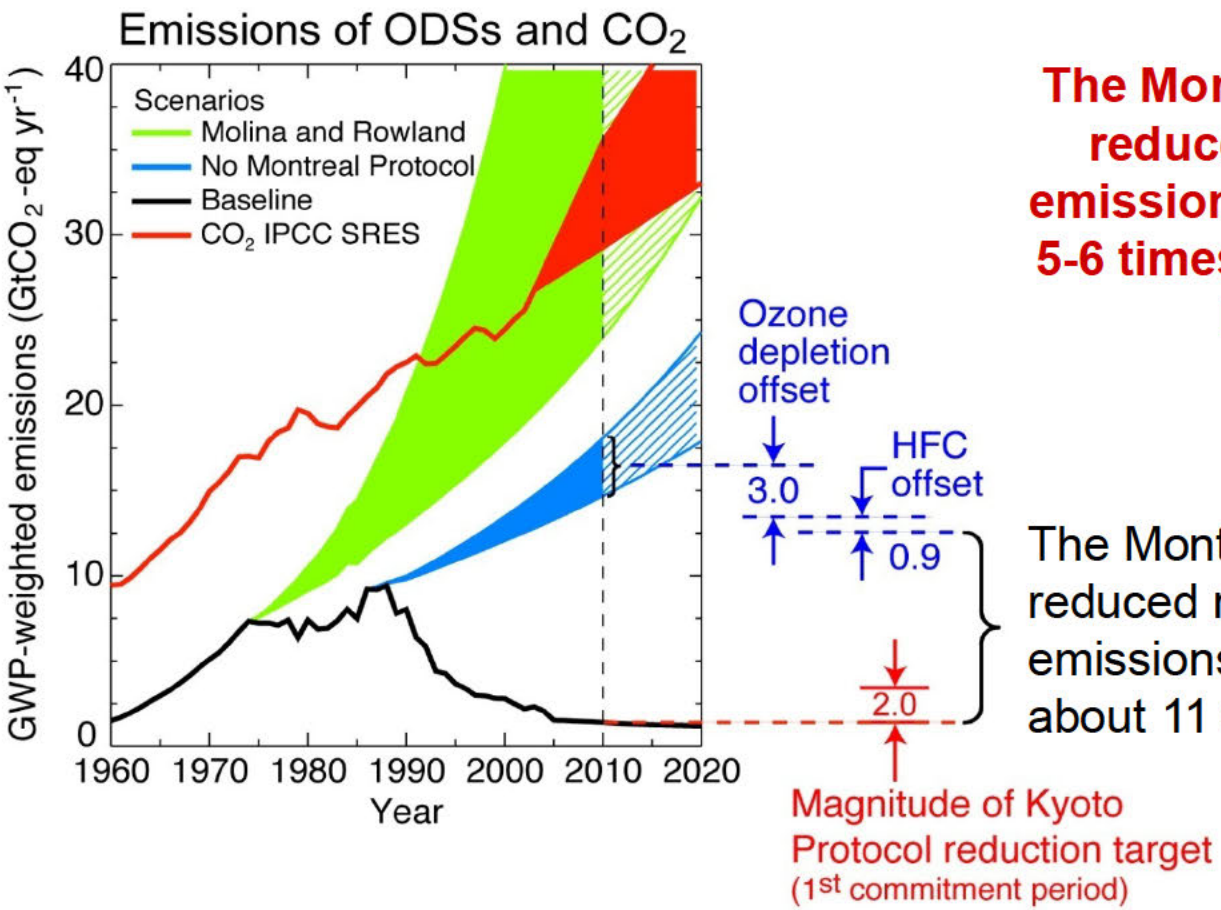

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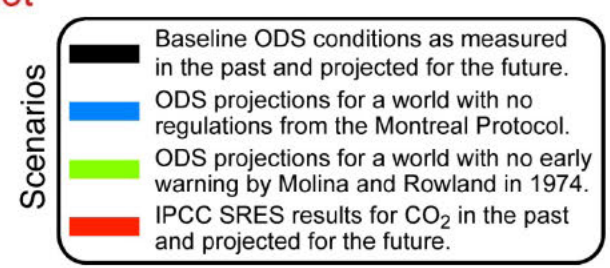

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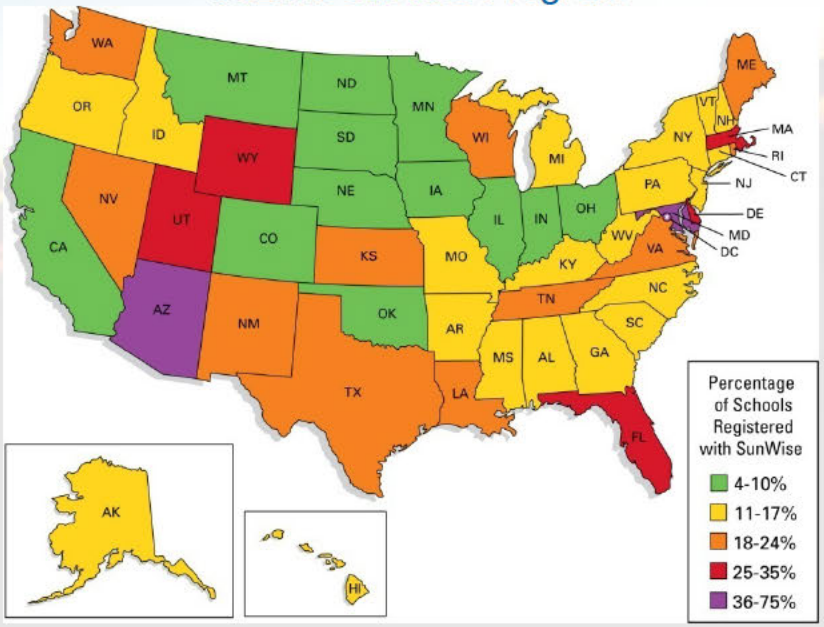

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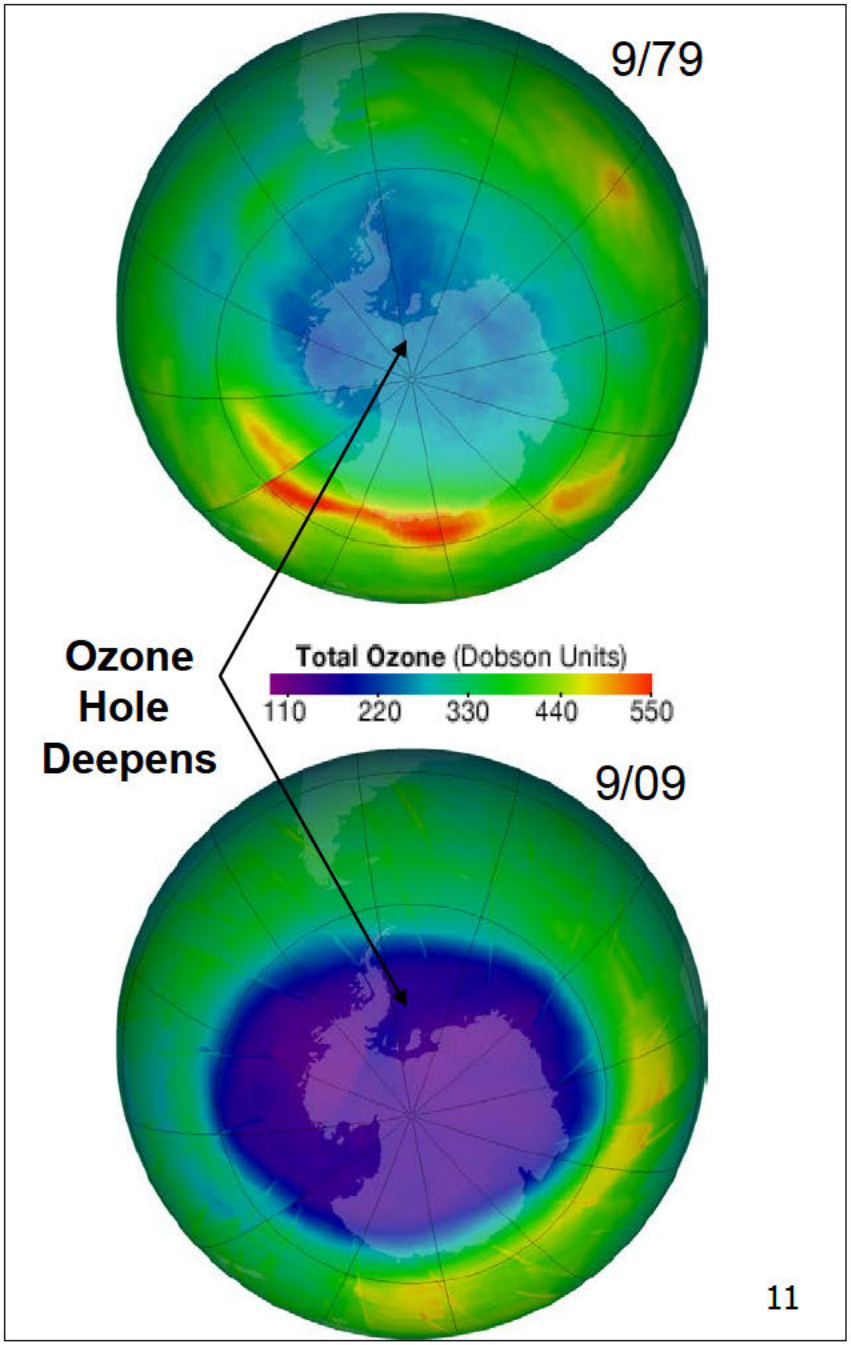

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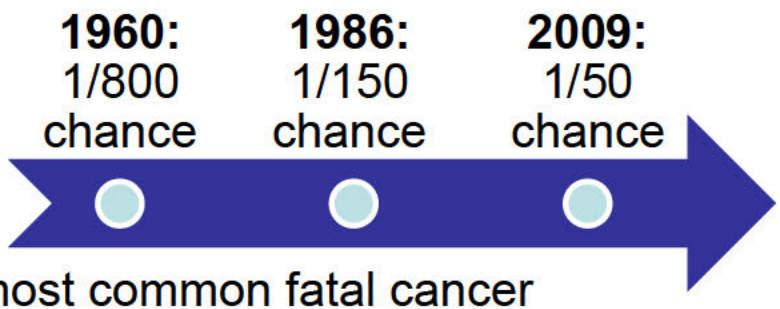

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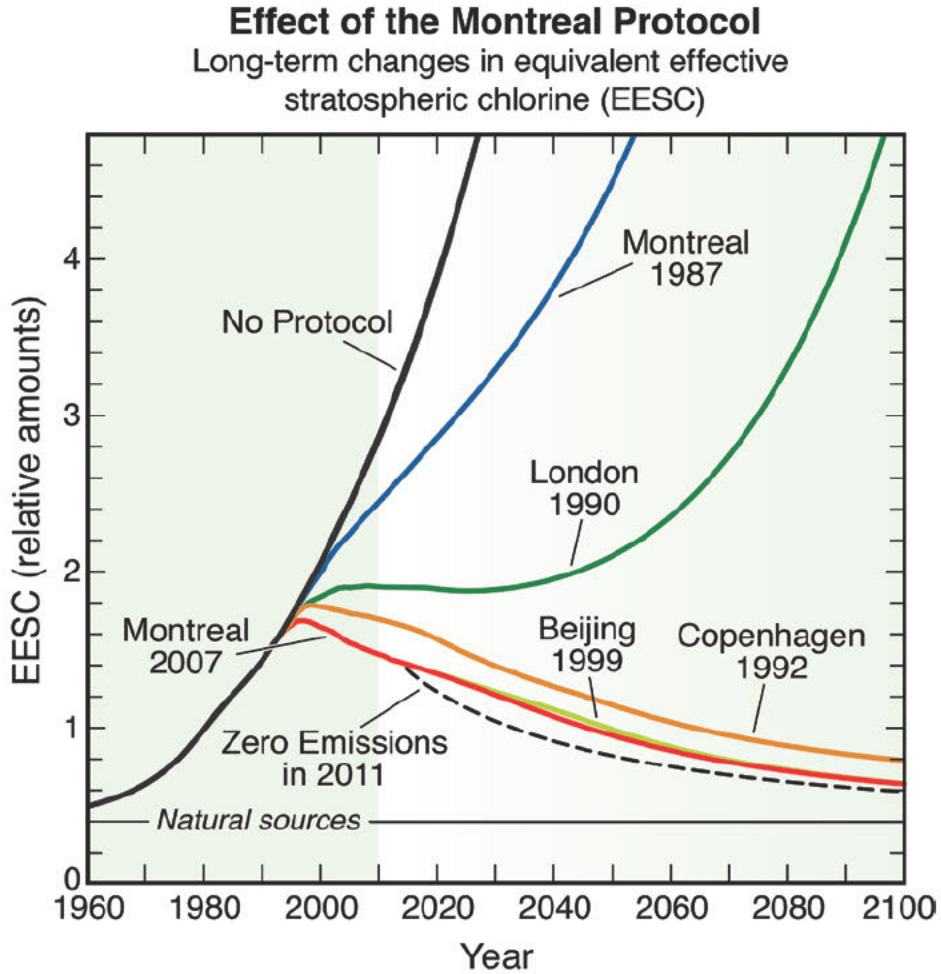

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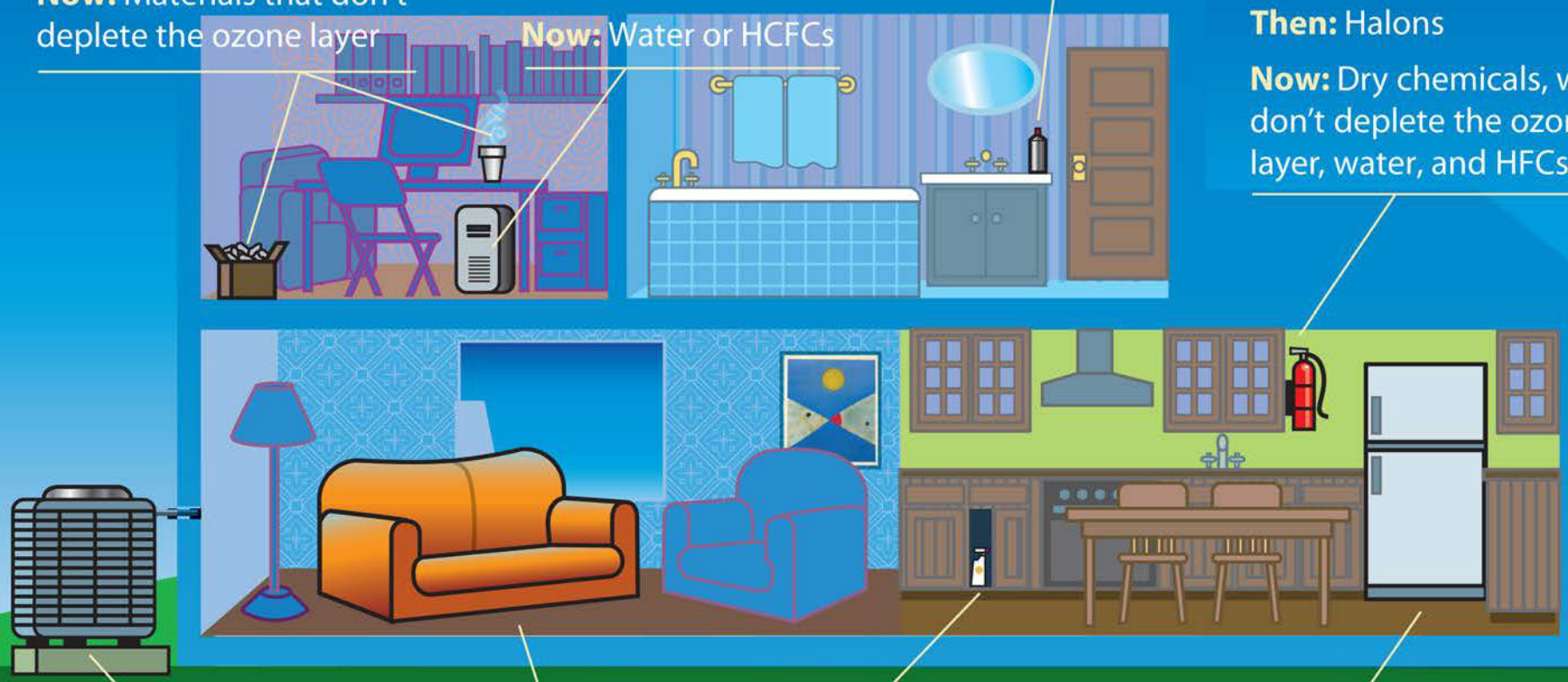

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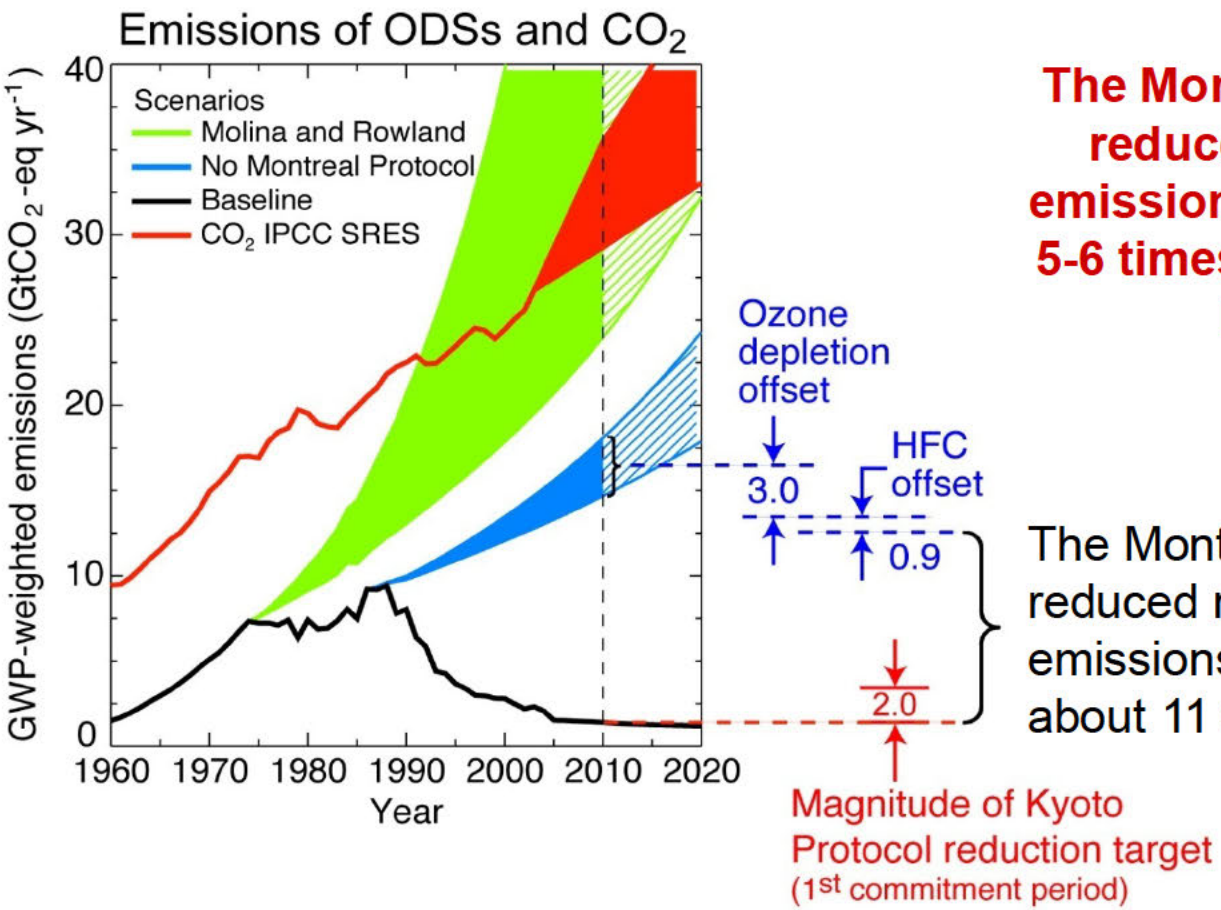

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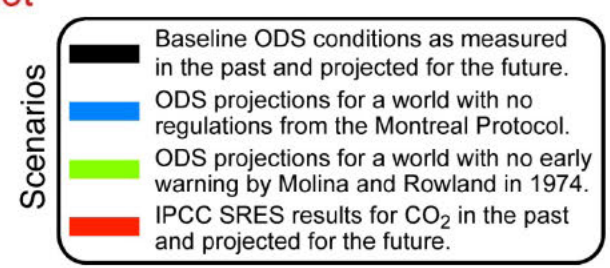

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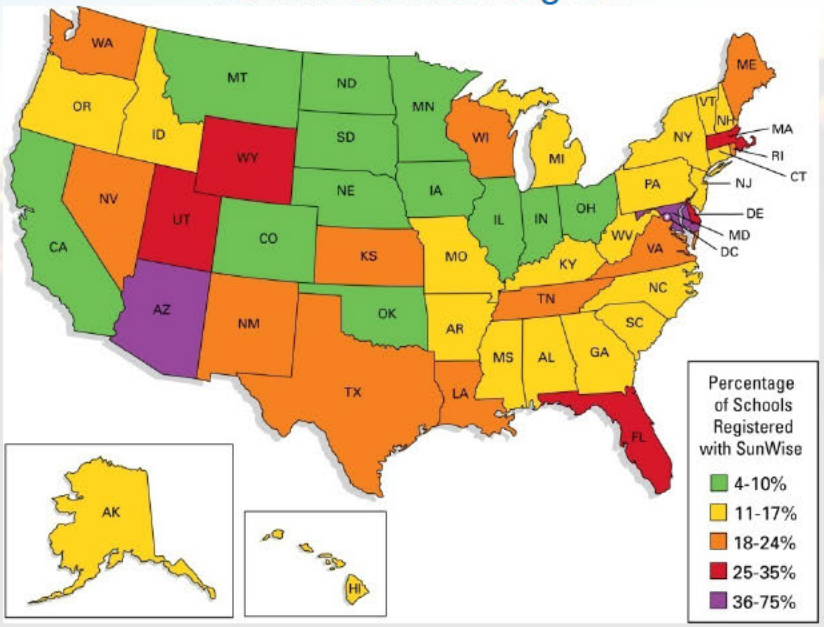

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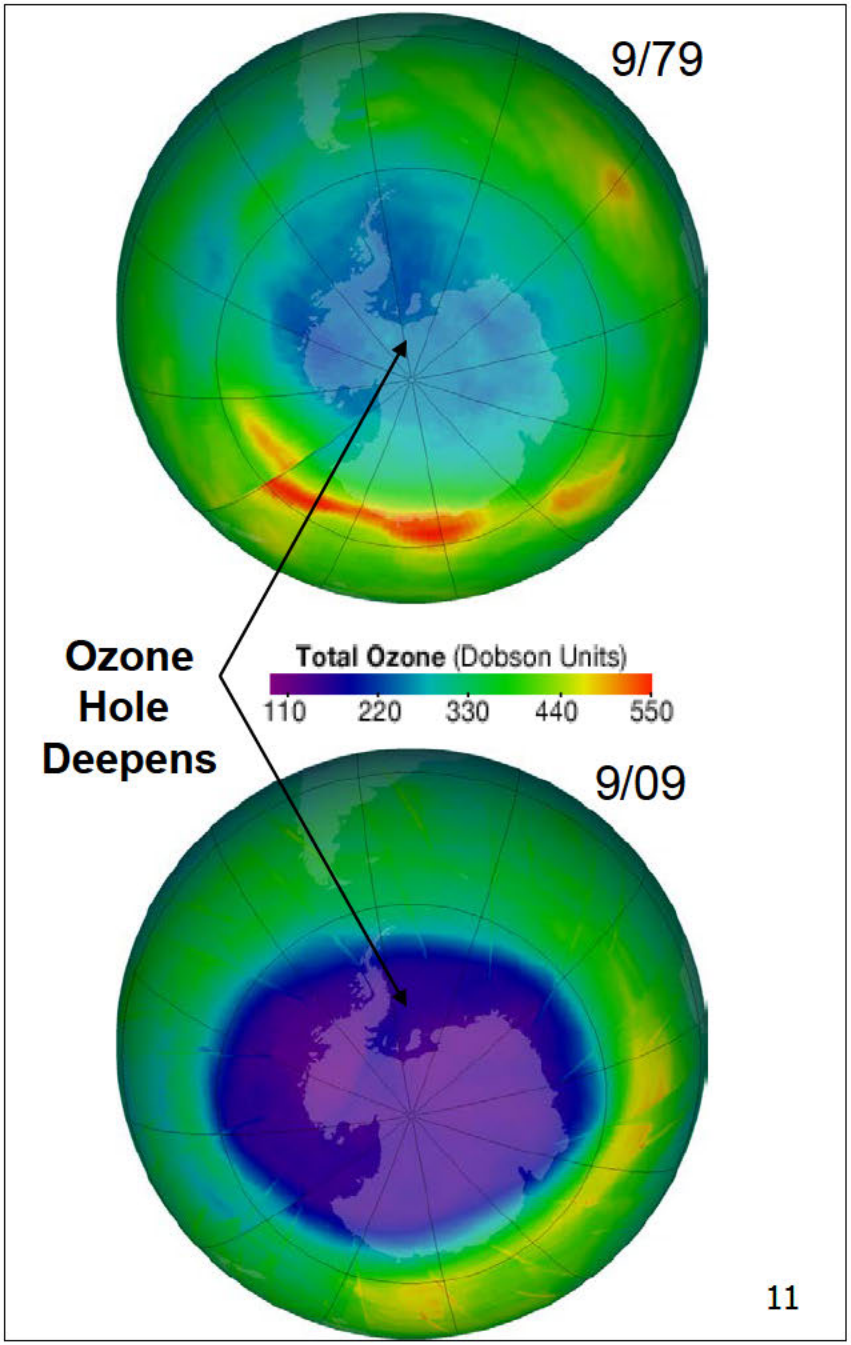

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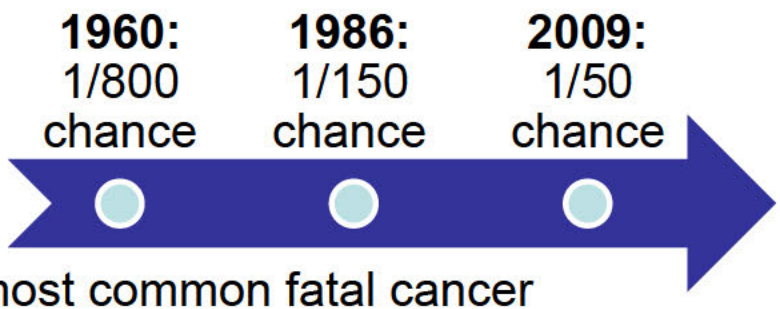

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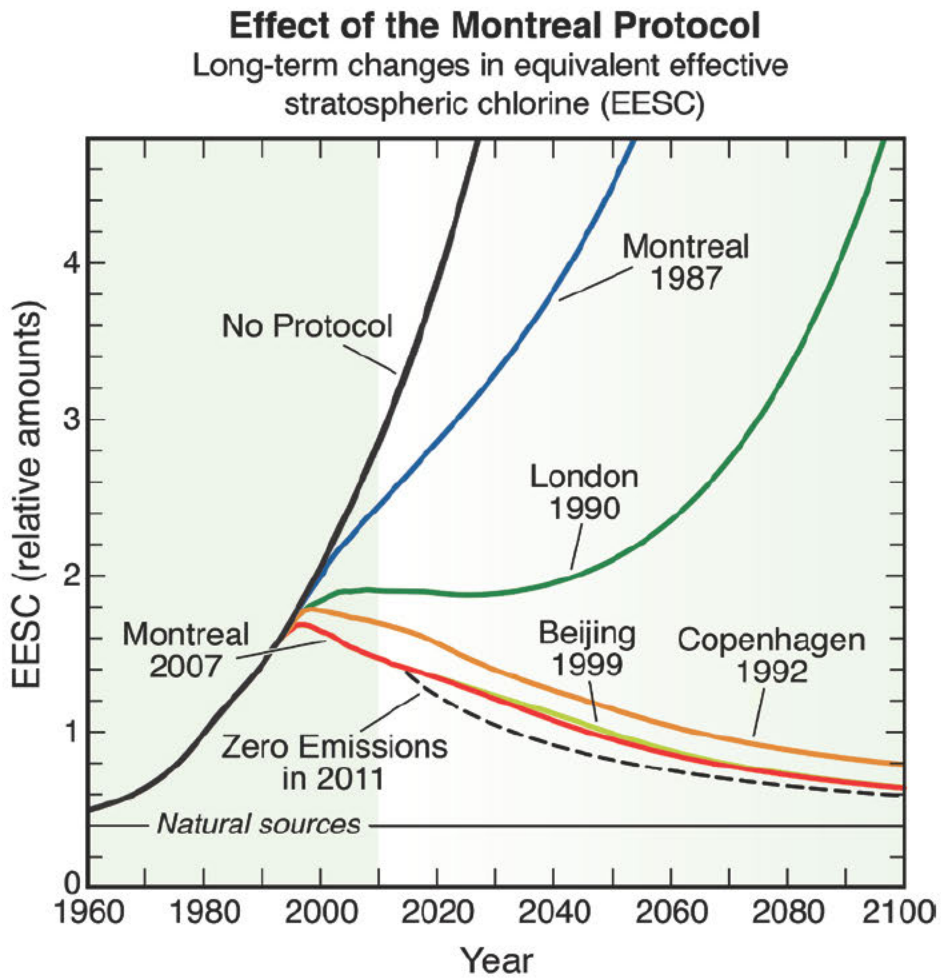

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- Prevent skin cancer: SunWise, school-based voluntary education program, teaches children about sun safety, ozone science, and protection from UV radiation

U.S. Clean Air Act (CAA)

- Title VI of CAA
  - Requires phaseout regulations & other requirements *as stringent as* Montreal Protocol
  - Supports production phaseout with other elements: Nonessential product bans, labeling, evaluation of alternatives, exemptions in special cases
- EPA Regulations - 40 CFR Part 82
  - Implement CAA & Montreal Protocol
  - Set up phaseout targets & tradable allowance system for Class I & Class II substances (production exemptions for certain uses)
  - Review and list alternatives
  - Emphasize emissions control *and* recycling
  - Strong enforcement component

Then and Now: Progress in Ozone Layer Protection

Polystyrene Cups and Packing Peanuts

Then: CFCs

Now: Materials that don't deplete the ozone layer

Computer Circuit Boards

Then: CFCs or methyl chloroform

Now: Water or HCFCs

Aerosol Cans

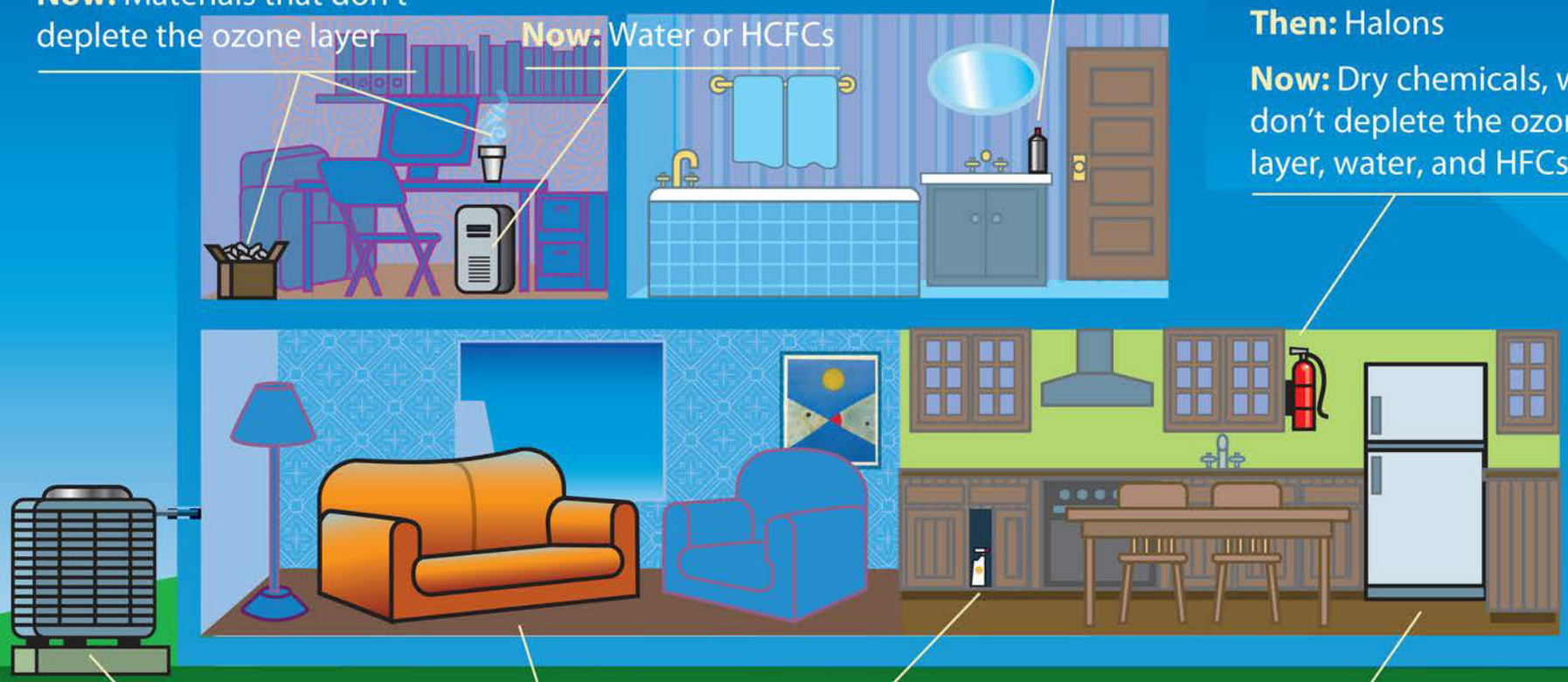
Then: CFCs

Now: Hydrocarbons

Fire Extinguishers

Then: Halons

Now: Dry chemicals, which don't deplete the ozone layer, water, and HFCs



Home and Car Air Conditioners

Then: CFCs

Now: HCFCs and HFCs

Furniture

Then: CFCs

Now: Water-blown foam

Degreasers

Then: CFCs or methyl chloroform

Now: Water-soluble compounds and hydrocarbon degreasers

Refrigerators

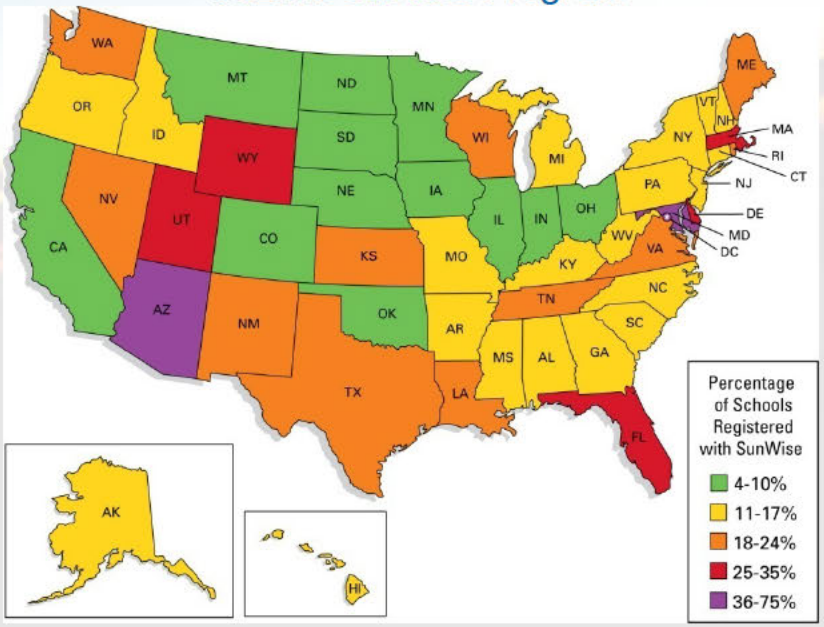
Then: CFCs

Now: HFCs

Teaching Sun Safety: *Because the ozone layer may remain compromised for more than 50 years…*

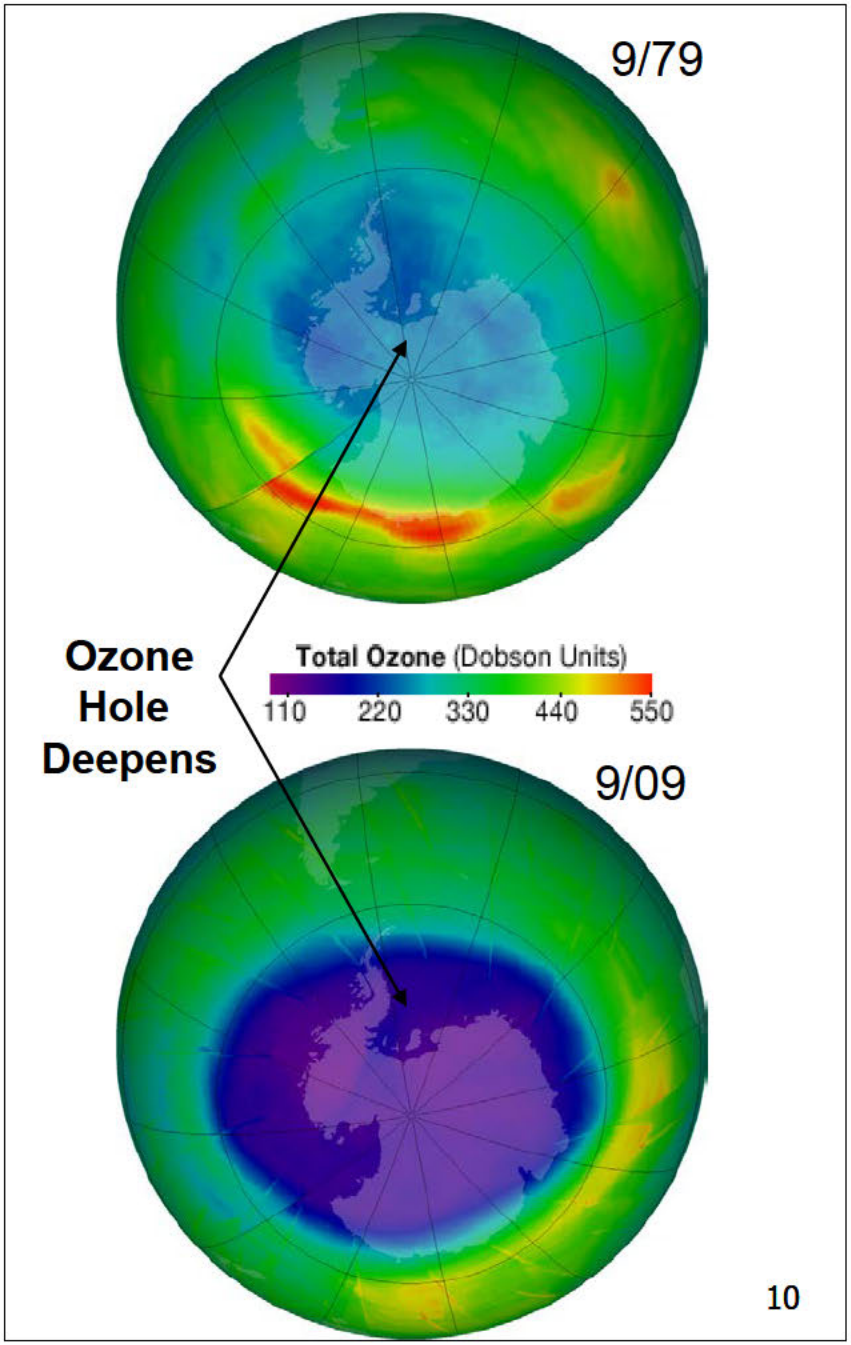
- Modelled on Australia's highly successful SunSmart program, SunWise teaches children how to protect themselves from overexposure to UV radiation
- > 25,000 schools, 30,000 educators, and 5,000 museums, camps & others registered to teach kids K-8 in all U.S. states
- Some U.S. states have implemented SunWise on a statewide basis:
  - Arizona
  - Washington
  - Wisconsin

Percentage of K-8 Schools Participating in EPA's SunWise Program



Are We There Yet?

- *Among the most difficult things to sustain is support for a victory in progress*



Source: NASA's Ozone Hole Watch Web Site, Sept. 2009

Completing Successful Ozone Layer Protection

- Maintain U.S. compliance with Montreal Protocol, collaborating with other countries to strengthen accord in sensible ways as appropriate, as in 2007 stronger HCFC phaseout
  - Assure smooth transitions to alternatives in remaining sectors, keeping in view Science Assessment Panel guidance in 2010 Update: "*The ozone layer and climate change are intricately coupled, and climate change will become increasingly more important to the future ozone layer* "
- Pursue opportunities for more environment, public health protection
  - Trilateral HFC Amendment
- Share with U.S. families simple steps to avoid overexposure to UV radiation that causes skin cancer

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- 197 Countries – universal participation a unique achievement
- Dramatic Health, Environmental Benefits
  - Scientists predict ozone layer recovery by mid-century
  - Millions of skin cancer deaths, cataracts avoided by 2165
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MONTREAL PROTOCOL 25 1987-2012

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- Includes both Developed & Developing Countries
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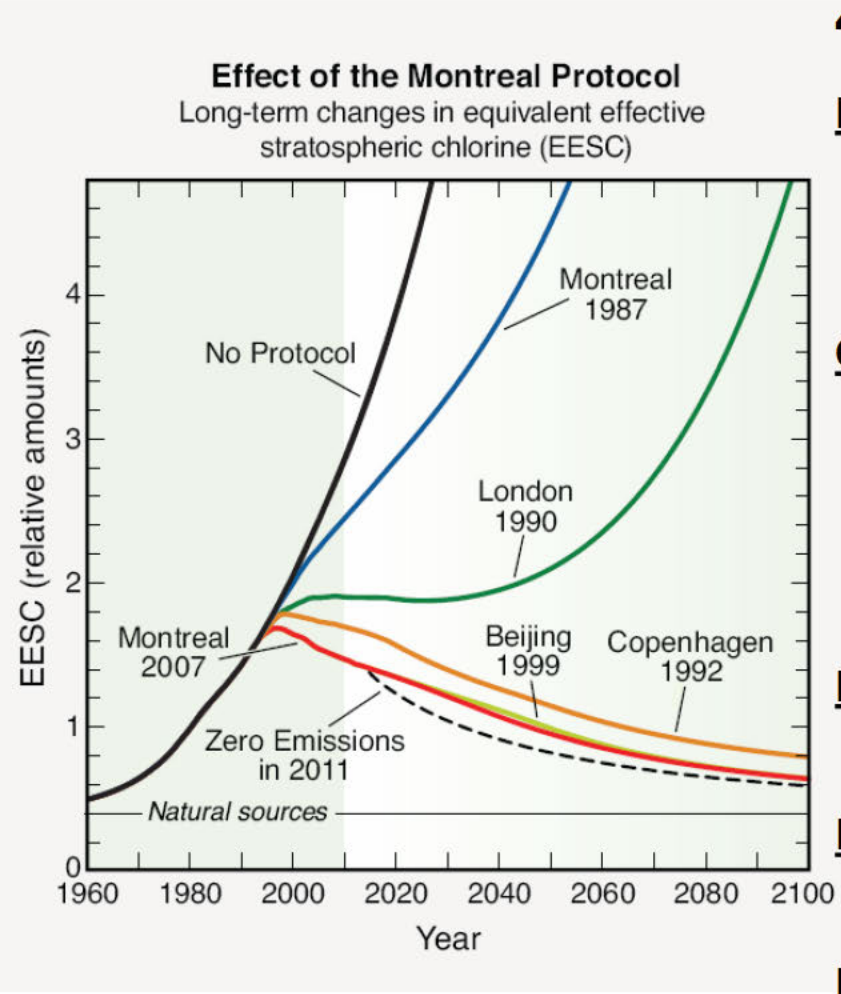

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SNAP Program

- Lists safer substitutes that reduce overall risk to human health & environment in industrial sectors
  - e.g., Refrigeration, A/C, Foams, Solvents, Fire Suppression, Aerosols, etc.
- 400+ substitutes considering:
  - Ozone Depletion Potential (ODP), GWP, flammability, toxicity, local air quality, ecosystem effects, occupational & consumer health/safety
- Alternatives include:
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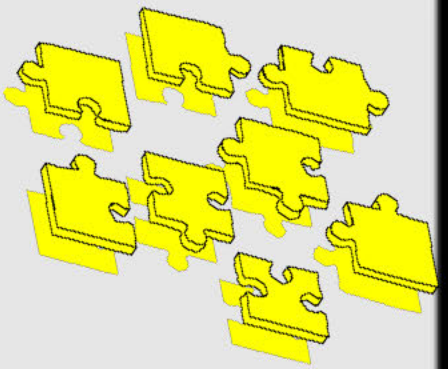
  - Alternative technologies (e.g., thermoelectric)
- Next Generation Alternatives
  - Alternatives for ODS & high GWP-HFCs



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  - SUPERVALU: 1st U.S. store using entirely non-fluorinated refrigeration, innovative ammonia/CO_2 system

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- Voluntary program builds on Title VI to capture refrigerant and ODS or HFC foam blowing agents in appliances
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  - Manufacturers
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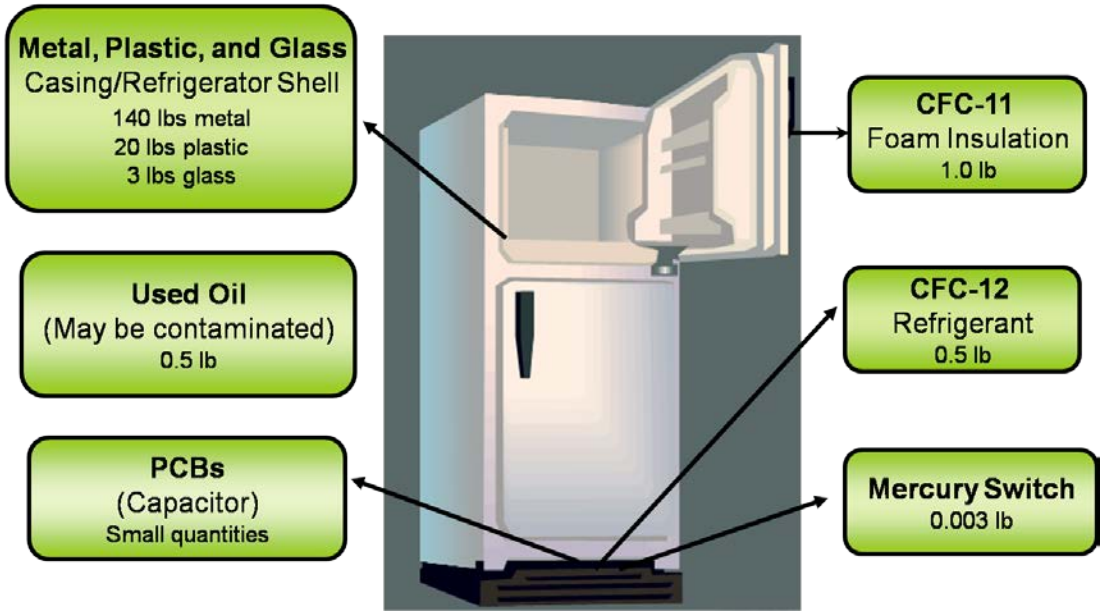

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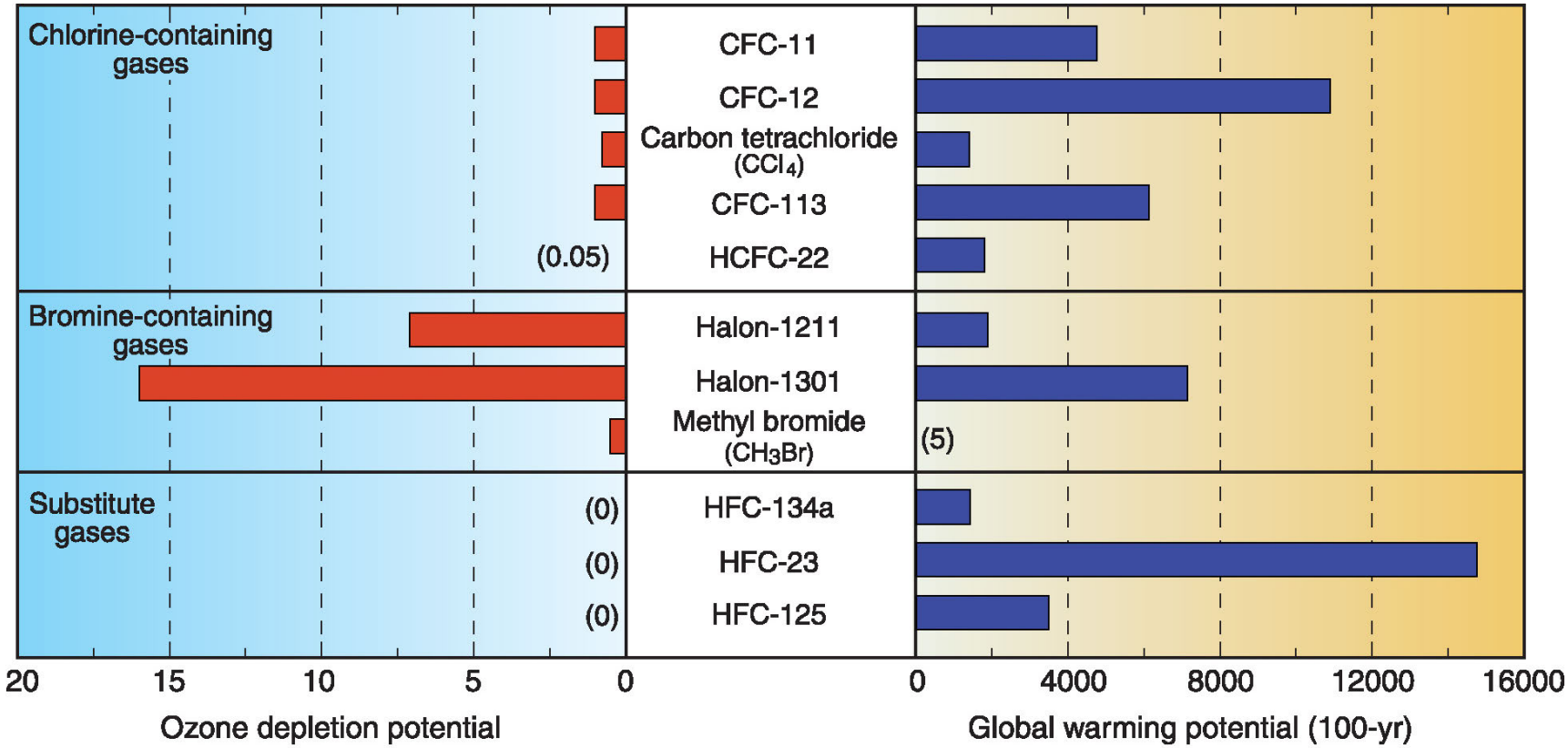

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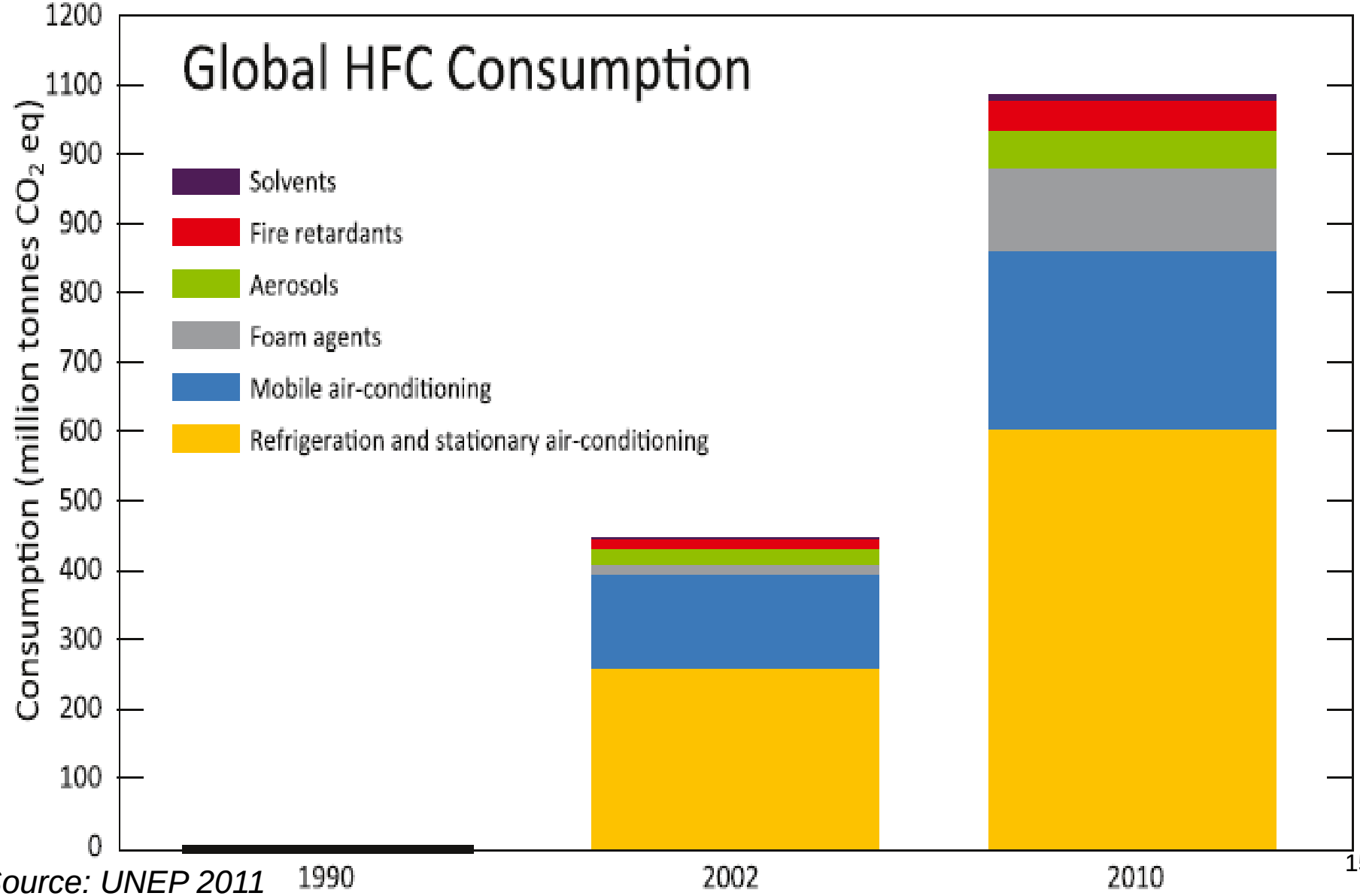

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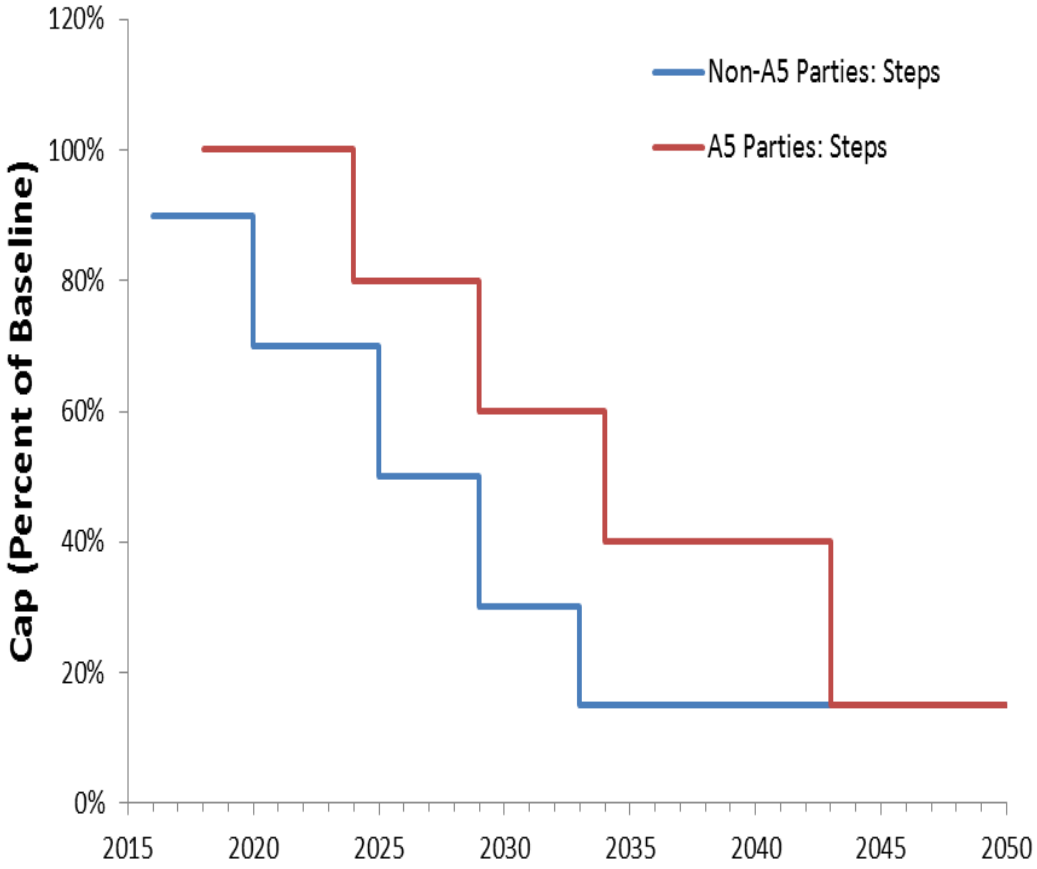

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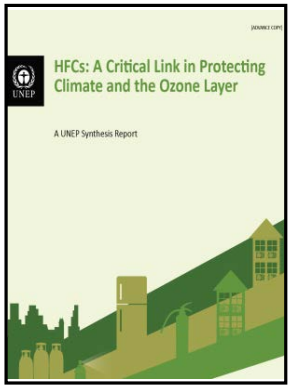

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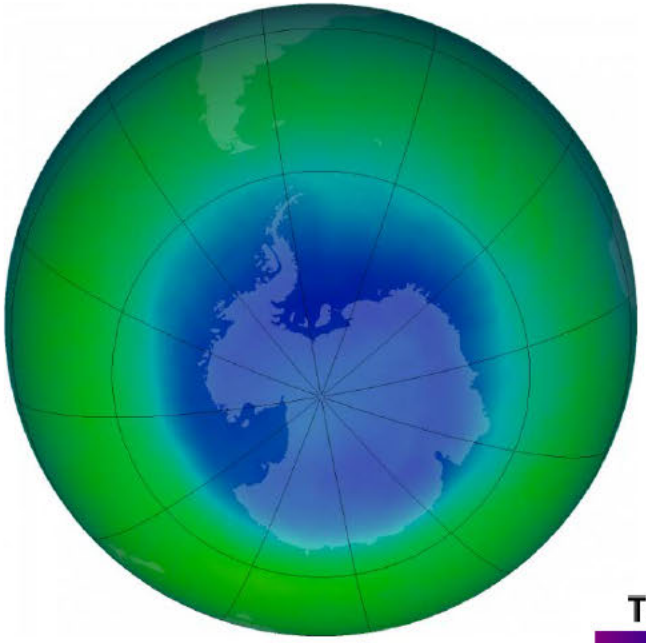

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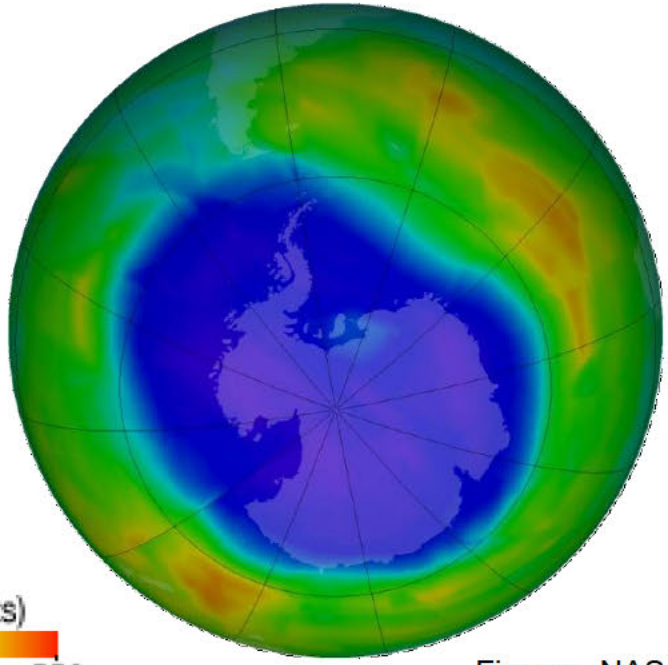


Figures: NASA

- *Ozone layer is Earth's "sunscreen" – protects people, plants and animals from too much ultraviolet radiation.*
- *Because ozone-depleting substances (ODS) persist for long periods in the ozone layer, damage cannot be reversed rapidly; scientists predict recovery by about 2065.*

SunWise®

a program that **radiates** good ideas

A Partnership Program of the U.S. Environmental Protection Agency

www.epa.gov/sunwise

Goal: While ozone layer recovers, reduce skin cancer & cataracts by sharing sun safety information with schools, kids, and families

Proven Effective

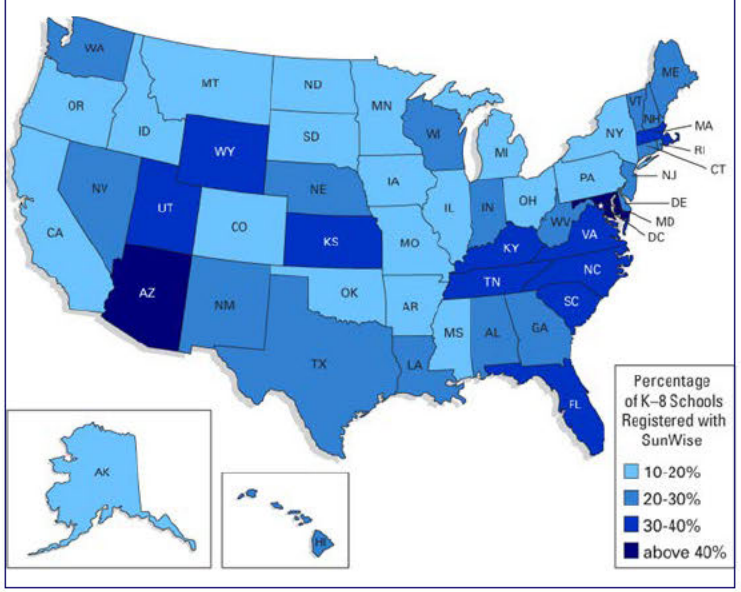
SunWise students show an 11% decrease in sunburns.

Every $1 invested in SunWise earns $2 to $4 in public health savings.

OncoLink EditorsChoice

GOLD TRIANGLE Award

In All 50 States



Free Resources

Summary

- In 2012, Montreal Protocol marks its 25th anniversary as a uniquely successful environmental agreement
- U.S. implementation through CAA Title VI has allowed consistent compliance and overcompliance in key areas
  - Flexible regulatory scheme blends upstream and downstream controls for lower cost results
  - Voluntary programs build on CAA framework to achieve greater environmental and public health protection

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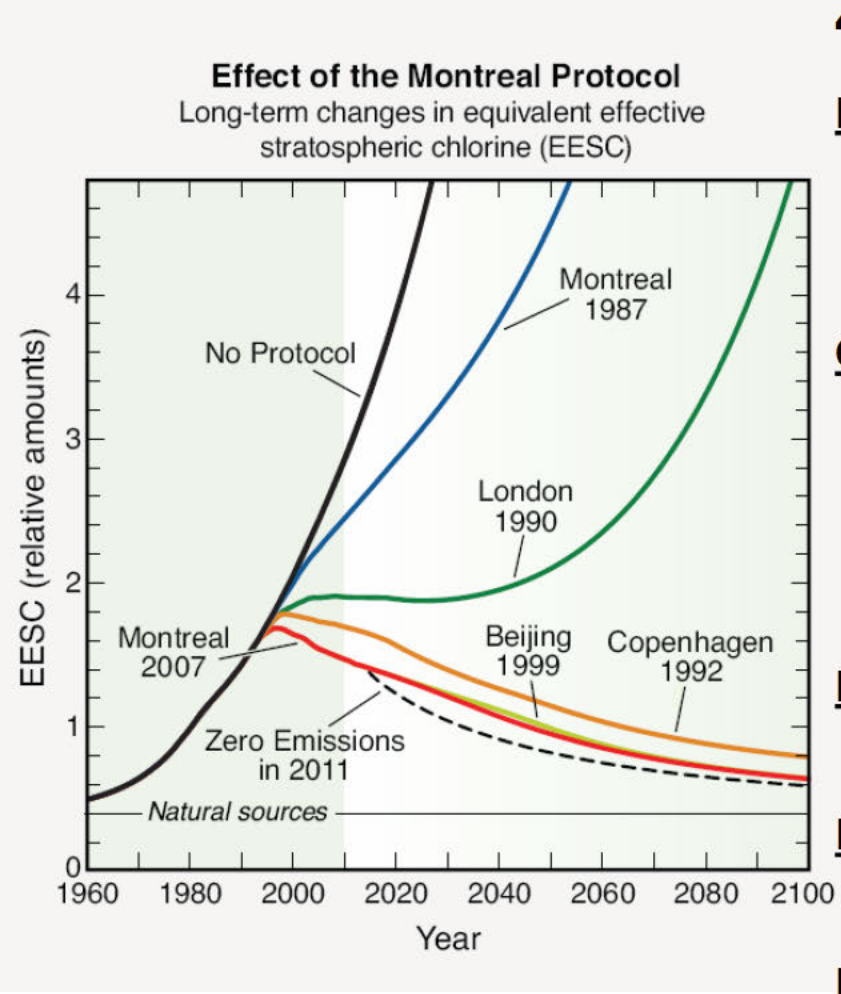

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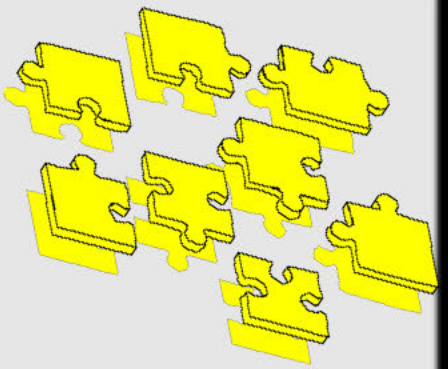

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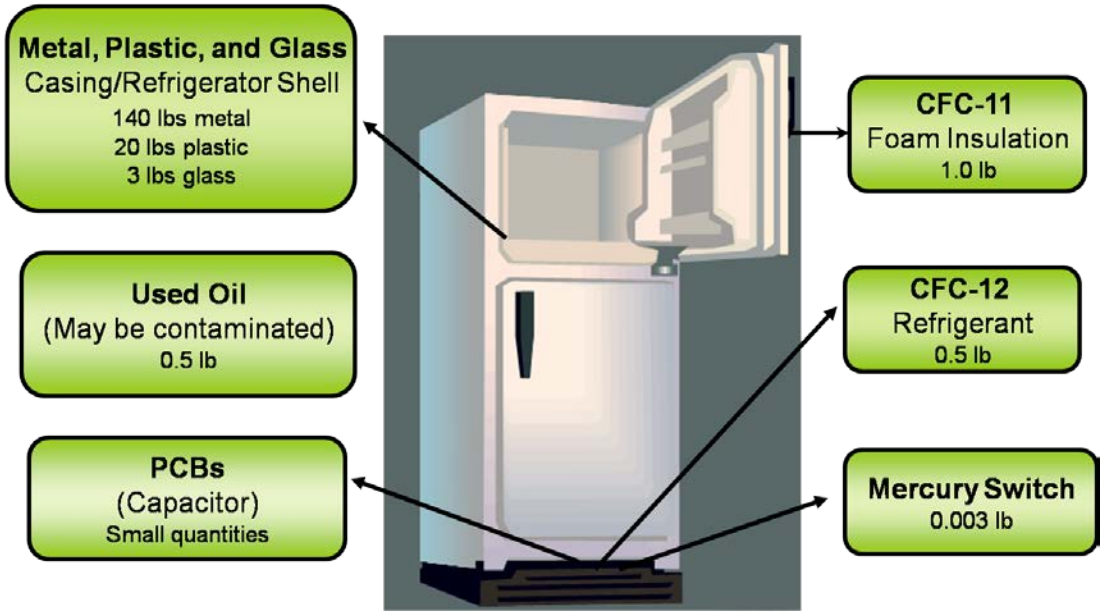

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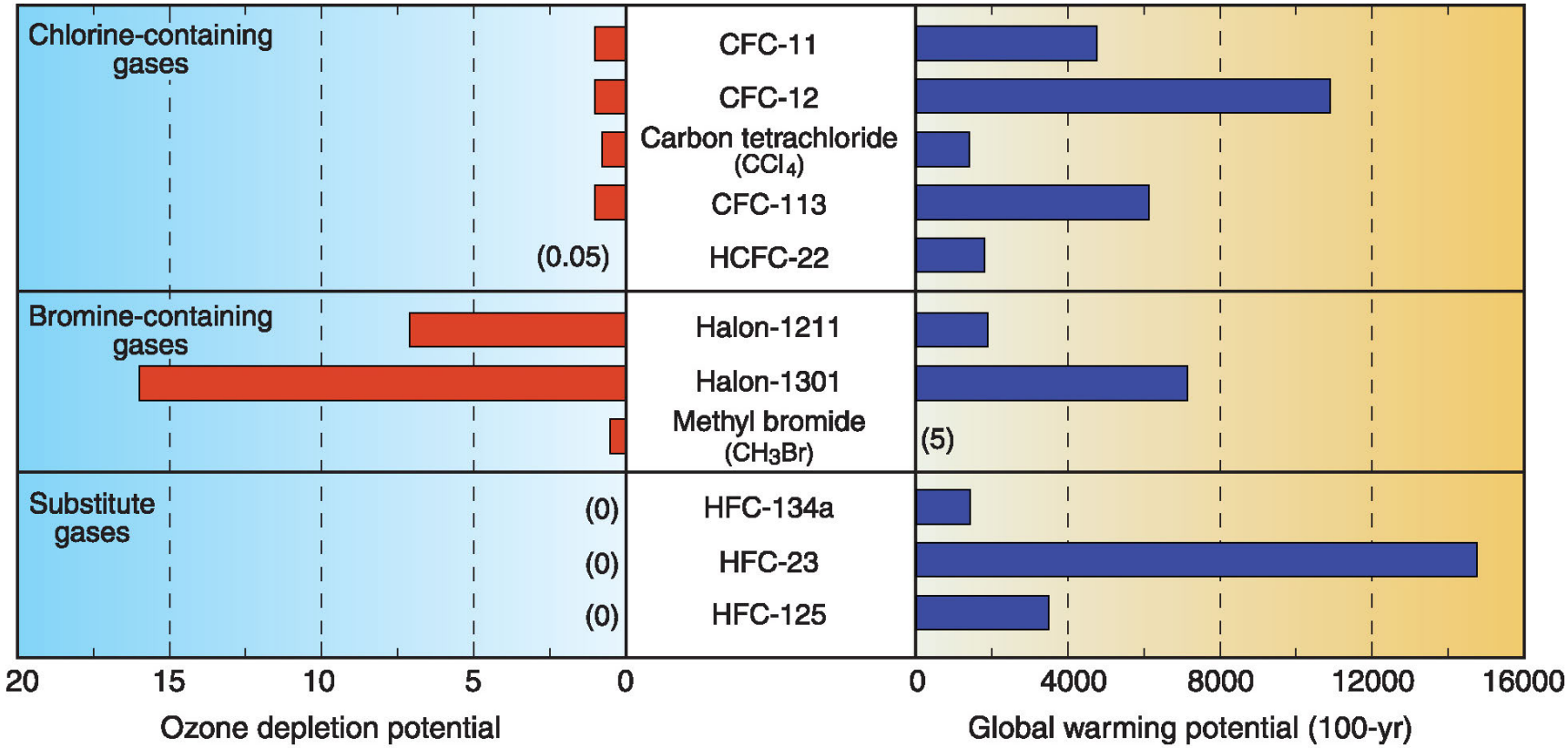

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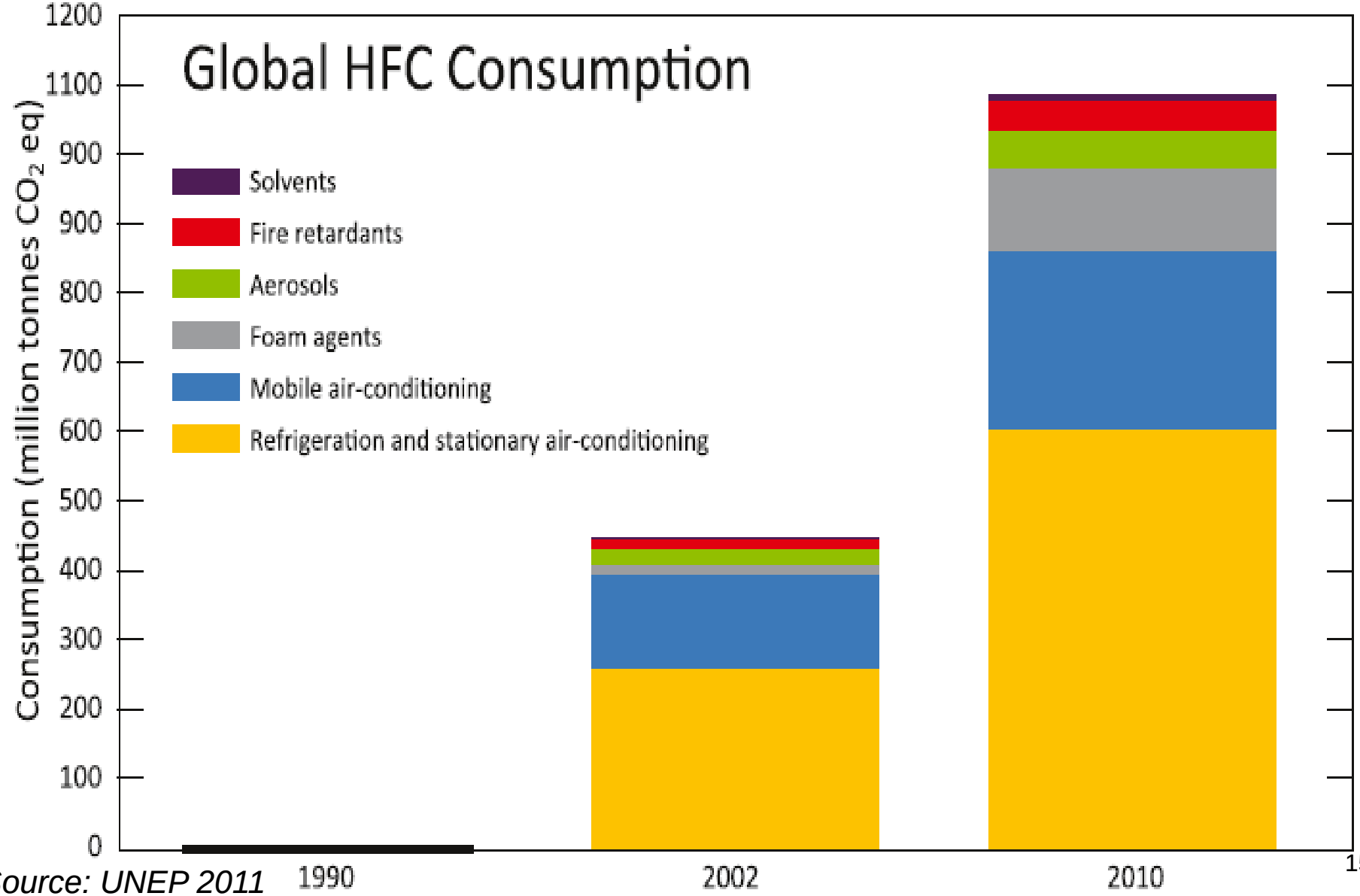

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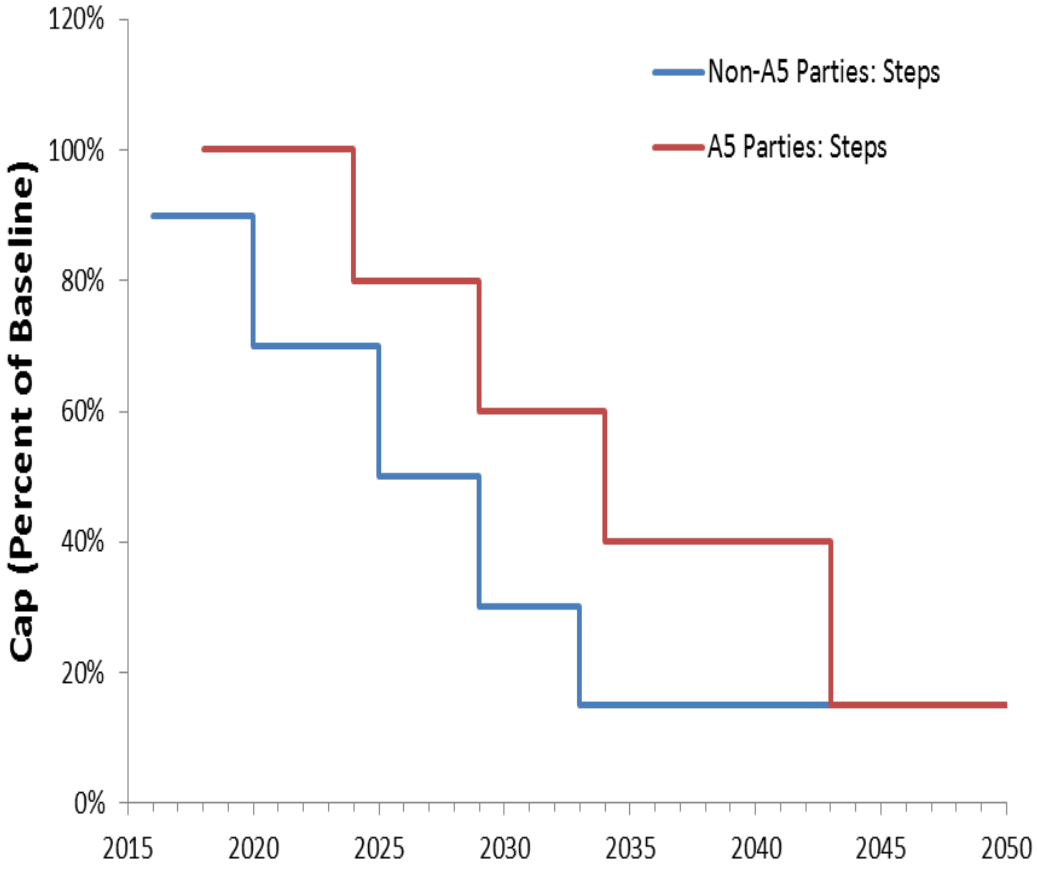

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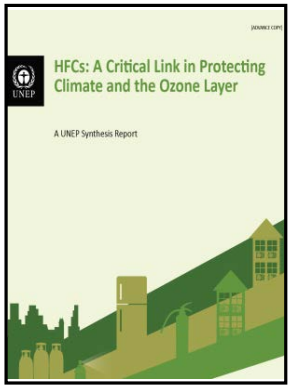

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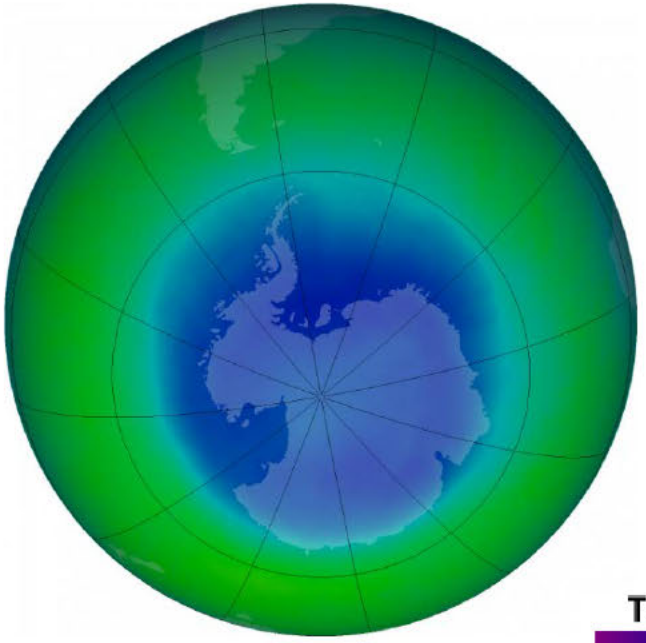

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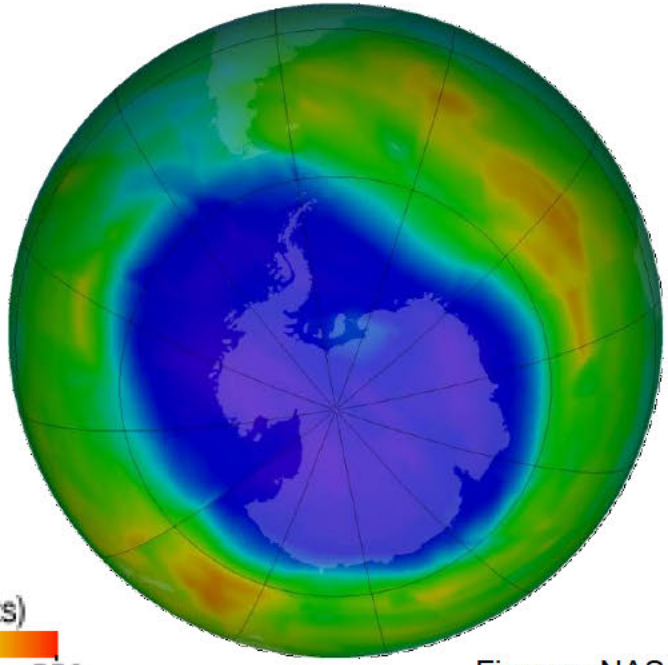

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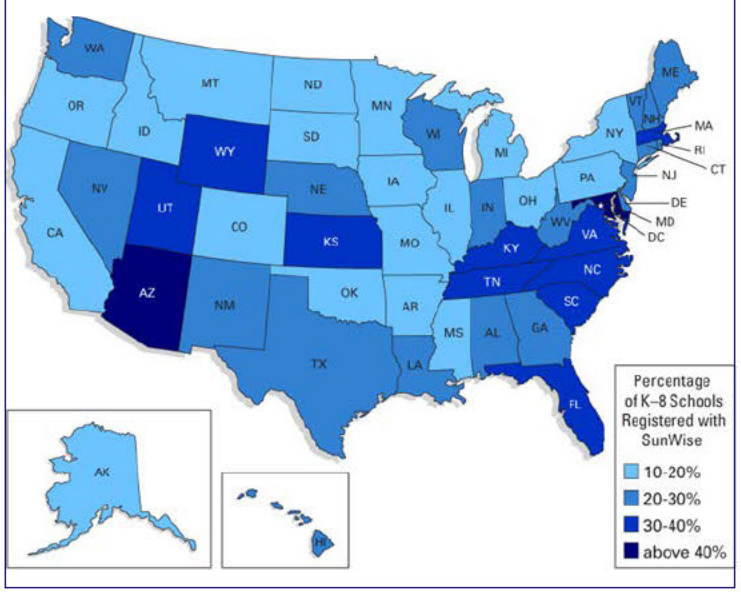

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MONTREAL PROTOCOL 25 1987-2012

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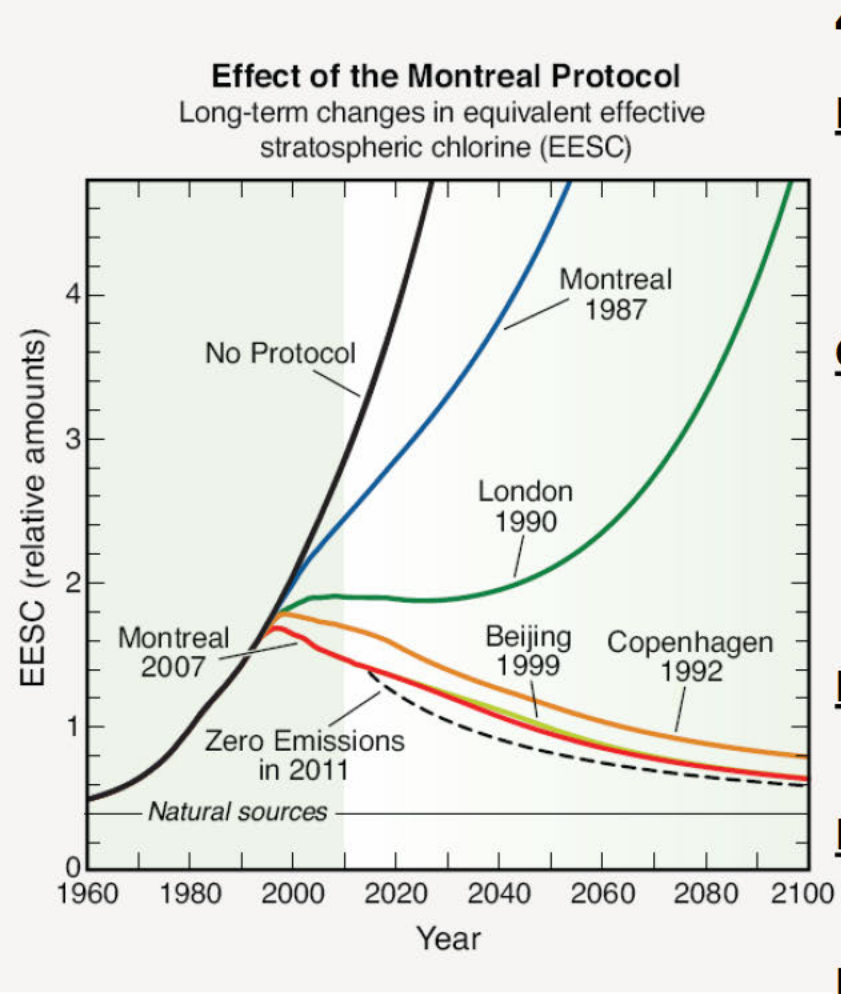

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  - e.g., Refrigeration, A/C, Foams, Solvents, Fire Suppression, Aerosols, etc.
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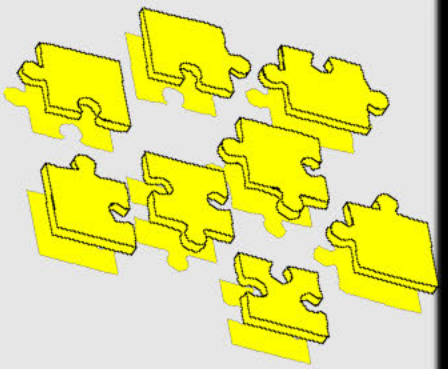

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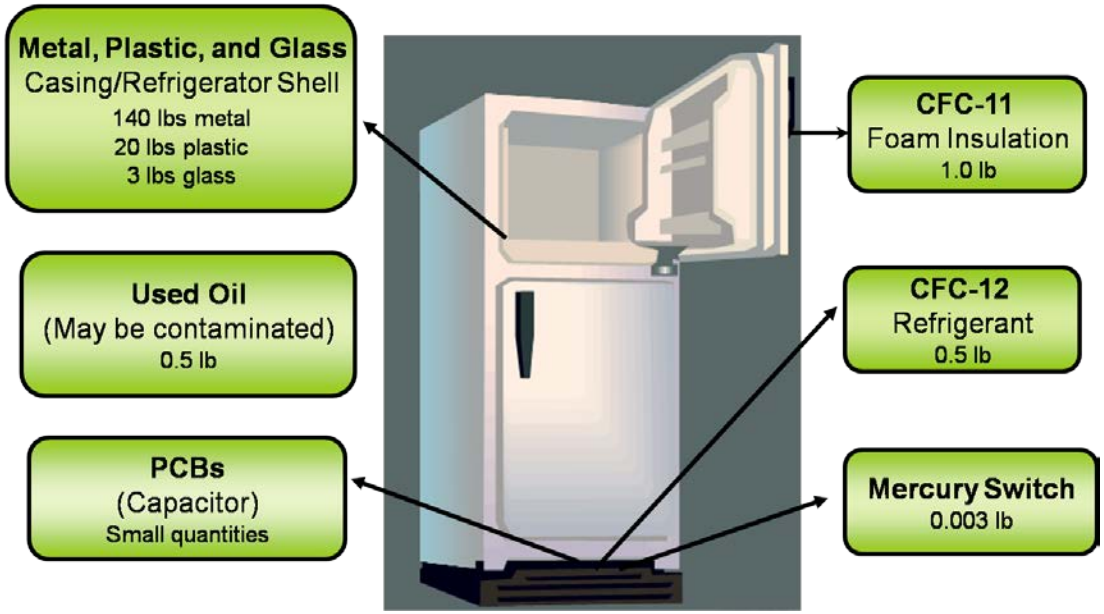

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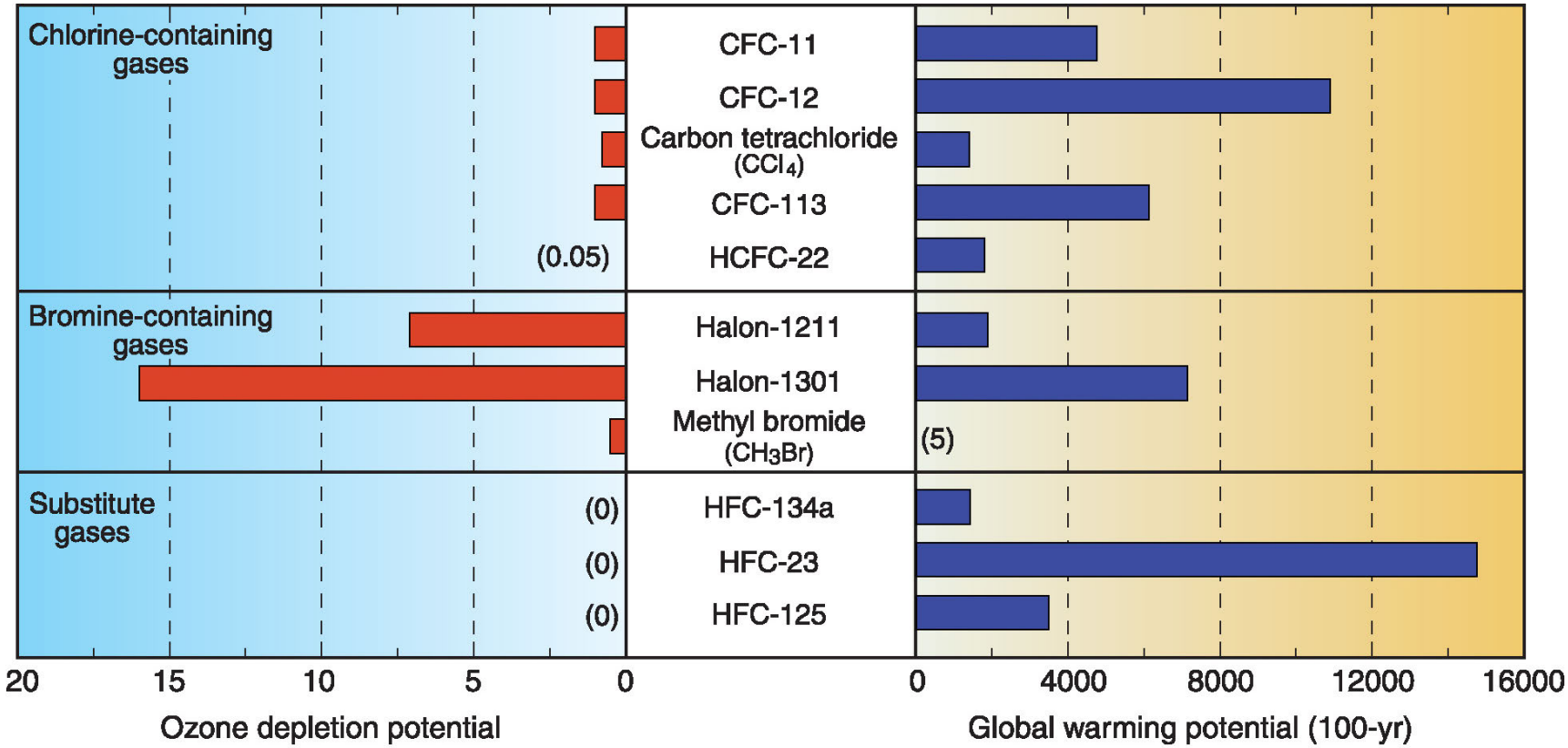

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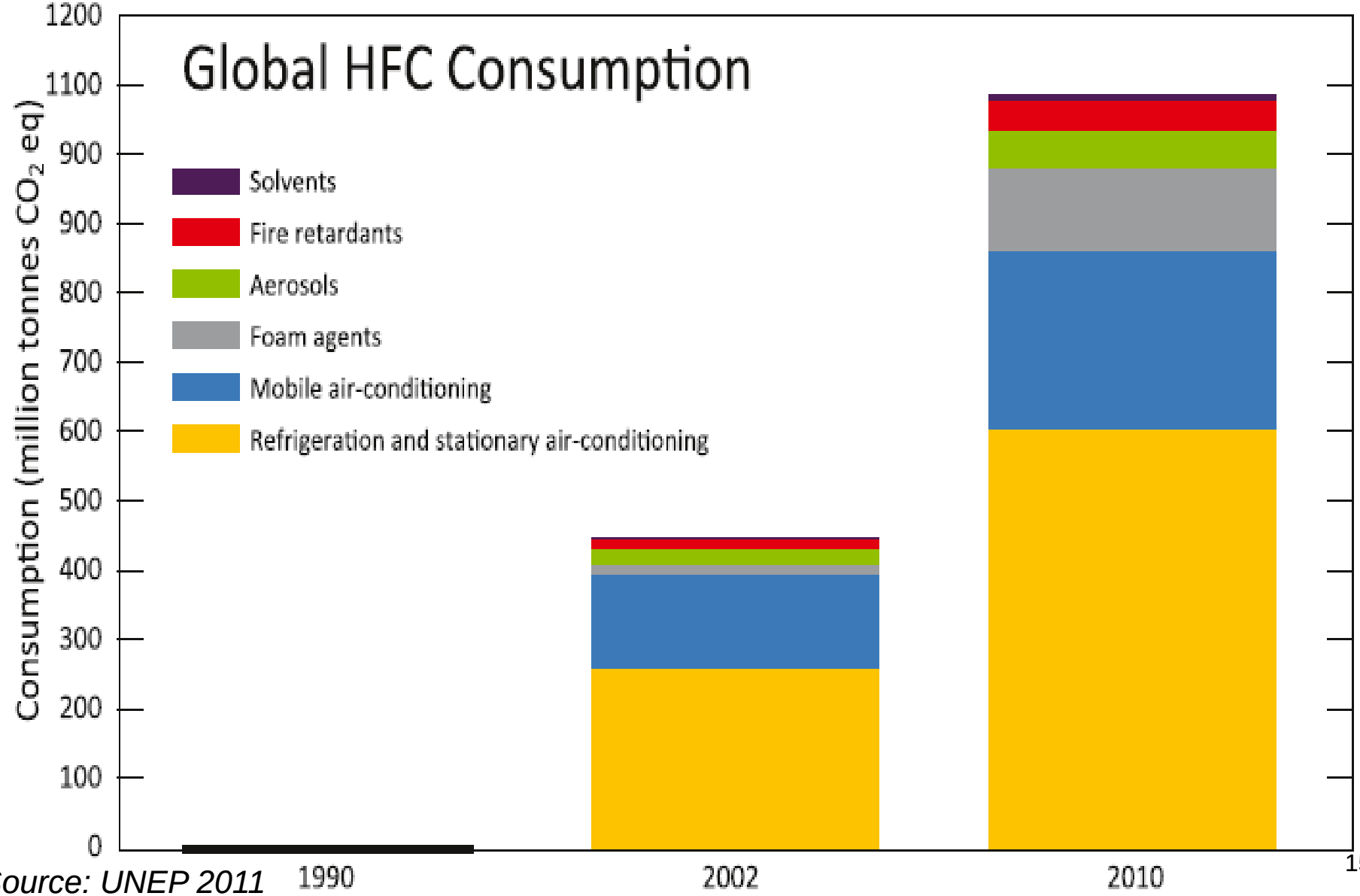

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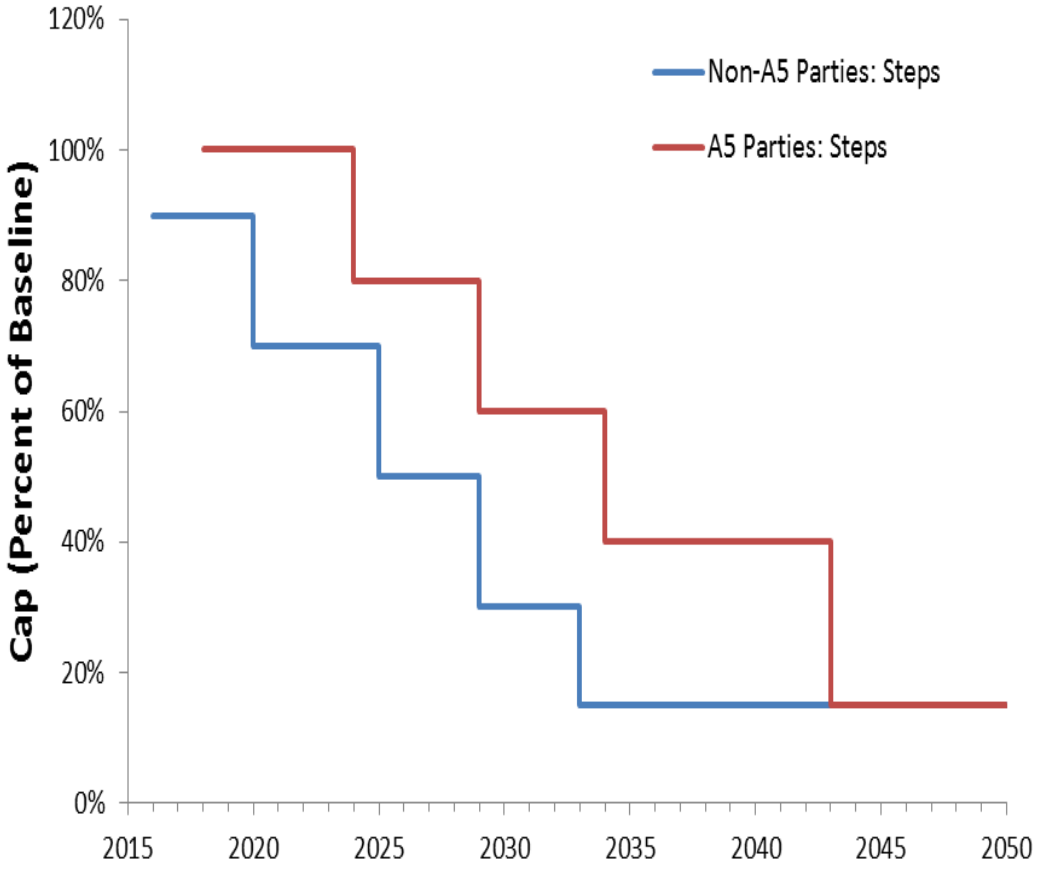

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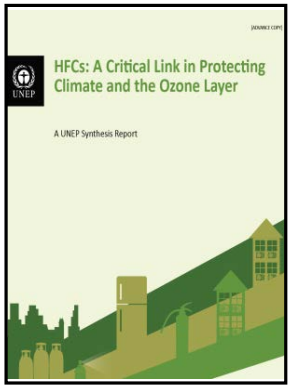

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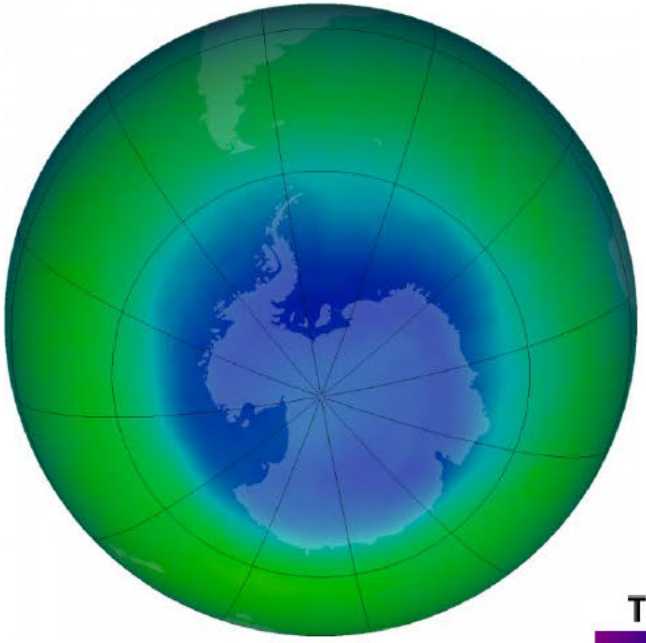

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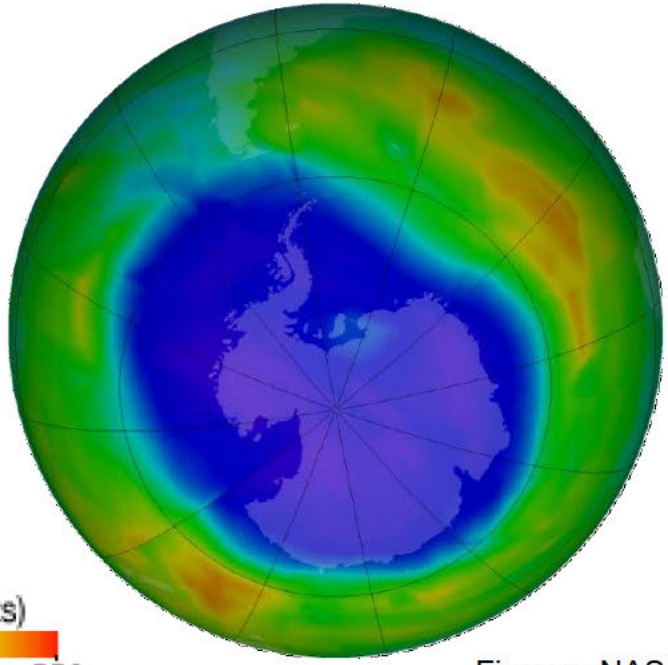

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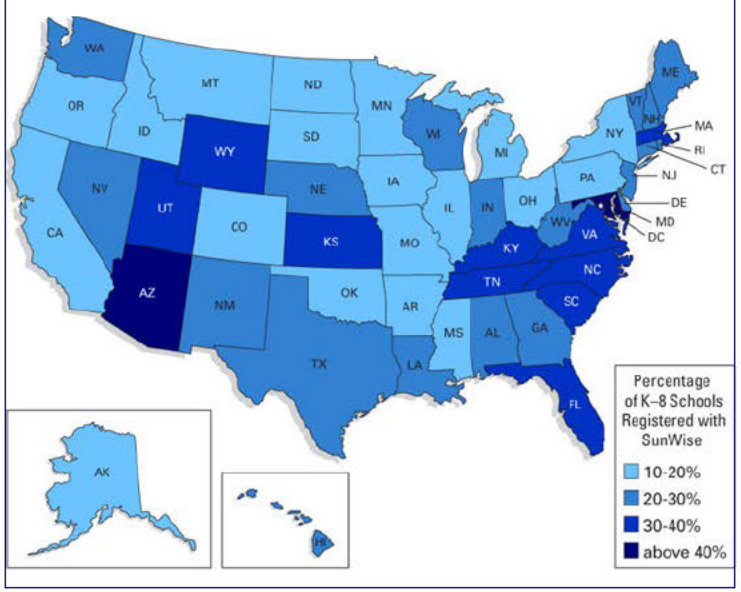

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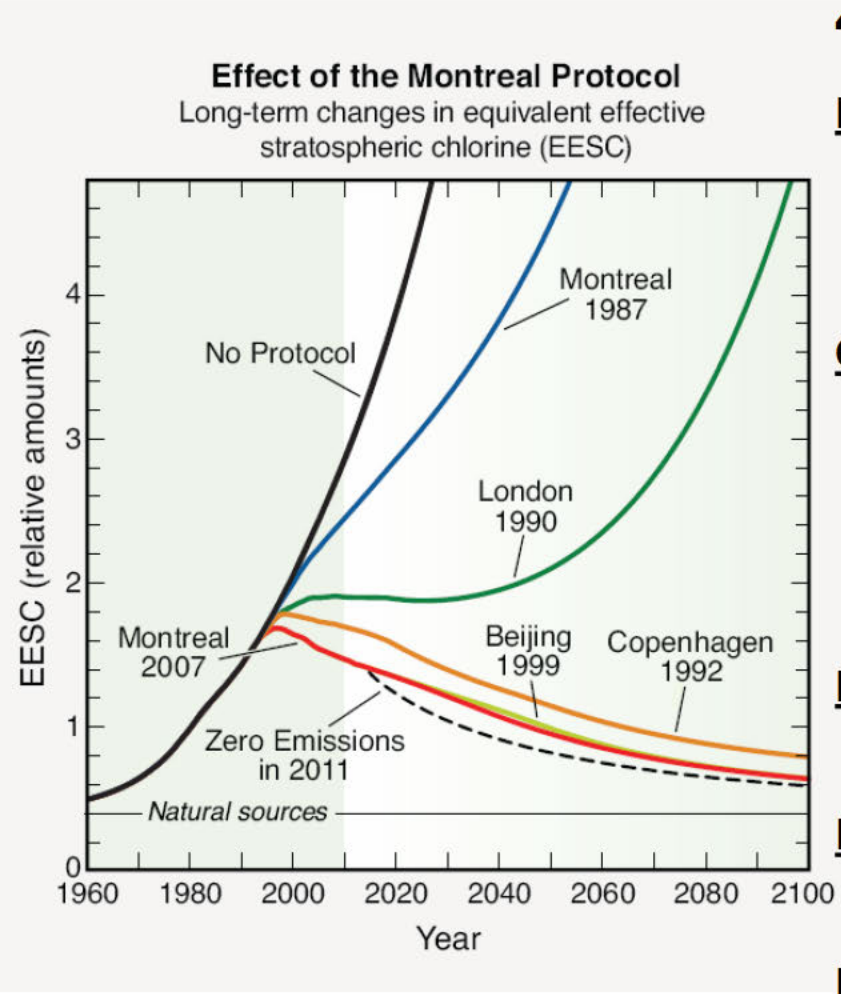

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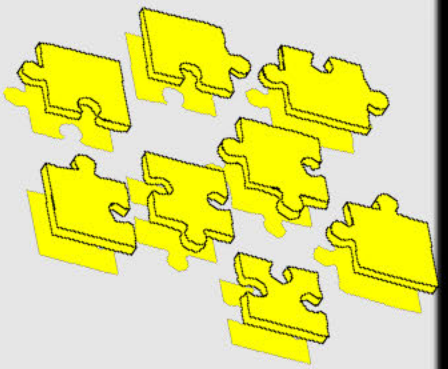

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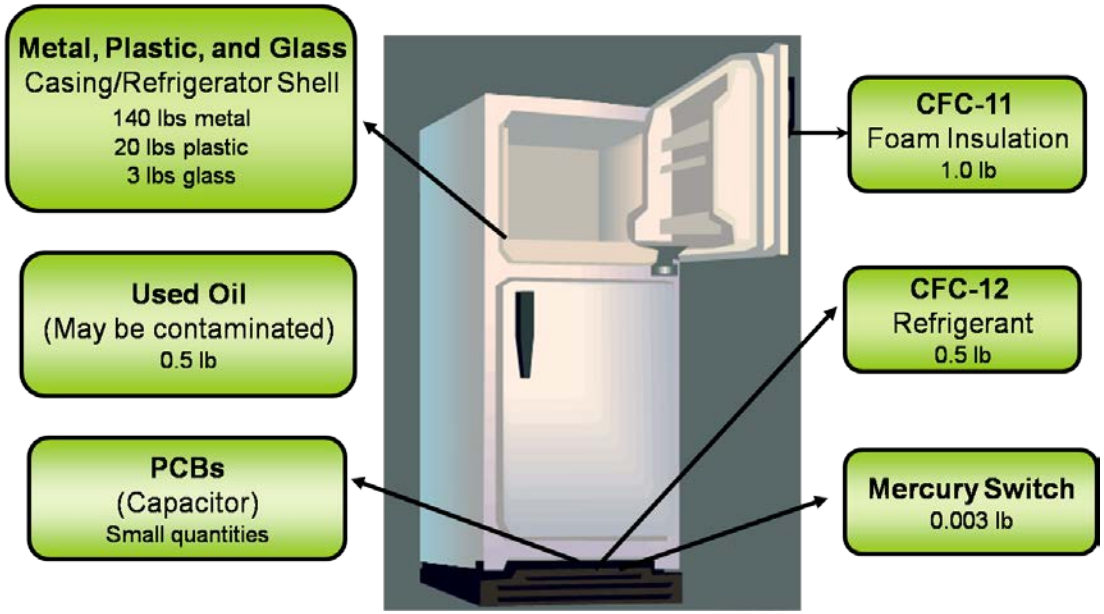

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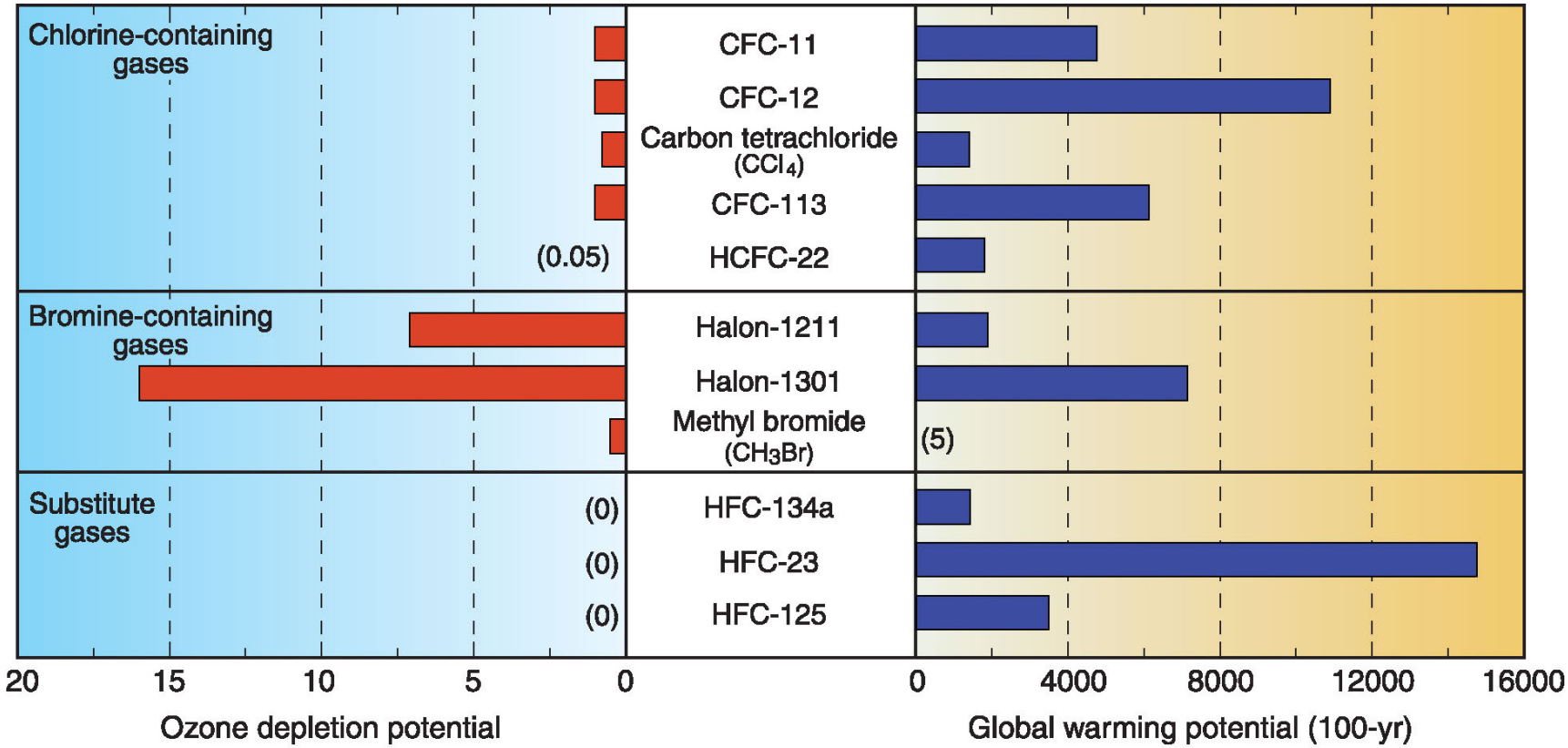

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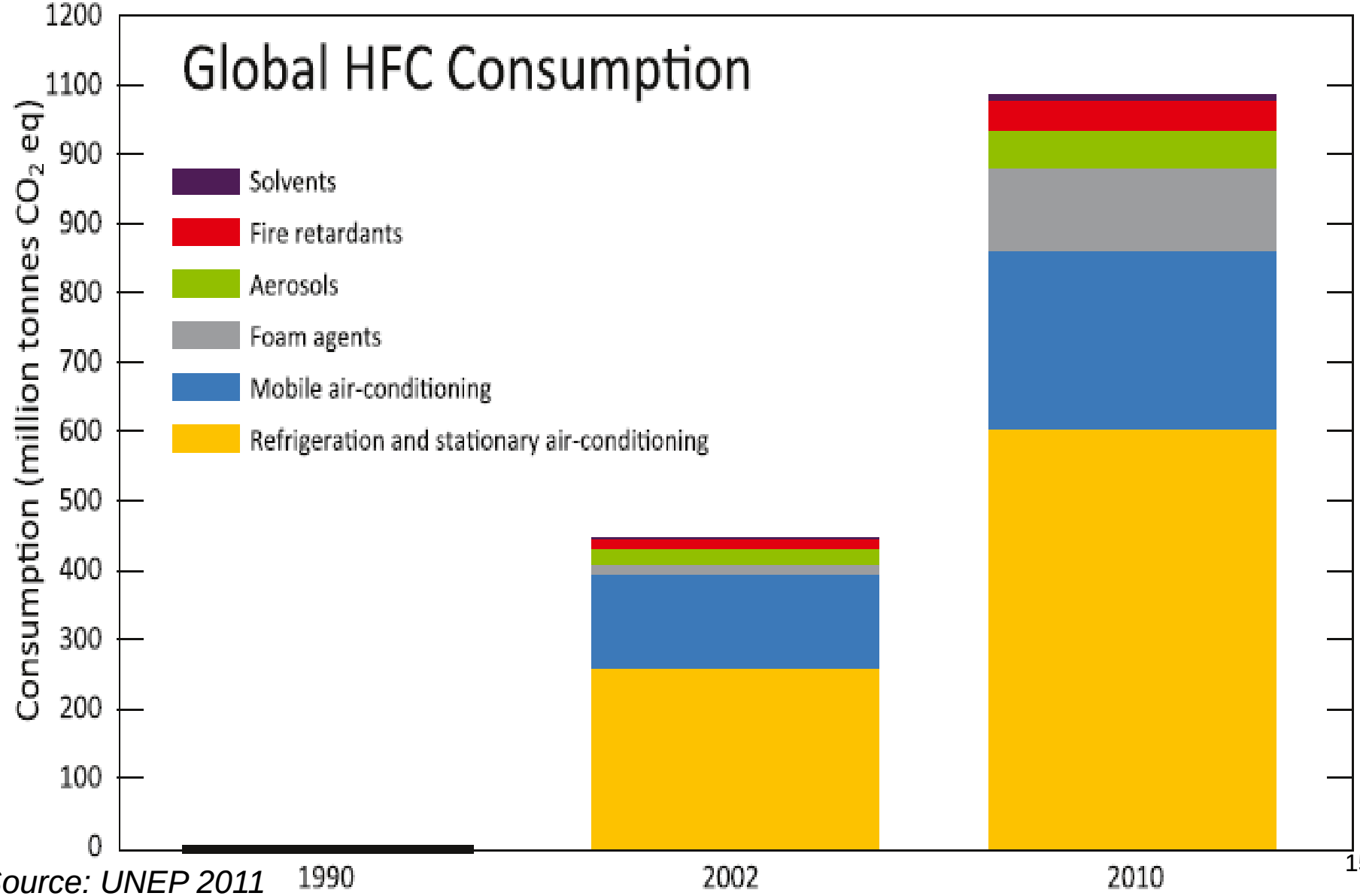

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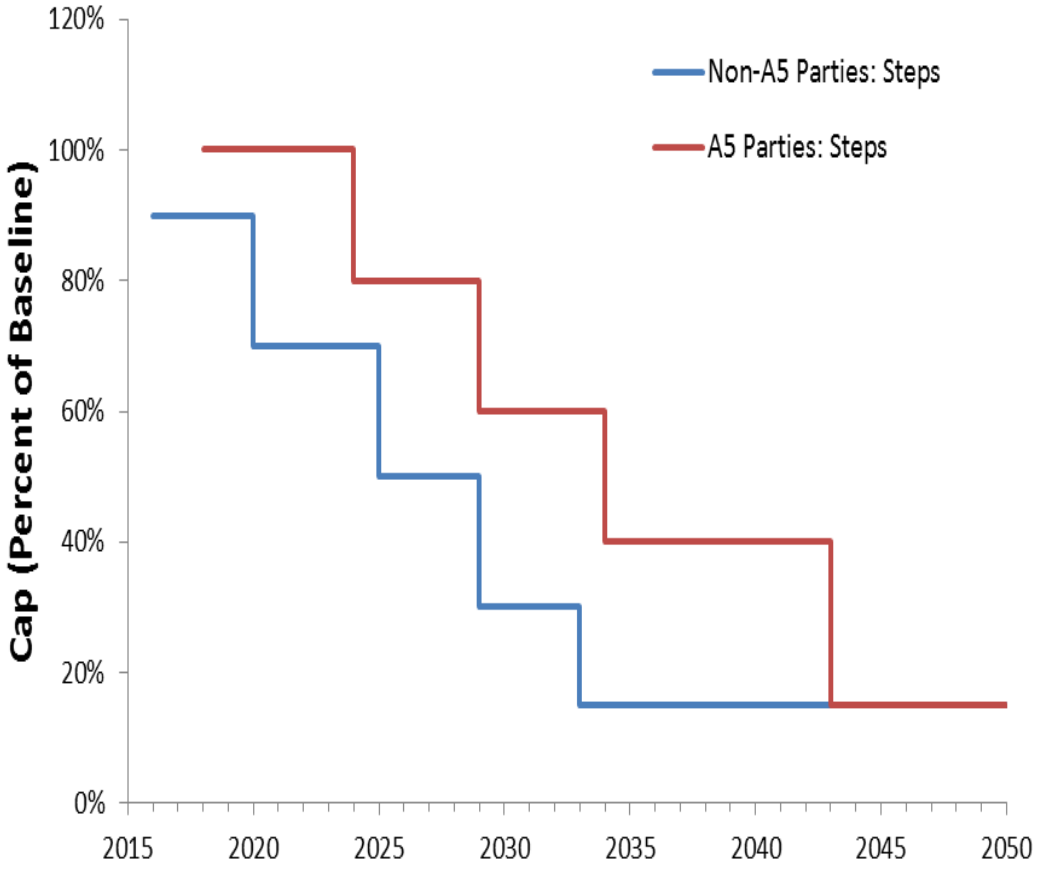

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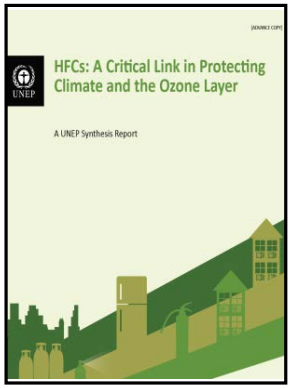

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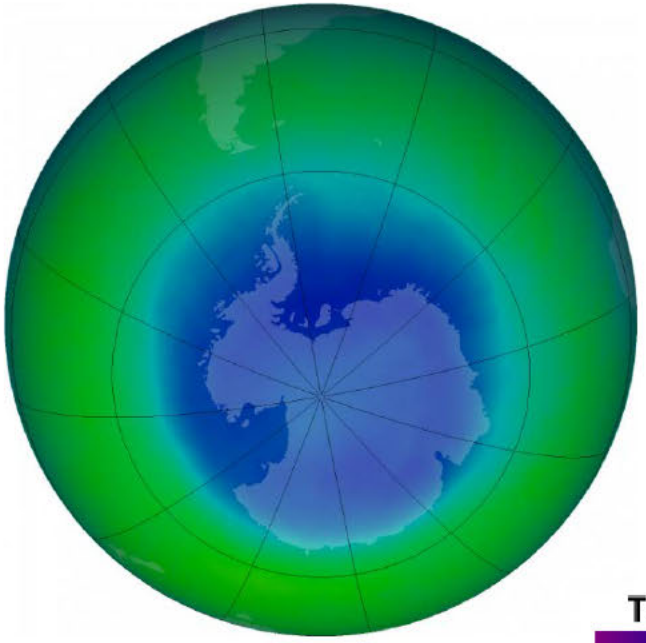

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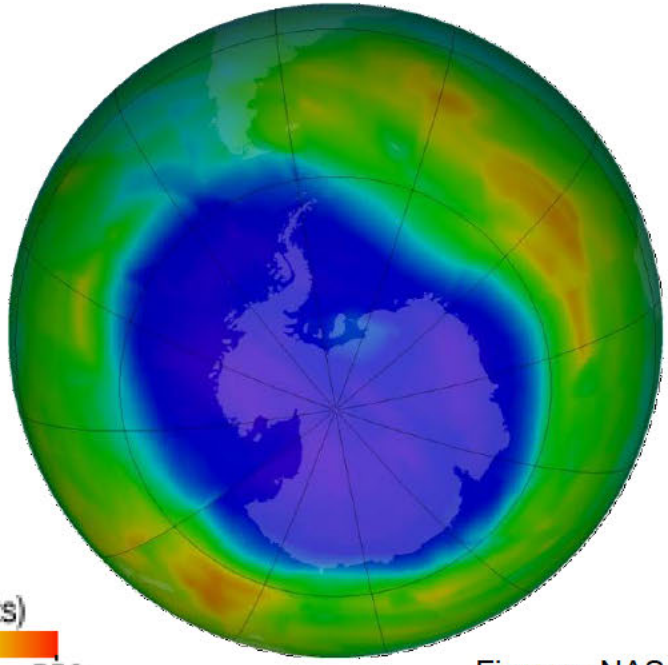

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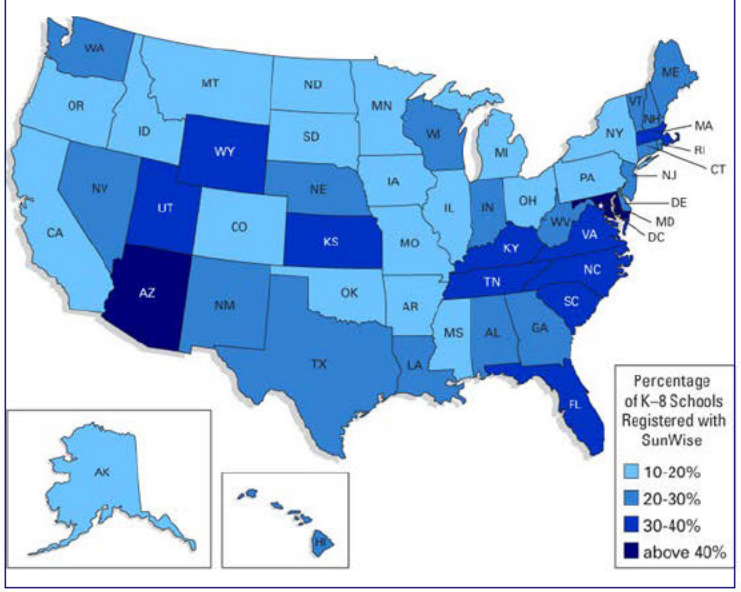

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U.S. ENVIRONMENTAL PROTECTION AGENCY

AND THE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

U.S. DEPARTMENT OF COMMERCE

Whereas, the U.S. Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA) recognize the serious health, welfare, and economic impacts of long term exposure to ultraviolet radiation;

Whereas, the missions of both agencies include stewardship of our natural resources and protection of the health of our citizens;

Whereas, they are convinced of the need for enhancing the scientific and technical underpinning for environmental policies;

Whereas, both agencies can enhance research, application, and interpretation efforts by utilizing the unique meteorological modeling expertise of NOAA and EPA's expertise in assessing the adverse effects of ultraviolet radiation on emissions on public health;

Whereas, the Administrators of EPA and NOAA believe that a formal memorandum will provide the structure and basis for implementing/expanding the existing joint research, development, and application activities in the environmental field;

Whereas, they agree that this common problem continues to require mutual collaboration; therefore, to facilitate the above goals, EPA and NOAA intend to provide the following:

I. PARTIES

This document constitutes an agreement between the U.S. Environmental Protection Agency and the National Oceanic and Atmospheric Administration, U.S. Department of Commerce to facilitate the routine preparation and dissemination of ultraviolet radiation forecasts and alerts.

II. AUTHORITIES

NOAA, through the National Weather Service (NWS), provides weather, hydrologic, and climate forecasts and warnings for the United States, its territories, adjacent waters, and ocean areas for the protection of life and property and the enhancement of the national economy as described in 15 U.S.C. § 313. NOAA data and products can be used by other governmental agencies, the private sector, the public, and the global community. NOAA, through the NWS National Centers for Environmental Prediction (NCEP) provides scientific expertise in the areas of numerical and physical modeling of the atmosphere, and fate of solar ultraviolet (UV) radiation reaching the ground. NOAA derives its authority from 33 U.S.C. § 883(d), which authorizes the Secretary of Commerce to undertake investigations and research into the geophysical sciences, and 15 U.S.C. § 1525, the Department of Commerce's Joint Project Authority, which authorizes the Secretary of Commerce to enter into projects with nonprofit, research or public organizations if the project is of mutual interest to the parties and the costs of the project are apportioned equitably.

EPA, through the Stratospheric Protection Division (OPD), Office of Atmospheric Programs (OAP), Office of Air and Radiation (OAR), cooperates with NOAA under Section 103 of the Clean Air Act (CAA), 42 U.S.C. § 7403, to promote and facilitate the coordination of research to conduct UV radiation research, perform pollution prevention and modeling studies, develop pollution reduction strategies, and conduct other activities relating to EPA's responsibilities to prevent and control air pollution. Under Title VI of the CAA, 42 U.S.C. Chapter 85, Subchapter VI, EPA's Stratospheric Protection Division is responsible for several programs that protect the stratospheric ozone layer. Regulations promulgated by EPA to protect the ozone layer are in 40 C F.R. Part 82.

III. PURPOSE

EPA and NOAA have cooperated for more than 10 years in conducting research programs related to the coupling of air chemistry, and meteorology to develop and utilize scientifically-credible UV radiation models. These models are employed by EPA, the health community and the private sector in developing and implementing environmental policy and regulations, and in disseminating information on UV radiation and the related health effects to the public. In light of the above, it is the purpose of this Memorandum of Agreement to formalize and reaffirm the ongoing collaboration between EPA and NOAA with regard to the forecasting of UV radiation and related health effects.

IV. RESPONSIBILITIES OF THE PARTIES

A. NOAA intends to cooperate with EPA by conducting scientific research, development and application activities that furthers the mutual interests of the parties to this Memorandum of Agreement, including, but not limited to: developing UV radiation forecast models and tools for integrating meteorology and air chemistry; evaluating and improving the suite of UV radiation forecast products and services as client needs or the state-of-the-science change or advance; and providing expert guidance to EPA on matters relating to UV radiation modeling, and atmospheric sciences.

NOAA intends to generate on a routine basis, publicly available information such as operational UV radiation forecasts and alerts on a national scale, and provide those forecasts to end users, private sector interests, EPA and other public or private parties as jointly determined by EPA and NOAA.

B. EPA intends to interpret the NOAA-provided UV radiation forecasts and alerts and officially issue the products and alerts as part of its SunWise program to facilitate the dissemination of this information to the public and private sector; to promote educational outreach of the public health effects; to release public information indexes (e.g. UVI) and statements of UV radiation; and to assist other parties who will provide UV radiation forecasts and alerts to the public.

C. Other cooperative research activities may be identified by negotiation between the parties. The Parties plan to document and formalize such additional responsibilities through separate interagency agreements that will be effected in writing by representatives of both parties

V. Cooperation on Scientific Research

NOAA:
— UV radiation models for integrating meteorology and air chemistry.
— Improvements and modifications to UV radiation forecast models.
— Verification and validation of model output.
— Requirements for national UV radiation forecasts.
— Research, development, and operational model forecasts of meteorological and UV radiation parameters as determined by EPA and NOAA, on a real-time, routine basis, and on a national scale.
EPA:
— Dissemination of UV radiation forecasts and alerts; interpretation of UV radiation forecast products (UVI, UV Alert and links to public health warnings) based upon output from NOAA numerical forecast models.
— Consultation and assistance to health, media, and public parties.
— Criteria for health effect advisories.
- Educational Outreach of the public health effects
- Provide contact information for public and private sector inquiries.

VI. PERIOD OF AGREEMENT AND MODIFICATION/TERMINATION

This Memorandum of Agreement will be effective when signed by all parties. This Memorandum of Agreement may be amended at any time by mutual consent of the parties. The parties will review this Memorandum of Agreement at least once every five years to determine whether it should be revised, renewed, or canceled. Any party may terminate this Memorandum of Agreement by providing 90 days written notice to the other party.

VII. Limitations

All commitments made in this Memorandum of Agreement are subject to the availability of appropriated funds and each agency's budget priorities. Nothing in this Memorandum of Agreement, in and of itself, obligates EPA or NOAA to expend appropriations or to enter into any contract, assistance agreement, interagency agreement, or incur other financial obligations. Any endeavor involving reimbursement or contribution of funds between the parties to this agreement will be handled in accordance with applicable laws, regulations, and procedures, and will be subject to separate interagency agreements that will be effected in writing by representatives of both parties.

Any terms of this agreement found to be inconsistent with current NOAA or EPA directives or policies will be invalid, but the remaining terms will remain in effect.

This Memorandum of Agreement does not create any right or benefit, substantive or procedural, enforceable by law or equity against NOAA or EPA, their officers or employees, or any other person. This Memorandum of Agreement does not direct or apply to any person outside of NOAA and EPA.

Drusilla Hufford

Director
Stratospheric Protection Division
Environmental Protection Agency

Dennis McCarthy

Director
Office of Climate, Water, and
Weather Services
NOAA National Weather Service

MEMORANDUM OF AGREEMENT

ON COOPERATION IN FORECASTING ULTRAVIOLET RADIATION

BETWEEN THE

U.S. ENVIRONMENTAL PROTECTION AGENCY

AND THE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

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Director
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NATURAL RESOURCES DEFENSE COUNCIL

September 26, 2011

Docket # EPA-HQ-OAR-2010-1040
Air and Radiation Docket and Information Center, U.S.
Environmental Protection Agency
Mail Code: 6102T
1200 Pennsylvania Ave., NW
Washington, DC 20460

Re: **Comments On August 2011 Interim Final Rule Adjusting Allocation System for HCFC-22 (EPA-HQ-OAR-2010-1040)**

On behalf of the Natural Resources Defense Council (NRDC), I respectfully submit the following comments regarding EPA's interim final rule, "Protection of Stratospheric Ozone: Adjustment to the Allowance System for Controlling HCFC Production, Import, and Export, 76 Fed. Reg. 47,451 (Aug. 5, 2011) ("IFR"). NRDC encourages EPA to accelerate the phase-out schedule for HCFC-22 in its rulemaking for 2012 and beyond.

I. EPA Should Not Increase Production Allowances

As I expressed in our June 2, 2011, letter to the Administrator regarding EPA's response to *Arkema v. EPA* (attached), NRDC opposes any increase in allowances of HCFC-22 for 2011 or any subsequent year. NRDC appreciates EPA's decision in the IFR to maintain total allocation levels for 2011 and urges EPA not to make any upward adjustments to current production allocations in response to comments. Increasing HCFC-22 production, whether for domestic use or export, would result in additional burdens on the stratosphere, public health, and the natural environment.

Arguments that increasing production allocations will result in net environmental benefits are counterintuitive and unfounded. Some commenters have claimed that greater US production allocations will allow increased exports and displace dirtier HCFC-22 production abroad – production that takes place with more HFC-23 byproduct emissions. The claimed benefit occurs only if it is assumed that increased HCFC-22 exports would be counterbalanced by reduced foreign production. Recent history of the HCFC-22 market suggests this would not be the case – that increasing domestic exports would only increase the global HCFC-22 supply and push down HCFC-22 prices. Because total current HCFC-22 production is below Montreal Protocol caps,

increasing exports of HCFC-22 will not push foreign competitors out of the international market. Instead, increased exports will only worsen the glut of HCFC-22 on the market and further depress prices. This is especially true considering the carbon offset projects under the Clean Development Mechanism of the Kyoto Protocol incentivize participating plants in developing countries to continue production of HCFC-22 in order to receive compensation for destruction of the unwanted byproduct, HFC-23.

Because increasing production allowance allocations will increase worldwide production, increasing allocations would result in environmental harm. Increasing oversupply of HCFC-22 would further drive down prices. Cheap prices correspond with an increase in demand that would prolong dependence on this harmful substance. In fact, low prices have already encouraged equipment manufacturers to return to producing HCFC-22 based equipment. Even worse, low prices are hampering HCFC-22 reclamation from becoming competitive in the marketplace. We should be encouraging reclamation and re-use of already existing HCFC-22 in preference to new production. Permitting any increase in production allocations would work in exactly the wrong direction.

Additionally, increasing production allocations is not warranted by the Clean Air Act. Title VI states that the "[transfer] rules shall insure that the transactions under the authority of this section will result in greater total reductions in the production in each year of class I and II substances than would occur in that year in the absence of such transactions."[1] This IFR adjusts allocations as a result of the transfers made by Arkema and Solvay. In the process of that transfer, EPA took into account this provision such that the transfer resulted in a net reduction of emissions. This proceeding is an incident of that transfer transaction. Increasing production allowances now would conflict with the requirement for the transfer transaction to result in reductions.

II. EPA Should Accelerate the Phase Out Schedule

The comments already filed reflect a general consensus that there is a glut of HCFC-22 on the market and that the oversupply is driving down prices and increasing production of HCFC-22 based equipment. The current glut and low prices are compelling evidence that the current HCFC-22 phase-down schedule is not rapid enough. The glut is bad for both business and the environment, and the EPA should solve this problem by accelerating the phase-out and reducing allocations.

The EPA has a statutory mandate under Clean Air Act §606 to accelerate phase out of an Ozone Depleting Substance (ODS) where it is both necessary and feasible. The "necessary" component requires the EPA Administrator to determine if "such or more stringent schedule may be necessary to protect human health and environment."[2] The science has long established the need to phase out ODS emissions as soon as possible. ODS emissions increase the risk of fatal and non-fatal skin cancers, cataracts, and immunological disorders across the globe. The sooner emissions are phased out, the sooner the ozone will be able to repair itself.

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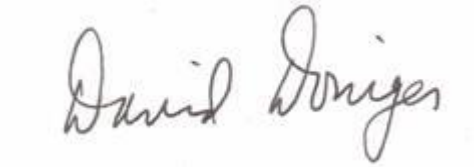
[1] Clean Air Act 42 U.S.C. §7671f(a).
[2] *Id*. at §7671e(a)(1).

Current evidence demonstrates that a faster HCFC-22 phase-out is also "feasible." This component requires the Administrator to determine whether a "more stringent schedule is practicable" based on "availability of substitutes," in addition to "technology achievability, safety and other relevant factors."[3] The present glut of HCFC-22 and the unused consumption allocations demonstrates that more stringent standards are practicable taking into account all these factors. Further supporting the practicability of more stringent standards is that current HCFC-22 prices are too low to incentivize reclamation or conversion to non-HCFC-22 dependant products. This means that it is the HCFC-22 oversupply, not concerns about the availability of substitutes that is preventing a timely transition from HCFC-22 dependence.

Since more stringent standards are both necessary and feasible, EPA should accelerate the phase out schedule and implement larger reductions in the 2012-2014 allocation period. NRDC urges EPA to include this accelerated phase-out in its next allocation rulemakings.

Sincerely,



David D. Doniger
Policy Director
NRDC Climate and Clean Air Program

[3] *Id.* at §7671e(a)(2).

NATURAL RESOURCES DEFENSE COUNCIL

September 26, 2011

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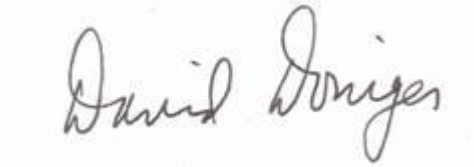

David D. Doniger
Policy Director
NRDC Climate and Clean Air Program

[3] *Id.* at §7671e(a)(2).

IYC Symposium – November 7 2011

Speaker Bios

Session (03/D2) Montreal Protocol I: Stratospheric Ozone Layer Protection

Kevin Fay

Kevin J. Fay, President of Alcalde & Fay, is an internationally recognized specialist on environmental and energy issues with particular emphasis on governmental policies involving the atmosphere and climate.

Currently, he serves as Executive Director of the International Climate Change Partnership, a coalition of companies and trade associations working to develop international policies on the global climate change issue. He has also been active as Counsel to the Alliance for Responsible Atmospheric Policy, a coalition of several hundred companies and associations working to address the ozone depletion issue; and with the Safe Buildings Alliance, a business-oriented association dealing with the problem of asbestos in construction materials.

He has twice been recognized by the Environmental Protection Agency for leadership in global environmental protection. He has also served in a management capacity for public affairs programs for major trade associations. He is an internationally recognized specialist on environmental and energy issues with particular emphasis on governmental policies involving the atmosphere and climate.

He was active in the legislative process that led to the 1990 Clean Air Act and has served as an industry representative on U.S. delegations dealing with these issues at international negotiations.

A trained media spokesperson, he has appeared on numerous television and radio shows, including ABC's "Nightline" and CNN's "Crossfire".

He is a member of the Virginia State Bar. He received his J.D. from American University in Washington DC and is an Honors graduate from the University of Virginia.

David Doniger

David is the policy director of NRDC's climate center, focusing on policies to cut global warming pollution from power plants, motor vehicles and other major industries. David also leads NRDC's work to complete the phase-out of chemicals that deplete the earth's protective ozone layer. David rejoined NRDC in 2001 after serving for eight years in the Clinton administration, where he was director of climate change policy at the Environmental Protection Agency and, before that, counsel to the head of the EPA's clean air program; he also worked for a year at the Council on Environmental Quality. David first began at NRDC in 1978 and worked on clean air issues for the next 14 years, helping to win adoption of the landmark Montreal Protocol and the Clean Air Act amendments of 1990.

Paul Horwitz

Paul Horwitz has worked on ozone issues since 1989, when he became the first Secretary of the newly formed Ozone Secretariat. Upon his return to the US Environmental Protection Agency, he worked on the development of the US acid rain rules, and then served for 13 years as EPA's chief Montreal Protocol negotiator.

While working as a national delegate, Paul served as Chairman and Vice-Chairman of the Executive Committee of the Protocol's Multilateral Fund, and as President of the Conference of the Parties to the Vienna Convention. He has received many awards for his contributions to the Protocol including UNEP's 20th anniversary Visionary award and China's first international ozone award.

Paul rejoined the Ozone Secretariat in 2005, and now serves as Deputy Executive Secretary of the body that facilitates UNEPs ozone work. He is currently stationed in Washington DC where he works out of UNEPs regional office and focuses on, among other things, issues related to Latin America and the Caribbean and North America.

He holds a BS degree from Indiana University's School of Public and Environmental Affairs, a law degree from Lewis and Clark Law School and a Masters Degree in Public Administration from Harvard's Kennedy School of Government.

A.R. Ravishankara

Dr. Ravishankara is the Director of the Chemical Sciences Division of the Earth System Research Laboratory of NOAA in Boulder, Colorado. He is also a Professor of Chemistry, Adjoint, at the University of Colorado in Boulder. Dr. Ravishankara has worked over the past three decades on the chemistry of the Earth's atmosphere as it relates to stratospheric ozone depletion, climate change, and regional air quality. His measurements in the laboratory and in the atmosphere have contributed to deciphering the ozone layer depletion, including the ozone hole; to quantifying the role of chemically active species on climate; and to advancing understanding of the formation, removal, and properties of pollutants. He is an author or coauthor of more than 300 peer-reviewed publications.

Dr. Ravishankara is a member of the US National Academy of Sciences, as well as Fellow of the American Geophysical Union, of the Royal Society of Chemistry, of the American Association for the Advancement of Science, and of the International Union of Pure and Applied Chemistry. His many awards include the Polanyi Medal of the Royal Society of Chemistry, the Stratospheric Ozone Protection award of the US Environmental Protection Agency, and the American Chemical Society's award for Creative Advances in Environmental Sciences. He is currently a co-chair of the WMO/UNEP Science Assessment Panel on Stratospheric Ozone. He has served on many national and international committees.

Drusilla Hufford

Drusilla Hufford joined the U.S. Environmental Protection Agency (U.S. EPA) in 1984 with an MBA from the Wharton School. Since joining EPA, she has worked on numerous environmental policy issues, including water pollution control, solid and hazardous waste management, and in EPA offices including the Administrator's Office of Policy.

Since 1992, Drusilla has worked to protect the stratospheric ozone layer, first as Chief of the Branch responsible for identifying and approving alternatives to ozone depleting substances in major industrial sectors through the U.S. Significant New Alternatives Policy (SNAP) Program. In 1997, Ms. Hufford was appointed Director of EPA's Stratospheric Protection Division. The SPD implements Title VI of the Clean Air Act protecting the ozone layer; the division's work has resulted in large reductions in production and use of ozone depleting substances in the U.S. and is the mechanism for U.S. implementation of the international treaty to protect the ozone layer, the ***Montreal Protocol on Substances that Deplete the Ozone Layer.***

Because depletion of the ozone layer causes skin cancer, Ms. Hufford has also developed public health campaigns to prevent skin cancer. In 1994, she helped establish the U.S. UV Index, now reported in all major U.S. media markets. In 1997, her work in skin cancer prevention developed a focus on protecting children's health, as she created the SunWise Program, a standards-based curriculum now used to teach sun safety to children at more than 25,000 schools K-8 in all U.S. states. From 2007-2010, in addition to her work at EPA directing SPD, she served as Co-Chair of the U.S. National Council on Skin Cancer Prevention.

Session 2 (04/D3) – Montreal Protocol II: Climate Protection

Dan Reifsnyder

Dan Reifsnyder became Deputy Assistant Secretary for Environment in the Bureau of Oceans, Environment and Science on August 20, 2006. He is responsible for a broad suite of issues related to environmental protection and conservation, including: transboundary air quality, protection of the stratospheric ozone layer, international chemicals management, the transboundary movement of hazardous wastes, persistent organic pollutants, environmental aspects of free trade agreements, international forestry conservation, biological diversity, desertification, wildlife conservation and the protection of wetlands and coral reefs. In these areas, he leads the U.S. delegation under multiple bilateral and multilateral treaties and agreements.

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Initiative. From 1989 to 2006, he helped shape the work of the Intergovernmental Panel on Climate Change and co-chaired its Financial Task Team. He was alternate head of the U.S. delegation in negotiations that led to the U.N. Framework Convention on Climate Change.

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Dr. Velders is a senior scientist on ozone layer depletion, climate change, and air quality at the Netherlands Environmental Assessment Agency. He holds an MSc in applied physics and a PhD in quantum chemistry from the University of Twente, The Netherlands. In the past Dr. Velders has worked at the Royal Netherlands Meteorological Institute studying the effects of aircraft emissions on the composition of the atmosphere, at the Aeronomy Laboratory of NOAA (Boulder, CO) as a visiting scientist studying tropospheric nitrogen dioxide concentrations, and for twelve years with the National Institute of Public Health and the Environment (The Netherlands). Dr. Velders is involved in both scientific research and in assessments on the national (Dutch Government), European (European Environment Agency) and global scale (IPCC, UNEP, and WMO). Topics of expertise include chemistry and transport in the atmosphere, ozone layer depletion from production of CFCs to effects on humans, UV radiation, climate change, global and regional atmospheric modeling, data assimilation and inverse modeling, and air quality. In 2009, Dr. Velders earned the EPA Scientific and Technological Achievement Award for his published research on the linkages between ozone and climate

science. Apart from being author and co-author of various scientific publications, Dr. Velders was also coordinating lead author of the IPCC Special report on ozone layer depletion and climate change and lead author of the WMO/UNEP Scientific Assessment of Ozone Depletion: 1998, 2006, and 2010. Dr. Velders was also an author of several other UNEP, WMO and EEA assessment reports as well as of various national assessment reports.

Mack McFarland – attached as PDF

Durwood Zaelke

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IYC Symposium – November 7 2011

Speaker Bios

Session (03/D2) Montreal Protocol I: Stratospheric Ozone Layer Protection

Kevin Fay

Kevin J. Fay, President of Alcalde & Fay, is an internationally recognized specialist on environmental and energy issues with particular emphasis on governmental policies involving the atmosphere and climate.

Currently, he serves as Executive Director of the International Climate Change Partnership, a coalition of companies and trade associations working to develop international policies on the global climate change issue. He has also been active as Counsel to the Alliance for Responsible Atmospheric Policy, a coalition of several hundred companies and associations working to address the ozone depletion issue; and with the Safe Buildings Alliance, a business-oriented association dealing with the problem of asbestos in construction materials.

He has twice been recognized by the Environmental Protection Agency for leadership in global environmental protection. He has also served in a management capacity for public affairs programs for major trade associations. He is an internationally recognized specialist on environmental and energy issues with particular emphasis on governmental policies involving the atmosphere and climate.

He was active in the legislative process that led to the 1990 Clean Air Act and has served as an industry representative on U.S. delegations dealing with these issues at international negotiations.

A trained media spokesperson, he has appeared on numerous television and radio shows, including ABC's "Nightline" and CNN's "Crossfire".

He is a member of the Virginia State Bar. He received his J.D. from American University in Washington DC and is an Honors graduate from the University of Virginia.

David Doniger

David is the policy director of NRDC's climate center, focusing on policies to cut global warming pollution from power plants, motor vehicles and other major industries. David also leads NRDC's work to complete the phase-out of chemicals that deplete the earth's protective ozone layer. David rejoined NRDC in 2001 after serving for eight years in the Clinton administration, where he was director of climate change policy at the Environmental Protection Agency and, before that, counsel to the head of the EPA's clean air program; he also worked for a year at the Council on Environmental Quality. David first began at NRDC in 1978 and worked on clean air issues for the next 14 years, helping to win adoption of the landmark Montreal Protocol and the Clean Air Act amendments of 1990.

Paul Horwitz

Paul Horwitz has worked on ozone issues since 1989, when he became the first Secretary of the newly formed Ozone Secretariat. Upon his return to the US Environmental Protection Agency, he worked on the development of the US acid rain rules, and then served for 13 years as EPA's chief Montreal Protocol negotiator.

While working as a national delegate, Paul served as Chairman and Vice-Chairman of the Executive Committee of the Protocol's Multilateral Fund, and as President of the Conference of the Parties to the Vienna Convention. He has received many awards for his contributions to the Protocol including UNEP's 20th anniversary Visionary award and China's first international ozone award.

Paul rejoined the Ozone Secretariat in 2005, and now serves as Deputy Executive Secretary of the body that facilitates UNEPs ozone work. He is currently stationed in Washington DC where he works out of UNEPs regional office and focuses on, among other things, issues related to Latin America and the Caribbean and North America.

He holds a BS degree from Indiana University's School of Public and Environmental Affairs, a law degree from Lewis and Clark Law School and a Masters Degree in Public Administration from Harvard's Kennedy School of Government.

A.R. Ravishankara

Dr. Ravishankara is the Director of the Chemical Sciences Division of the Earth System Research Laboratory of NOAA in Boulder, Colorado. He is also a Professor of Chemistry, Adjoint, at the University of Colorado in Boulder. Dr. Ravishankara has worked over the past three decades on the chemistry of the Earth's atmosphere as it relates to stratospheric ozone depletion, climate change, and regional air quality. His measurements in the laboratory and in the atmosphere have contributed to deciphering the ozone layer depletion, including the ozone hole; to quantifying the role of chemically active species on climate; and to advancing understanding of the formation, removal, and properties of pollutants. He is an author or coauthor of more than 300 peer-reviewed publications.

Dr. Ravishankara is a member of the US National Academy of Sciences, as well as Fellow of the American Geophysical Union, of the Royal Society of Chemistry, of the American Association for the Advancement of Science, and of the International Union of Pure and Applied Chemistry. His many awards include the Polanyi Medal of the Royal Society of Chemistry, the Stratospheric Ozone Protection award of the US Environmental Protection Agency, and the American Chemical Society's award for Creative Advances in Environmental Sciences. He is currently a co-chair of the WMO/UNEP Science Assessment Panel on Stratospheric Ozone. He has served on many national and international committees.

Drusilla Hufford

Drusilla Hufford joined the U.S. Environmental Protection Agency (U.S. EPA) in 1984 with an MBA from the Wharton School. Since joining EPA, she has worked on numerous environmental policy issues, including water pollution control, solid and hazardous waste management, and in EPA offices including the Administrator's Office of Policy.

Since 1992, Drusilla has worked to protect the stratospheric ozone layer, first as Chief of the Branch responsible for identifying and approving alternatives to ozone depleting substances in major industrial sectors through the U.S. Significant New Alternatives Policy (SNAP) Program. In 1997, Ms. Hufford was appointed Director of EPA's Stratospheric Protection Division. The SPD implements Title VI of the Clean Air Act protecting the ozone layer; the division's work has resulted in large reductions in production and use of ozone depleting substances in the U.S. and is the mechanism for U.S. implementation of the international treaty to protect the ozone layer, the ***Montreal Protocol on Substances that Deplete the Ozone Layer.***

Because depletion of the ozone layer causes skin cancer, Ms. Hufford has also developed public health campaigns to prevent skin cancer. In 1994, she helped establish the U.S. UV Index, now reported in all major U.S. media markets. In 1997, her work in skin cancer prevention developed a focus on protecting children's health, as she created the SunWise Program, a standards-based curriculum now used to teach sun safety to children at more than 25,000 schools K-8 in all U.S. states. From 2007-2010, in addition to her work at EPA directing SPD, she served as Co-Chair of the U.S. National Council on Skin Cancer Prevention.

Session 2 (04/D3) – Montreal Protocol II: Climate Protection

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NATURAL RESOURCES DEFENSE COUNCIL

Testimony of David D. Doniger
Policy Director and Senior Attorney, Climate and Clean Air Program
Natural Resources Defense Council

Hearing on the U.S. Agricultural Sector Relief Act of 2012

Subcommittee on Energy and Power
Committee on Energy and Commerce
House of Representatives
July 18, 2012

Summary

- Protection of the ozone layer is a huge bi-partisan public health success story. The phase-out of ozone-destroying chemicals, including methyl bromide, is saving literally millions of Americans, and tens of millions of people around the world, from death and disease, from skin cancer, cataracts, and immune diseases. It is also saving farmers billions of dollars in UV-related crop losses.

- Now is not the time to tamper with the Montreal Protocol and the Clean Air Act. By slowing or even reversing the transition away from methyl bromide, "The U.S. Agricultural Sector Relief Act" will lead to more skin cancers, more cataracts, more immunological disease. It will benefit strawberry growers and others who have profited by abusing the "critical use exemption" for almost a decade. Thousands of other farmers growing other crops will suffer more UV-related crop losses as a result.

- Methyl bromide suppliers and users have dragged their feet on replacing this dangerous compound for two decades. No other industry has had more time and more leeway to transition from dangerous ozone-destroying chemicals.

- The United States is responsible for more than 90 percent of all methyl bromide exemptions. Every other strawberry- and tomato-growing country with California-like growing conditions – including Italy, Spain, Greece, and Australia – has ended use of methyl bromide. Mexican growers use less methyl bromide per acre than their California counterparts, and Mexico will end methyl bromide use entirely this year.

- California strawberry growers have done very well during the whole experience, according to a recent peer-reviewed economic study. Strawberry acreage is up 16% and yields are up 14% since 2004 despite significant reductions in methyl bromide allocations. So are U.S. grower prices and total crop values.

- U.S. critical use exemptions have been coming down. California strawberries are now the only field use for which the U.S. is still seeking critical use exemptions. Together with several structural and commodity uses, the total U.S. exemption request for 2014 is down to slightly more than 400 tons.

- The bill would do reckless damage in three major ways: First, it would permanently define as "critical uses" all of the uses that were labeled critical in 2005, even though the vast majority no longer even use methyl bromide. Absurdly, the bill would make even golf course turf grass a "critical use." It makes no sense to freeze into law an utterly out-dated list of "critical uses."

- Second, the bill relieves applicants of the need to show why they need exemptions. They could just submit their exemption wish lists without any supporting data. EPA then would bear the burden of gathering the data to support any reduction. Absent resources and data, EPA would have little choice but to forward the applicants' unsupported wish lists to the parties. This would be foolish even from the growers' perspective. It actually helps the U.S. government win approval for exemptions to have shown that it has exercised judgment and discipline in framing its requests, and has is not mechanically asked for everything its domestic applicants may have wanted.

- Third, the bill would blast an enormous new loophole into the Clean Air Act and our pesticide safety laws, by allowing any individual user to write his own ticket for up to 20 tons of methyl bromide

simply by asserting the existence of an "emergency." There could be a hundreds of emergency exemptions per year, totaling up to 2,000 tons per year (the 2011 critical use amount).

- This is a bad and unneeded bill. It would harm public health, harm other farmers, and indeed even harm the farmers it is intended to help. The process is working. This Committee should let well enough alone.

Thank you Chairman Whitfield and Ranking Member Rush for the opportunity to testify on behalf of the Natural Resources Defense Council on the proposed "U.S. Agricultural Sector Relief Act of 2012." Founded in 1970, NRDC is a national nonprofit environmental organization of scientist, lawyers, and environmental specialists with more than 1.3 million members and online activists, served from offices in New York, Washington, Chicago, San Francisco, Los Angeles, and Beijing. I am policy director of NRDC's Climate and Clean Air Program. I have been with NRDC twice, from 1978 through 1992 and from 2001 to the present. In the 1990's I served as director of climate change policy in the EPA Office of Air and Radiation. Relevant to the topic of today's hearing, I have worked on the phase-out of ozone-destroying chemicals for more than a quarter century.

There are few greater success stories than the global effort to phase out the ozone-damaging chemicals. Every American, and every citizen on this Earth, relies on the ozone layer to block dangerous ultraviolet radiation that causes skin cancer, cataracts, immune disorders and other diseases. The treaty to protect the ozone layer, known as the Montreal Protocol, has enjoyed bipartisan support from five presidents beginning with Ronald Reagan. So have the ozone layer protection provisions of the Clean Air Act. They are saving literally millions of Americans, and tens of millions of people around the world, from death and disease. They are also preventing billions of dollars in UV-related crop losses and other economic damages.

Yet the ozone shield is still being weakened by ozone-depleting chemicals that increase our exposure to dangerous UV radiation. Millions of Americans – including farmers – must work everyday in the sun. Millions more – from school children to seniors – spend hours of their days out of doors. Millions of concerned parents check the UV Index and cover their kids with sunscreen before letting them go out in the sun.

That brings us to methyl bromide. Methyl bromide is the most powerful ozone-depleter still in widespread use. All of the other more potent ozone-destroying chemicals have been successfully

eliminated – worldwide. Methyl bromide is also highly toxic, with inhalation or dermal exposure causing a wide range of acute and chronic effects, including death.

Mr. Chairman, I will not mince words. You are considering a bill to further slow the snail-like pace of the transition from this dangerous chemical – a bill that will lead to more skin cancers, more cataracts, more immunological disease, and more crop losses due to ozone-destruction and UV radiation, as well as more illness from direct exposure. Contrary to the bill's grandiose title, this bill will not broadly benefit "the U.S. agricultural sector." Indeed, thousands of farmers growing other crops will suffer more UV-related crop losses as a result. Instead, this bill will benefit only a small sliver of strawberry growers and few others who have profited handsomely by abusing the "critical use exemption" for the better part of a decade.

No industry has had more time and more leeway to transition from dangerous ozone-destroying chemicals than this one. The auto industry replaced CFCs in car air conditioners in less than four years. The electronics industry replaced ozone-depleting solvents in circuit board manufacture in less time than that. The air conditioning and refrigeration industry and the fire protection industry got rid of their potent ozone-depleters in well under a decade. Indeed, some of these industries have gone through two rounds of transitions to safer chemicals in the last 20 years. And all of these industries have been able to produce better, more energy-efficient, and more profitable products.

But methyl bromide stands apart. The producer and the users of this chemical have dragged their feet on replacing this dangerous compound for two decades. Let's review:

The phase-out of methyl bromide was supposed to be completed by 2001 pursuant to the 1990 Clean Air Act Amendments. With a decade of lead-time, growers and other users should have invested in developing and field testing other agents and other agricultural practices, like every other industry did. Their effort was minimal. And their minimal effort was rewarded by pushing the deadline back to 2005, in conjunction with amendments to the Montreal Protocol to phase out methyl bromide world-

wide. An post-2005 exemption was allowed for so-called "critical uses," but all observers then thought this would be just a small percentage of historical ("baseline") methyl bromide use, just as the "essential use" exemptions for other ozone-destroying chemicals had been only a small fraction of their baselines.

Indeed, other countries with comparable agricultural conditions played by those rules, submitting critical use exemption requests, if any at all, that reflected small fractions of their historical methyl bromide use levels. Only the U.S. took a different tack. In 2003, U.S. growers and others sought exemptions totaling some 15,000 tons, more than 60 percent of country's baseline use in the early 1990s. The U.S. government requested more than 10,000 tons of exemptions, and nearly broke the back of the Montreal Protocol. For the first time in its history, the parties were unable to come to a consensus decision. For the first time, there was an impasse that could not be resolved without calling an extraordinary meeting of the parties.

For eight years running, the United States alone has requested more than 90 percent of all exemptions. Over this period, nearly every other developed nation has eliminated its need for methyl bromide. Specifically, every other strawberry- and tomato-growing country with Mediterranean-like growing conditions – including Italy, Spain, Greece, and Australia – has moved beyond use of methyl bromide. Even Mexico – the California strawberry growers' only competitor – is committed to end its use of methyl bromide this year.[1]

Throughout this period, and here again today, the California strawberry growers have led the pack in coming to Congress playing the hardship violin. In fact, however, California strawberry growers have done very well during the whole experience, according to a recent peer-reviewed economic study by Erin N. Mayfield and Catherine Shelley Norman, published in the *Journal of Environmental*

[1] "The Government of Mexico has committed to achieve the complete phase-out of MB by the end of 2012." United Nations Environment Programme, Executive Committee of the Multilateral Fund for the Implementation of the Montreal Protocol, Sixty-sixth Meeting, Montreal, 16-20 April 2012, "Project Proposal: Mexico, National methyl bromide phase-out plan (third tranche), ¶9, http://www.multilateralfund.org/66/English/1/6641.pdf.

Management.[2] They have expanded their strawberry acreage and increased their yields dramatically despite significant reductions in methyl bromide allocations: California strawberry acreage in 2010 had increased 83 percent over 1991 levels and 16 percent over 2004. Yields per acre in 2010 increased 29 percent over 1991 levels and 14 percent over 2004. California's share of U.S. production also increased during this period, from about 80 percent in 1991 to more than 90 percent in 2010. U.S. grower prices and total crop values adjusted for inflation also increased during the exemption years.

The expansion of the strawberry acreage treated with methyl bromide is extremely troubling because it breaks a commitment made by the U.S. government not to allow such expansion. For instance, the "National Management Strategy for Methyl Bromide, United States of America, December 2005" states: "An important way that the United States addresses the issue of avoiding increases in MeBr use is our policy to disallow any increases in acreage or throughput that CUE applicants might include in their CUE request."[3] This turns out to have been a hollow promise.

The growers' complaints often center on the claim of unfair competition from Mexico. Throughout this period, however, Mexican growers used less methyl bromide per acre than their California counterparts, and Mexico, as I mentioned, has committed to stop using methyl bromide this year. Mayfield and Norman note that although strawberry imports from Mexico increased as the overall U.S. strawberry market grew, Mexico's share of total U.S. consumption did not increase significantly, and U.S. growers' strawberry exports to Canada rose by almost as much as imports from Mexico.

Mayfield and Norman also note that the economic analysis supporting the critical use nomination for 2014 – an analysis prepared by the strawberry growers – indicates that a range of alternatives to methyl bromide are effective and available at comparable cost and without yield losses.

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[2] E. Mayfield & C. Norman, *Moving away from methyl bromide: Political economy of pesticide transition for California strawberries since 2004,* Journal of Environmental Management, Vol. 106, Pp. 93-101 (2012), available at http://www.sciencedirect.com/science/article/pii/S0301479712001909, and attached to this testimony.
[3] http://www.epa.gov/ozone/mbr/downloads/MeBrNatMgmtStrat.pdf, p. 4.

Notably, these results do not depend on methyl iodide, which was withdrawn from the market by its manufacturer earlier this year.

As it turns out, the industry is still sitting on a stockpile of methyl bromide made before 2005 and stored in railroad cars in various communities around the country. Believe me, tank cars of highly toxic methyl bromide baking in the sun on rail sidings are not something I'd want in my community, or rolling through my Congressional district, yet few people know if they enjoy that privilege. As of today, the stockpile still exceeds 1,200 tons – three time the U.S. critical use nomination for 2014.

Why is the stockpile important? Because the rules of the road under the treaty are that a country may request permission to manufacture new methyl bromide to serve critical use needs only if it has exhausted its stockpiles. The industry attempted to conceal that stockpile from both the public and the government, and this led to the U.S. government's initially misrepresenting to the other Montreal Protocol parties in 2003 that there would be no stockpile left in 2005. But the true stockpile, divulged only later in response to an NRDC lawsuit, was nearly 13,000 tons – more than the entire amount the U.S. claimed to need for 2005. The methyl bromide stockpile has been used – illegally, in our view – for crops that no longer qualify as critical uses, such as golf course turf grass, and to exceed the critical use limits on crops such as strawberries. Each year since 2004, the stockpile has been larger than the next year's total critical use request. That is true for 2013 and 2014. The deception over the stockpile, once revealed, almost caused the breakdown of the treaty process, and the existence of a continuing stockpile is still a major irritant between the parties today.

NRDC acknowledges that the amounts of U.S. critical use exemptions have been coming down, however belatedly. Many growers and other users have finally taken up alternative chemicals and alternative pest management practices, so that we have now come to the point where the only field use for which a critical use nomination is still being made in 2014 is California strawberries. Together with several structural and commodity uses, the total U.S. exemption request is down to slightly more than

400 tons, as compared to nearly 10,000 tons in 2005. This progress, though long delayed, is noteworthy and must continue. Further progress is possible even in the short run, through practices such as greater use of impermeable films (something other countries have already adopted) and by continued adoption of alternatives.

In short, the process is working. Now is not the time to tamper with the methyl bromide phase-out requirements under Montreal Protocol and the Clean Air Act. Mr. Chairman, the bill before you would pointlessly weaken curbs on this dangerous ozone-destroying chemical, threaten the recovery of the ozone layer, and further strain our relations with other countries that are already experienced with U.S. abuse of critical use exemptions. The bill does reckless damage in at least three major ways:

First, the bill would permanently define as "critical uses" all of the uses that were labeled critical in 2005, regardless of the fact that the vast majority of those crops and applications have successfully transitioned to alternatives and no longer even use methyl bromide. Absurdly, the bill would make golf course turf grass a "critical use," even though the Bush administration's agriculture department dropped it from the list in 2006. Why in the world does it make sense to revive and freeze into law an utterly out-dated list of "critical uses"?

Second, since growers and other applicants are seeking exemptions for a chemical that is otherwise already banned under both domestic and international law, and since they are in the best position to innovate and test alternatives, they quite properly now bear the burden of showing the need for methyl bromide and the absence of economically practical alternatives. But the bill would turn that burden around. It would allow applicants to submit their wish lists for exemptions without providing any data in support. Even though this chemical is already supposed to be banned, the bill would then require EPA to shoulder the burden of developing the data to support any reduction from the growers' or other applicants' requests. As the growers would be quick to point out, EPA does not run farms, and EPA does not run alternatives testing programs.

Absent the resources and access to data, EPA would have little choice but to forward the applicants' wish lists to the parties for consideration. Even from the growers' perspective, this would be a fool's errand. It is difficult enough for the U.S. to gain approval for its out-sized exemption requests when it can bring a reasonably robust case forward for technical scrutiny by the other parties. It actually helps the U.S. win approval for exemptions to have shown that the government has exercised some judgment and discipline in framing its requests, and that the U.S. is not asking for everything its domestic applicants may have wanted.

Third, the bill would blast an enormous new loophole into the Clean Air Act and our pesticide safety laws, by allowing any individual user to write his own ticket for up to 20 tons of methyl bromide simply by asserting the existence of an emergency. "Emergency" is conveniently defined to mean any situation where someone wants to use more methyl bromide than is available under a critical use exemption, and where he declares that there is no alternative. The bill would allow a hundred 20-ton emergency exemptions per year, up to a total of 2,000 tons per year (the amount of critical use exemptions in 2011). This would be a massive abuse of the emergency exemption provision under the Montreal Protocol, which has been invoked only twice so far (once by Australia and once by Canada) in genuine emergencies.

Imagine, Mr. Chairman, how cool it would be to be able to withdraw more cash from the bank than you have in your account, just by calling it an emergency. There's another name for that: bank robbery.

This is a bad bill, and an unneeded bill. It would harm public health, harm other farmers, and indeed even harm the farmers it is intended to help. The process is working. This Committee should let well enough alone.

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Moving away from methyl bromide: Political economy of pesticide transition for California strawberries since 2004

Erin N. Mayfield [a], Catherine Shelley Norman [a,b,*]

[a] Department of Geography and Environmental Engineering, The Johns Hopkins University, 3400 North Charles Street, Baltimore, MD 21218, USA
[b] Department of Economics, The Johns Hopkins University, 3400 North Charles Street, Baltimore, MD 21218, USA

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ABSTRACT

We examine the progress of the phaseout of the use of the pesticide methyl bromide in the production of California field strawberries. This phaseout is required under the Montreal Protocol and has been contentious in this sector, which receives exemptions from the schedule initially agreed under the treaty, and in international negotiations over the future of the Protocol. We examine the various ex ante predictions of the impacts on growers, consumers and trade patterns in light of several years of declining allocations under the Critical Use provisions of the Protocol and the 2010 approval of iodomethane for use in California and subsequent 2012 withdrawal of this alternative from the US market. We find that, contrary to ex ante industry claims, the years of declining methyl bromide use have been years of rising yields, acreage, exports, revenues and market share for California growers, even when faced with a global recession and increased imports from Mexican growers who retain the right to use the chemical under the Protocol. This has implications for the Protocol as a whole and for the remainder of the US phaseout of this chemical in particular.

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1. Introduction and background

US fruit and vegetable growers using the fumigant methyl bromide (MeBr), scheduled for phaseout under the Montreal Protocol on Substances that Deplete the Ozone Layer, faced uncertainty about the cost and effectiveness of alternative chemicals and practices, and many of them applied for exemptions allowing continued use after the planned elimination of MeBr. This process was controversial – so much so that the United States suggested that they might withdraw from the Montreal Protocol, up to that point considered a model of successful international environmental policy, if their nominations for exemptions were not granted (Gareau and DuPuis, 2009). In the exemption process, which allowed exceptions to the scheduled 2005 complete phaseout date, one of the most contested uses was for strawberry farming, especially in California where many alternatives are strictly regulated or disallowed. Growers argued that none of the alternatives met the 'economic and technical feasibility' conditions of the Critical Use Exemption (CUE) rules. DeCanio and Norman (2005) discuss possible interpretations of the feasibility criteria at length, emphasizing that it cannot mean that no changes in costs or agricultural practices are required of methyl bromide users, but there is not a consensus definition of precisely what standard must be met.

Currently, the majority of CUEs for methyl bromide are allocated to the United States.[1] The share of field (rather than nursery) strawberries in total exemption requests has also grown; the 2014 US field strawberries nomination was for over 93% of the total US allocation, and was exclusively for use in California, which produces 90% of US strawberries (ERS, 2011c). In 2007 the same share was only 13% and more geographically dispersed, including uses in the southeastern US as well as California (USDoS, 2010, 2005, ozone.unep.org). Substitutes have been slower to develop in California,

* Corresponding author. Department of Geography and Environmental Engineering, The Johns Hopkins University, 3400 North Charles Street, Baltimore, MD 21218, USA. Tel.: +1 410 516 5184; fax: +1 410 516 8996.
E-mail addresses: erin.noel.mayfield@gmail.com (E.N. Mayfield), norman@jhu.edu (C.S. Norman).

[1] For the last seven years reported, 2007 2013, approved US CUEs have been more than 75% of non-Article 5 exemptions approved globally, so US strawberry uses are a significant amount of remaining global use of MeBr. In the first year of the exemption process, US allowances were a bit over 40% of total non-Article 5 allocations. For 2013, the United States has received over 90% of approved CUE allowances. Article 5 parties, which are, roughly speaking, less developed countries, do not have to complete phaseout until 2015, but their total use peaked in 1998, and by 2010 total consumption in Article 5 and non-Article 5 countries were approximately equal (exclusive of quarantine and pre-shipment uses, which are regulated separately and excluded from the discussion throughout this paper) (ozone.unep.org).

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due to different farming practices and a relatively stringent regulatory climate that has slowed the approval of some MeBr alternatives. The California strawberry crop is worth more than $2 billion annually and is the 6th highest valued fruit crop in the state, so while the industry is small at the national level it is economically significant in the region.[2]

California growers and those negotiating the CUE process on their behalf were deeply concerned that the main source of US imports of fresh strawberries, Mexico, would not be required to eliminate the use of MeBr at the same time that California growers were scheduled to. The Montreal Protocol allows delays in the elimination of ozone depleting substances for less developed countries, and growers feared that lowered trade barriers under NAFTA would combine with a technological advantage to Mexican growers using the fumigant, leading to dramatically increased imports of fresh strawberries and reduced sales of and/or prices for domestic berries.

This work investigates how the process of phaseout has affected the California field strawberry industry and finds that management and regulatory decisions at the international, national, and state levels have allowed California growers to maintain and enhance their dominance in the domestic and North American market as the phaseout has progressed. The period between the beginning of the methyl bromide phaseout and the availability of iodomethane, the closest thing to a 'drop in' substitute yet developed, for use in the state has been characterized by slow elimination of MeBr, rising acreage, yields and consumption, improved balance of trade, increasing domestic market share, and rising or relatively stable prices. Iodomethane itself has recently been voluntarily withdrawn from the US market, and we consider how this might affect our assessment of the phaseout process to date.

2. Ex-ante analyses of economic effects and political factors influencing phaseout

Economic analyses earlier in the process did not reach a consensus regarding the likely impacts of phaseout. Norman (2005) relied heavily on data from nominations for CUEs and found that trends in demand growth for fresh strawberries[3] and significant pass through of cost increases to consumers were expected to outweigh the stated negative effects of production cost increases associated with use of alternative fumigants, even in the absence of direct government support, under fairly conservative assumptions, and that increased consumer costs per household would be minimal, even if they were substantial in aggregate.

Carpenter et al. (2000) simulated production, consumption, and crop prices for methyl bromide users (e.g., California) and direct competitors (e.g., Mexico) – prior to and after the 2005 MeBr ban using a spatial partial equilibrium model. To simulate post ban conditions, shifts in production technology and corresponding changes in production costs and monthly yields were assumed.[4] Model results suggested that following a ban, US consumers would pay higher prices for strawberries and consume fewer of them. The increased price of strawberries would outweigh increases in CA production costs for growers and, when coupled with increased acreage devoted to CA strawberry production, CA strawberry growers' gross and net revenues would increase and remain stable, respectively.

Goodhue et al. (2005) and Carter et al. (2005), on the other hand, suggested that MeBr phaseout could cause significant problems for US or California growers. The former included field trials to estimate weed control costs using MeBr and various available alternatives but were unable to estimate yield losses from the use of MeBr alternatives directly, and concluded that acreage and thus supply would have to decline significantly to raise market prices enough to eliminate the net losses to remaining growers. The latter note that a single annual demand elasticity parameterization obscures important variation in seasonal demand and supply functions and can bias estimates of losses downward, with the most significant losses accruing between mid May and early July. Their simulation results suggest full season losses of between 4 and 20% of revenue, with a point estimate of around 12%, excluding revenue realized from lower valued crops as acreage in strawberries decline. Neither study considered longer term trends in the fresh strawberry market.

The design of these studies reflected concerns that Mexico, which provided (and continues to provide) more than 99% of imported fresh strawberries to the US (ERS, 2010, Table 14), was an Article 5 country under the Montreal Protocol and thus not required to eliminate MeBr until 2015, at which point their MeBr use would also have to comply with CUE standards to be permitted. NAFTA rules would make it hard to shield US growers from Mexican competition. Rising costs to US producers forced to transition away from their preferred fumigant could make Mexican imports more competitive over more of the year, reducing market share and revenues to domestic growers. Carpenter, Gianessi, and Lynch (2000) projected that after the 2005 ban – exemptions notwithstanding – increased acreage in Mexico devoted to strawberry production would be observed, and in the absence of land and water constraints, Mexico would continue to increase acreage and displace acreage in California.

On the regulators side, there was concern that significant exemptions would slow the phaseout and increase lobbying efforts at the expense of efforts to develop and implement alternate fumigation strategies. Using even the lowest estimate of the cost burden of the elimination of MeBr for California strawberries growers from Norman (2005) of $51[5] ha/year suggests that diversion of funds to directly unproductive rent seeking around CUE rights could be significant; the 2011 industry survey indicates that 15,145 ha are planted in strawberries in California, and less than 5% of that land is devoted to organic production (CSC, 2011). This implies that delays in phaseout for conventionally grown berries could be worth more than $700,000 annually (15,145 × .95 × $51 $733,775), and any successful efforts to secure delays that cost less than this amount are profit maximizing for the industry as a whole.

The California Strawberry Commission (CSC), the most active industry group, doubled (nominal) federal lobbying expenditures from $40,000 in each of 2001–2007 to $80,000 in 2008, and expenditures have remained at that level through 2010 (Center for Responsive Politics, 2011). State nominal lobbying expenditures were about $30,000 for the 2001–2002 legislative session, as decisions about initial CUE applications were being made, and then dropped to around $3000 for the next session, rising for each subsequent legislature to a level of about $20,000 in 2009–2010 (CalAccess, 2011). It is likely, of course, that only some of these

[2] http://www.californiastrawberries.com.

[3] We focus on fresh berries throughout; in the US, frozen berries are largely a residual crop (ERS, 2011c), and as they are not perishable this market operates quite differently. Large increases in the share of production going for frozen or otherwise processed berries might suggest quality issues associated with various changes to fumigation processes, but we do not observe this in the data.

[4] The model assumes that the best alternative technology which is assumed to be the technology resulting in the highest yield per acre for the lowest cost per acre is selected. Given that the study was completed in 2000, the best technologies projected at the time do not entirely correspond to the alternatives actually employed during the phaseout.

[5] All figures converted to 2010 dollars using the CPI unless otherwise noted.

efforts were focused on preserving MeBr phaseout exemptions for growers. We were not able to find evidence of significant lobbying expenditures for strawberry growers in other regions. While lobbying expenditures are one indicator of lobbying efforts, the rapidity of regulatory movement – in this case, the reduction timeline – may also be suggestive. The reduction timeline in California has been much less aggressive than in other US regions, which no longer use MeBr for field strawberries, and more broadly, the reduction timeline in the US has been much less aggressive than other non Article 5 parties. Taken together, the lobbying expenditures and reduction timeline suggest that if lobbying has slowed the phaseout of methyl bromide for strawberries in CA, it has been a rational investment for the industry, even if the costs of using alternative pesticides are a relatively small fraction of revenues and profits.

The Critical Use Exemption process involves stakeholders who use the regulated chemical, national nominations, and recommendations or analysis by the Technology and Economic Assessment Panel (TEAP) of the Montreal Protocol, leading to final amounts which must be approved by the Parties to the Protocol at their annual meeting. In the US, the Environmental Protection Agency (EPA) solicits yearly applications with supporting information on use patterns and economic impacts from growers, and then the Department of State submits these as Critical Use Nominations (CUNs). For the last year for which data are available – the nominations and final decisions for 2012 exemptions – the CSC requested permits to treat 4454 ha, which were passed on to the Parties to the Montreal Protocol, who approved 4421 of those hectares, albeit at a lower application rate than was originally requested.[6] If this smaller amount receives the low estimate of value from continued use of MeBr, CA growers have gained about $225,000 in 2012 by securing the 2012 exemptions, as well as slowing further phaseout and broader price impacts until their chief competitor in the North American fresh strawberry industry completes their phaseout. At this point Mexican growers presumably lose any price advantage gained by ongoing MeBr use, and alternative pest control practices will be more established in California.

Interestingly, this approved MeBr fumigation allowance for about 30% of California acreage annually could mean use over the majority of the growing region on an intermittent basis. The CSC notes that "[m]ethyl bromide is often being used in rotation with alternative fumigants. Many growers will use alternative fumigants for 2–3 years then rotate back to methyl bromide to clean up emerging weed and disease problems" (California Strawberry Commission, 2008. *Request for a critical use exemption for methyl bromide on strawberries for the 2011 use season.* Cited in 2013 US Field Strawberries CUN). While a move towards using MeBr every 2–3 years rather than annually is certainly a substantial reduction in MeBr applications, it is not a reduction in the geographic area reliant on MeBr as part of strawberry production, and thus reflects less progress towards achieving a permanent phaseout than the reported reductions in acreage needing treatment would suggest. Unobserved cooperation within the industry to produce this outcome would undermine the intent of the Parties to the Protocol, particularly as it could allow the use of MeBr on fields put into production after the beginning of phaseout. In California, 2009 acreage represented an increase of 89%, or 7600 ha, over the 1991 'baseline' year established for MeBr under the Protocol (ERS, 2010, Table 4). It is not possible to determine if new acreage is using MeBr on the basis of allocations currently in use, as these are not broken out by sector or sub state geographic regions by the US EPA once exemptions are granted (Federal Register, 2011). While the United States did articulate a policy of not allowing growth in CUNs due to new acreage (UNEP, 2005), they did not specify that new acreage reliant on MeBr was not allowed even if it did not drive increasing total amounts of requested MeBr, and so the continued decline in CUNs for this sector seems to satisfy this domestic policy.

While lobbying efforts are ongoing, the CSC and other industry groups also work closely with farmers and researchers developing and testing MeBr free growing methods. CSC reports research expenditures of over ten million dollars to date toward this end, presumably beginning in the early to mid 1990s, which suggests that research expenditures are a substantial part of the CSC budget (calstrawberry.com). Additionally, within regional nomination applications, research expenditures and funding resources have historically been reported and used to substantiate nominations.[7] Sufficient data to elicit trends in those expenditures is not available. Overall, it seems reasonable to deduce that investment in new technology hedged by investment in lobbying for continued exemptions represents an effective risk management strategy for growers and has been an influential driver of industry and regulator decision making.

The political economic and sociological issues around agricultural exemptions to the MeBr phaseout have been studied extensively. Clark (2001) offers an early analysis of the relationship between growers, the state of California, and the Federal EPA. Badulescu and Baylis (2006) consider the harmonization of pesticide rules under NAFTA and the possibility that that process has favored US strawberry producers. Kent Monning (2007) raises concerns about the environmental justice implications of the use of the CUE process in California.

More recently, DuPuis and Gareau (2008); Gareau (2008, 2010, 2012) and Gareau and DuPuis (2009) argue in a series of papers that increasing pressure to provide market solutions rather than command and control ones – as evinced partly by the economic justification for exemptions to agreed phaseout schedules, which was not allowed for the previously established 'Essential Use Exemptions' granted for other ozone depleting substances in earlier stages of the Protocol – undermined the later stages of the Montreal Protocol. They further suggest that an emphasis on the credibility of estimates of private costs over estimates of public benefits will drive decision making about exemptions in the future, while in the past a precautionary principle approach to the human and environmental risks associated with ozone depleting substances was more important. Stakeholder processes have been 'captured' to a significant degree by industry groups rather than involving a broader group more focused on the welfare of civil society as a whole. That this mode of discourse is so dominant in US policymaking is thus offered as an explanation for the ongoing use of significant amounts of MeBr in the US when other countries granted early exemptions have completed phaseout.

[6] The 2013 nominations proved very contentious in 2011; additional bilateral (including with the CSC as well as with representatives of affected nations) and TEAP meetings were added to the schedule and multiple submissions were revised and new research offered during the process (UNEP, 2011a). The decision in the advance draft report of the 23rd Meeting of the Parties reflects the MBTOC (the Methyl Bromide Technical Options Committee, part of the TEAP) recommendation (a 2013 exemption of 461.186 metric tons for field strawberries) but not that of the minority report offered by several members of the MBTOC (UNEP, 2011a,b), which recommended granting the full nomination amount (531.737 metric tons). Application rates used to calculate CUNs and CUEs and the availability of alternative pesticides in specific California growing regions were disputed within the TEAP and among governmental and nongovernmental stakeholders.

[7] Publically reported research expenditure information is incomplete CSC has reported research expenditures as Confidential Business Information, and detailed expenditure data are not typically reported in regional nominations.

3. Progress and barriers in eliminating MeBr under the Montreal Protocol

For the first year of CUNs, 2005, 28 countries nominated critical uses. This number has declined steadily and most recently, four nominating parties (the US, Japan, Australia, and Canada) requested CUEs for 2013 (UNEP, 2011). Global CUEs for non Article 5 countries have decreased by 94% since 2005. Use in Article 5 countries has also declined, falling below total non Article 5 use for the first time in 2007. This decline is partly due to the support of phaseout programs paid for by the Protocol's Multilateral Fund, which is not available to non Article 5 countries. 2010 MeBr use in Article 5 countries was 5.2% of the 1991 baseline.

Nominations by the US and requests for nominations from the California Strawberry Commission between 2005 and 2014 are shown in Fig. 1. The US, which has had the slowest average annual rate of decrease in MeBr usage of non Article 5 countries using the CUE process, had nonetheless reduced CUN amounts by 78% from 2003 to 2013. Although the US has been accelerating the MeBr phaseout in recent years, with a large drop in the 2014 nomination, a complete phaseout has not been planned and it remains unclear when complete phaseout will be achieved.

Within the US, California is now the only state still requesting critical use exemptions for field strawberries. Porter et al. (2006) conducted a global meta analysis of strawberry yields based on hundreds of studies and found that many alternatives produce "statistically equivalent yields" to MeBr, and thus worked to undermine arguments for exemptions related to technical feasibility. The resistance to phaseout of MeBr in California has centered on technical issues but also on economic feasibility and uncertainties associated with the availability of alternative fumigants – namely iodomethane. Approval of iodomethane for use in California was predicted for 2003, and then 2005 (Carter et al., 2005), but it was not actually available for use until December 2010. The failure of California to permit the use of iodomethane was a key rationale for the ongoing exemption request in that state (UNEP, 2011); this is consistent with the US not decreasing its CUN request between the nominating years 2010 and 2011. Since the registration of iodomethane in the 2011 growing season, however, only one California strawberry grower has used it, and that usage was small in scale (Wozniacka et al., 2012).

The registration of iodomethane by the US Environmental Protection Agency and the California Department of Pesticide Regulation was controversial due to potential public and occupational health hazards resulting from its use in pre plant soil applications. After first denying registration of iodomethane in April 2006, the US EPA granted a one year registration in October 2007 and, by 2008, licensed iodomethane for sale and use in the US with some restrictions on its application. Most states – with California the most notable exception – quickly followed suit by registering the fumigant. California eventually did approve the sale and use of iodomethane, but with restrictions more stringent than those imposed by the US EPA and other states. Legal challenges to the approval of this fumigant are ongoing, and an ongoing dialogue with respect to concerns about the registration of iodomethane persists between the general public, the US EPA, the California state legislature, and the risk assessment community, including government scientists involved in assessing the risk of iodomethane, a neurotoxin and possible carcinogen (Urevich, 2011). In early 2012, while no legal ruling against the use of iodomethane was made, the manufacturer announced that, based on an internal review of the fumigant and its economic viability in the U.S. marketplace, they would no longer sell this alternative fumigant in the United States and withdrew its registration in California (Chawkins and Marcum, 2012; ALC, 2012).

4. California strawberries today

US strawberries had record production levels in 2009; production, real value per unit and the total real value of the fresh strawberry crop have risen every year since 2004 according to the USDA (ERS, 2010, Table 1). Real US cash receipts have risen in every year from 2005 to 2010, the last year reported (ERS, 2011a, Table A 8). As noted above, acreage in California has also increased according to each of several data series (California Agricultural Resource Directory, 2010 2011, CSC, 2011; ERS, 2010), contrary to the predictions of declining acreage in the Carter et al. (2005) work and consistent with Carpenter et al. (2000). The ERS data go back the farthest and show that harvested acres of California strawberries have increased steadily since 1970. An OLS linear regression of acreage on time for 2001–2009 data fits well and yields an estimated increase of 650 ha/year; regressions including the earlier decades also show positive and significant trends but do not fit the data as well, suggesting that the time trend alone is not as explanatory over longer periods. These data show acreage increases in every year since 1997, with the exception of 2007, when they declined by less than 1%. Additionally, the ERS data show that the share of California acres in US strawberry acreage has grown steadily over time, from less than a third of the total in the early eighties, to more than half by the mid 90s and rising over two thirds in 2006, where it remains.

Productivity of planted acres has also risen during this time period. ERS data on California yields from 1970 to 2009 show steadily increasing output per acre (ERS, 2010 Table 4). This trend continues for years subsequent to the onset of efforts to eliminate MeBr, though yields are, predictably, subject to weather and other conditions and thus more volatile than acreage. The share of California production in total domestic production has also grown over the time period covered, and has hovered around record highs of 88–89% since 2003. More recently, the Fruit and Tree Nuts report notes of 2010 that "last year, the increase in average yields per acre

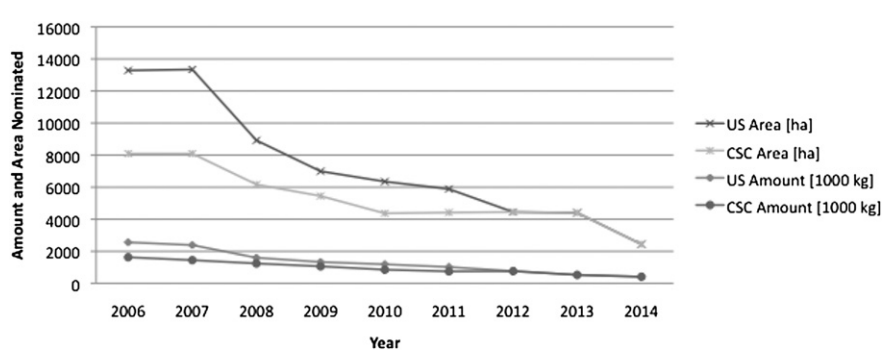

Fig. 1. US and California Critical Use Nominations, with MeBr requests and acreage.

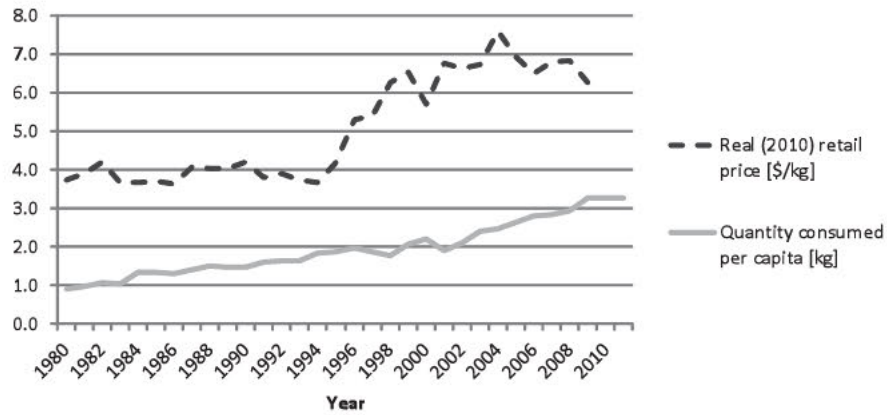

Fig. 2. US fresh strawberry prices and consumption.

in California (up 7 percent from 2009) more than made up for the decline in harvested acres (down 3 percent), resulting in a larger crop" (ERS, 2011c).

On the consumption side, we see that per capita consumption and total consumption of fresh and frozen strawberries continues to rise. In fact, per capita annual consumption of fresh strawberries has broken record levels in each year from 2003 to 2009 (ERS, 2011c; ERS, 2010, Table 12) even as real retail prices have stayed relatively stable or declined slightly. The most recent figures suggest an increase of 48% in per capita consumption of fresh berries since 2002, the last year covered in Norman (2005); with population growth that has amounted to a 67% increase in total US consumption over the same period. The continuing increase in per capita consumption as well as trends in real retail prices can be seen in Fig. 2.

We examine seasonal patterns in retail prices to evaluate hypotheses about patterns of trade raised in some of the ex ante studies discussed above. Real retail prices in June, the period identified by Carter et al. (2005) as most vulnerable to losses in a MeBr phaseout, rose in 5 of the 10 most recent years for which data are available (2000–2009). The average of real June retail prices from 2005 to 2009 was 1% higher than for 2000–2004, suggesting no significant change in the trend over time as a driver of this observation. Looking more closely, however, and in contrast with all but 3 of the preceding 24 years of available data, we note that for 2004–2008 May retail prices were higher than April prices, reversing again in 2009. Grower prices confirm this trend; for 2005–2011, May prices to growers for fresh berries were higher than April prices in 5 years and lower in two years (http://quickstats.nass.usda.gov).

While farming is subject to significant variability from year to year, both in the various growing regions domestically and abroad, this is suggestive of an increasingly competitive market in North America. Norman (2005) predicted that the pre 2005 gap between higher April prices and lower May prices was likely to decrease in size in the absence of methyl bromide. Ex post, we see that the gap has not just diminished but has reversed, while significant MeBr use continues. In the past, imports from Mexico peaked in April and domestic deliveries peaked in May or June. The historic drop in prices as domestic berries hit the markets in bulk suggested that exporting costs were high enough for Mexican growers that expanding exports during this period was relatively unattractive. In recent years, we have not observed a significant shift in strawberry acreage away from northern California growing areas, which deliver strawberries later in the season, and towards southern regions, where strawberries come in earlier (CSC, 2011), which might offer a domestic explanation for this shift in the pattern of relative prices throughout the year, so the currently observed pattern of relatively lower April prices is consistent with the US market becoming more attractive for Mexican growers wishing to export for more of the season or US growers facing rising costs in their peak production periods. It could also be that unobserved changes in crop timing associated with the use of MeBr alternatives have shifted the timing of peak deliveries in some parts of the state.

Investigating trends in imports and exports of fresh strawberries in more detail, however, does not provide strong supporting evidence for the hypothesis that increased Mexican imports are driving intra year changes in relative prices. Imports of fresh strawberries to the United States, almost exclusively from Mexico, have indeed grown substantially, continuing a trend observed well before MeBr restrictions began. They have more than doubled since 2004 (ERS, 2011b and Table G 1, ERS, 2011a). The share of Mexican imports in domestic consumption has changed less, however, trending slowly upward since the mid 1980s and now around 8%.[8] This may reflect increasing retail availability and consumption in the off seasons for domestic strawberries as well as increased April exports from Mexico.

United States exports also grew during this time, rising more than 50% from 2004 to 2010 (Table G 2, ERS, 2011a). The bulk of these exports go to Canada, which consumes considerably more strawberries than are produced there. The increase in tonnage of exports to Canada is very similar to the increase in imports from Mexico, suggesting that changing price patterns over time cannot be cleanly ascribed to trade advantages for Mexican growers selling in the United States. Domestic exports could well increase the scarcity of domestic berries at peak periods, driving domestic prices up. Strawberry exports do peak in May (ERS, 2011a, Tables G6–G8). Unfortunately, import and export data by month are only available for a few years, making it difficult to discern trends over time with confidence.

Also affecting trade patterns in North America may be the promulgation of Country of Origin Labeling (COOL) regulations in the United States (http://www.ams.usda.gov/AMSv1.0/COOL). For the 2009 and subsequent seasons all fresh strawberries sold in the United States were required to carry labels indicating where they were grown and packed. One expectation of supporters of this policy was that consumers would prefer domestic products over imports, and this may have reduced the vulnerability of California growers to cheaper imports from Mexico in particular. Carter and Zwane (2003) argue that this was in essence a (costly) protectionist policy. Van Ittersum et al. (2007) note that consumers may prefer domestic or local region products both because they believe them to be better or safer, or because they have a preference for

[8] Calculations based on ERS (2011b) yield slightly different shares than those given in ERS (October 2010, Table F-14).

supporting growers in geographic regions that they identify with. Either of these would help California growers and hurt Mexican exporters in the domestic market. While we cannot isolate any impact of this over the short period since the rules have been established, it remains clear that the majority of the US market continues to be served by domestic growers.

The MeBr alternative iodomethane has been approved for use in Mexico and a commercial launch there is planned for 2012 (ALC, 2010). As an Article 5 country, Mexico has until 2015 to phaseout MeBr under the Montreal Protocol; however, the government of Mexico has committed to completely phaseout methyl bromide by 2012 (UNEP, 2010),[9] by which point it seems likely that growers there will be able to use iodomethane and California growers will use continuing allocations of MeBr and any of several alternatives which show little to no yield changes in current research (summarized in USDoS, 2012). Costs for various production inputs and growing conditions will of course vary and be drivers of comparative advantage in international trade as with any commodity. It is unlikely that changes in land use in California or Mexico have been driven by an expectation of continued MeBr use in Mexico after it is curtailed in the United States.

Additionally, increases in imports may reflect changing trade advantages unrelated to MeBr phaseout in the United States. From 2002 to 2009, imports of Mexican lemons increased from negligible to a major trade commodity, increasing to 54 times initial levels. Avocados increased eleven fold, raspberries increased eight fold, pineapples were up 250%, and pecans and cocoanut meat also increased more rapidly than fresh strawberries. Tangerine, lime, and mango imports grew more slowly than strawberries but still rose significantly (ERS, 2011a, Table G 1). Trade changes driven by NAFTA or other drivers of increased globalization should not be ascribed to the ongoing MeBr phaseout without more substantial evidence than we are able to find.

5. California strawberry production cost estimates

Looking at the various sample budgets available from Cooperative Extension in California (UC Cooperative Extension, 2001a–c, 2004a–d, 2006, 2010, 2011a–b), we do not observe clear links between decreasing availability of MeBr and costs or profits. 2010 and earlier reports note that alternatives to MeBr are available and in use, but the sample budgets assume fumigation with MeBr and chloropicrin (or 'Pic'); Pic allows for significantly lower rates of MeBr application in areas where MeBr had previously been used alone. Of the two 2011 reports one notes that methyl bromide availability is limited and does not specify a fumigant in the line item budgets and the other uses Pic alone.

In the geographically central of the three largest growing regions, fumigation costs as a share of total costs were 2.4% in the 2001 sample budget, 3.7% in 2004, 3.5% in 2006 and 2.9% in 2011. For the same 3 years estimated net returns were 1.6, 14.2, 7.6, and 3.2% of total costs. In the main growing region to the south we have budgets for 2001, 2004, and 2011 which show a decline in fumigation costs as a share of the total, from 6.0 to 5.7 to 3.1%, while net returns increased from 9.5 to 13.4% and then dropped to 2.2%. In the northernmost growing region, budgets for 2001, 2004 and 2010 show increasing fumigation costs (5.2, 5.4 and 6.9% of total costs, respectively) and fluctuating net returns (6.6, 9.4 and 4.0%). These numbers offer some insights into input and production costs, in particular suggesting weakly declining fumigation costs and yielding some evidence of declining net revenues in the most recent years, but we note that the sample budgets are designed to offer a general understanding of costs and revenues using current methods rather than to support rigorous economic analysis.

Critical Use Nominations themselves are another source of data on trends in production costs and revenues. The nominations through 2013 give a baseline yield rate for fumigation with 100% methyl bromide and discount it by some fraction for each alternative pest control regime. While detailed budgets are not provided, annual CUNs for CUEs also include estimates of the economic impacts of MeBr as compared to alternatives.[10] These estimates are developed to support the case that additional exemptions to use MeBr in California are needed to avoid 'significant market disruption,' which is a key part of the standard established in Decision IX/6 of the Montreal Protocol to define a use as critical. Alternatives are shown with associated yield estimates and implied costs to producers facing changed yields and other practices. For 2006–2013 CUNs, the baseline MeBr yield estimates fluctuate a bit, dropping by around 15% from 2006 to 2008 levels in 2009–2010 and then rising again for 2011–2013 nominations. Reported yields per hectare are well below those reported in the sample budgets referenced above, typically around 40–50,000 kg/ha in recent CUNs, with some alternatives in the 30–40,000 range in earlier nominations, while first year strawberry yields in the sample budgets are around 60–80,000 kg/ha and the most recent second year yield reported is over 50,000 kg/ha (UC Cooperative Extension, 2011c). The yield loss associated with moving from MeBr to a mixture of 1,3 dichloropropene (1,3 D) and chloropicrin is steady at 14% throughout, suggesting that the loss rate estimate was not revised over time but simply applied to the MeBr number for a given year. This alternative is the only one included in every nomination[11]; metam sodium (MS) and a mixture of Pic and MS were excluded from 2010 to 2009, respectively, and a mixture of Pic and MeBr was not added until the 2010 nomination. Iodomethane is included for the first time in the 2013 nomination.

Projected strawberry prices drop by about 30% from 2010 to the 2011 nomination estimates, and they remain at this low level through the 2013 nomination. This price, $1.37/kilogram,[12] is well below current and recent reported grower receipts (ERS, 2010); it is not clear why recent nominations have used such a low baseline price. This price drop helps explain why the estimated value of MeBr use as opposed to 1,3 D+Pic can be relatively stable, ranging between $43–68 per kilogram for 2006–2013 nominations, while the figure for "percentage loss in net revenues" swings up to 1269% in 2011 and subsequent years, after previously being estimated at 55 and 87%. While the loss to net revenue is appealing as a proxy for disruption suffered by growers, the nominations note that the

[9] In 2008, Mexico's MeBr consumption was below consumption allowed under the Montreal Protocol. As of 2010, those implementing the National Methyl Bromide Phase-Out Plan for Mexico (the United Nations Industrial Development Organization (UNIDO) along with the governments of Italy, Spain, and Canada) intended to eliminate the remaining MeBr (approximately 900 ODP tonnes) by 2012, provided requested monies from the Multilateral Fund were received. The plan initially proposed that the strawberry sector convert near the end of the phaseout because "strawberry growers were reluctant to reduce MB consumption" (UNEP, 2010, p. 5). However, Mexico's strawberry growers have since requested immediate assistance in order to accelerate completion of the phaseout.

[10] These figures are all reported in nominal dollars, as the requests are filed a few years in advance of the proposed use, and do not specify nominal or real figures. Additionally, many of the numbers do not change from year to year, suggesting that the precision of the estimates is not such that deflating them should drive conclusions.

[11] It is worth noting that the 1,3-D mix is not available to all growers, as many California townships restrict 1,3-D use (Carpenter et al., 2001) and some counties restrict Pic application. This may be why the extension service budgets above exclude it, and this may also make it difficult to draw statewide conclusions on the basis of variation in yield estimates between 1,3-D alone and in combination and MeBr.

[12] The CUN itself reports 'units'; we believe these to be kilograms based on matching with previous California nominations.

required gross revenues less operating costs are "difficult to measure and verify" (USDoS, 2004–2011). Net revenues are sensitive to the implied change in gross revenues of much lower strawberry prices even in the absence of significant cost shifts, and smaller net revenues produce bigger percentage changes for a given nominal cost increase or yield decrease.

As this article was being finalized for publication, the 2014 Critical Use Nomination for field strawberries in California was made public. It requests 415 metric tonnes of MeBr for field strawberries, a bit over a 20% decline from the request for 2013. The drop in requested acreage to be treated is about 50%, suggesting decreasing use of MeBr in combination with other chemicals and thus at higher rates, while the baseline fumigant in the economic impact table is now a mixture of MeBr and Pic rather than MeBr alone. The economic impact analysis shows no yield losses for any alternative, a substantially higher output price for growers of $2.51 per unit, a roughly 60% increase in reported yields to nearly 80,000 kg/ha, and greatly reduced or even negative loss measures. The estimated loss or gain as a percentage of net revenue ranges from 9% (for an alternative using iodomethane) to 5% across all reported alternatives (USDoS, 2012). Chloropicrin alone yields an increase in net revenue of 2% relative to the baseline. Thus the key driver of the request is now the limited access in some specific areas to use of some of the alternative fumigants, or the requirement for buffer zones around schools and residential areas. However, the township caps that limit 1,3 D are being reached in regions where strawberry acreage has grown substantially since the US agreement to phaseout methyl bromide. It is difficult to argue that a sub state regulatory decision that limits the amount of acreage in all crops that can be treated with certain pesticides represents a substantial disruption of the California strawberry market due to the elimination of methyl bromide.

It is interesting to note that with the exception of the 2006–2008 nominations the economic impact estimates in the CUNs assume no price gap per unit produced using MeBr and using alternatives. Wolverton (2012) indicates that in 2006–2008 the change in prices was used to reflect anticipated planting delays and subsequent later deliveries of crops to market for growers using alternative fumigation practices rather than broader market impacts. Constant output prices across alternatives with significantly differing yields suggest that these economic impact estimates assume no market price responses to significant supply swings (including projected yield losses of up to 30% for California growers, which would certainly affect the domestic and North American markets), and thus do not account for the significant amount of any cost increase that will be passed along to consumers as the market reaches a new equilibrium price (see Norman, 2005 for detailed discussion of the impact of relatively inelastic consumer demand for fresh strawberries on market prices and the distribution of the burden of rising production costs). If all acres not receiving exemptions were using alternatives with substantially lower yields and similar or increased costs, we would expect market prices to rise and moderate reductions in profits.

While we do not observe profits directly in the way that we do acreage and revenues, it is difficult to reconcile the history of CUN figures for California yields and costs using alternatives with the increasing use of alternatives and the increasing yields per acre and increases in total acreage noted above. The continued expansion in acres noted above is not consistent with an industry facing large losses as the phaseout continues; basic economics tells us that rising profits attract entry into an industry and falling profits drive exit, as more remunerative investments are sought for the land and capital previously employed in the failing sector. It seems likely that modifications of farming practices in concert with the use of non iodomethane MeBr alternatives have been increasingly successful at preserving yields in those areas that are doing without MeBr either altogether or at least in some years. Input substitution as the price of fumigation relative to other inputs into the strawberry growing process rises – altered weeding practices or schedules, perhaps, or alternate cultivars or crop rotations – would be expected to lower the costs of compliance with the phaseout process. We have found no evidence suggesting zero input substitution characterizes this industry, and any substitutability across inputs will reduce cost burdens on growers. Learning by doing should also lower costs and gaps in yields across different pest control strategies over time, as growers and fumigation contractors become accustomed to using alternatives. Further and perhaps most significantly, it seems that the calculations used to support the granting of CUEs in this sector do not allow for the ability of growers to share cost increases with consumers, who may by their numbers and relatively inelastic demand bear the majority of any remaining burden without individually experiencing price increases as economically disruptive.

6. Additional drivers of change and trends

While per capita consumption of fresh berries by Americans has continued to rise since 2004, it is not obvious that this is driven by rising per capita incomes as earlier data suggested to Norman (2005). Mean and median household and per capita income trends were disrupted by the global recession, with US median household income falling in 2008, 2009 and 2010, mean household income falling in 2007, 2008, 2009 and 2010, and per capita income falling in 2009 and 2010 (Historical income tables, www.census.gov). With a relatively short data period to contend with and a lack of detailed information about changes in income distribution

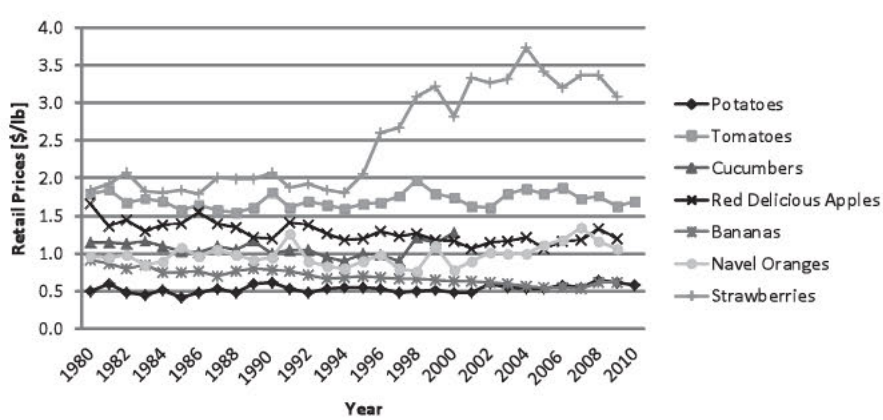

Fig. 3. US fruit and vegetable real retail prices.

and the relationship between income and strawberry consumption, disentangling trends in prices, consumption, and income to estimate relationships is imprecise.

One thing we do note in this market is that while prices of many fresh fruits and vegetables, including strawberries, have trended slightly downwards since 2008 (ERS, 2010 Table 12 and October 2011 Table A 7), over a longer time horizon, we observe a marked difference in fresh strawberry prices, which have increased by 85% from 1994 to 2008, compared to the prices of some other fruits and vegetables, which have largely been stable or increased to a much lesser extent (Fig. 3). Per capita consumption of fruits overall remained constant from 1994 to 2008, while per capita vegetable consumption initially increased from the mid 90s to 2000 but declined subsequently. This suggests that significantly increased strawberry consumption in the face of rising or stable prices in recent years is not likely to be driven by a decline in the price of strawberries relative to substitute fruits and vegetables. Changes in income, tastes, and preferences as well as the increased availability of strawberries at all times of the year are combining to support increased per capita and total strawberry consumption.

7. Conclusion

We offer an ex post analysis of the impact of the mandated phaseout process for methyl bromide on California strawberry growers to date. Ex ante estimates of the economic impact of the elimination of MeBr were required by and influential in the CUN and CUE processes, in contrast with either a benefit cost approach including public health and environmental protection gains, as required by many of the domestic environmental policies of Parties to the Montreal Protocol, or with the Essential Use Exemption process used for other ozone depleting substances eliminated earlier in the ozone protection regime. While this is not an ex post analysis of the originally expected complete phaseout, and thus cannot be directly compared with ex ante predictions based on the complete elimination of MeBr use, it does offer insight into the gap between predictions and outcomes of a strawberry industry moving away from this ozone depleting pesticide while facing import competition from a major trading partner with a more lenient phaseout schedule.

Contrary to many ex ante predictions and concerns expressed by stakeholders, California strawberry growers have thrived in recent years relative to both domestic and foreign competitors. They have successfully worked to ensure that MeBr has been available for significant fractions of their significantly expanded acreage, increased exports, and continued to enjoy rising yields and revenues as well as increased demand from consumers. The interim years between the planned elimination of MeBr and the increasing success of alternatives as detailed in the 2014 CUN and other reports have been years of expansion in the face of global recession and increased imports from Mexico, and successful navigation of technical and regulatory changes. Industry data suggests that the real burdens associated with changing agricultural practices have not kept this sector from profitability and growth in a challenging economic environment, though we cannot know how much faster growth might have been if MeBr use had continued unabated.

Alarming numbers in the CUNs sent to the Parties to the Montreal Protocol are not consistent with the success of California strawberry growers in aggregate as use of MeBr has been reduced. Nor are they consistent with basic economics. The 'economic disruption' standard of the CUE process was not intended to require the Parties to permit application of MeBr on new acreage to allow limitless expansion of a given industry using MeBr, and it is difficult to justify ongoing exemptions to support expansion rather than protect existing growers and growing regions. If all the new acres in production since 2005 are being managed profitably without MeBr, and existing acres are using less MeBr less often while overall and per acre yields and revenues rise steadily, it seems we have reached a point where alternatives are demonstrating successes for field strawberries in California.

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NATURAL RESOURCES DEFENSE COUNCIL

Testimony of David D. Doniger
Policy Director and Senior Attorney, Climate and Clean Air Program
Natural Resources Defense Council

Hearing on the U.S. Agricultural Sector Relief Act of 2012

Subcommittee on Energy and Power
Committee on Energy and Commerce
House of Representatives
July 18, 2012

Summary

- Protection of the ozone layer is a huge bi-partisan public health success story. The phase-out of ozone-destroying chemicals, including methyl bromide, is saving literally millions of Americans, and tens of millions of people around the world, from death and disease, from skin cancer, cataracts, and immune diseases. It is also saving farmers billions of dollars in UV-related crop losses.

- Now is not the time to tamper with the Montreal Protocol and the Clean Air Act. By slowing or even reversing the transition away from methyl bromide, "The U.S. Agricultural Sector Relief Act" will lead to more skin cancers, more cataracts, more immunological disease. It will benefit strawberry growers and others who have profited by abusing the "critical use exemption" for almost a decade. Thousands of other farmers growing other crops will suffer more UV-related crop losses as a result.

- Methyl bromide suppliers and users have dragged their feet on replacing this dangerous compound for two decades. No other industry has had more time and more leeway to transition from dangerous ozone-destroying chemicals.

- The United States is responsible for more than 90 percent of all methyl bromide exemptions. Every other strawberry- and tomato-growing country with California-like growing conditions – including Italy, Spain, Greece, and Australia – has ended use of methyl bromide. Mexican growers use less methyl bromide per acre than their California counterparts, and Mexico will end methyl bromide use entirely this year.

- California strawberry growers have done very well during the whole experience, according to a recent peer-reviewed economic study. Strawberry acreage is up 16% and yields are up 14% since 2004 despite significant reductions in methyl bromide allocations. So are U.S. grower prices and total crop values.

- U.S. critical use exemptions have been coming down. California strawberries are now the only field use for which the U.S. is still seeking critical use exemptions. Together with several structural and commodity uses, the total U.S. exemption request for 2014 is down to slightly more than 400 tons.

- The bill would do reckless damage in three major ways: First, it would permanently define as "critical uses" all of the uses that were labeled critical in 2005, even though the vast majority no longer even use methyl bromide. Absurdly, the bill would make even golf course turf grass a "critical use." It makes no sense to freeze into law an utterly out-dated list of "critical uses."

- Second, the bill relieves applicants of the need to show why they need exemptions. They could just submit their exemption wish lists without any supporting data. EPA then would bear the burden of gathering the data to support any reduction. Absent resources and data, EPA would have little choice but to forward the applicants' unsupported wish lists to the parties. This would be foolish even from the growers' perspective. It actually helps the U.S. government win approval for exemptions to have shown that it has exercised judgment and discipline in framing its requests, and has is not mechanically asked for everything its domestic applicants may have wanted.

- Third, the bill would blast an enormous new loophole into the Clean Air Act and our pesticide safety laws, by allowing any individual user to write his own ticket for up to 20 tons of methyl bromide

simply by asserting the existence of an "emergency." There could be a hundreds of emergency exemptions per year, totaling up to 2,000 tons per year (the 2011 critical use amount).

- This is a bad and unneeded bill. It would harm public health, harm other farmers, and indeed even harm the farmers it is intended to help. The process is working. This Committee should let well enough alone.

Thank you Chairman Whitfield and Ranking Member Rush for the opportunity to testify on behalf of the Natural Resources Defense Council on the proposed "U.S. Agricultural Sector Relief Act of 2012." Founded in 1970, NRDC is a national nonprofit environmental organization of scientist, lawyers, and environmental specialists with more than 1.3 million members and online activists, served from offices in New York, Washington, Chicago, San Francisco, Los Angeles, and Beijing. I am policy director of NRDC's Climate and Clean Air Program. I have been with NRDC twice, from 1978 through 1992 and from 2001 to the present. In the 1990's I served as director of climate change policy in the EPA Office of Air and Radiation. Relevant to the topic of today's hearing, I have worked on the phase-out of ozone-destroying chemicals for more than a quarter century.

There are few greater success stories than the global effort to phase out the ozone-damaging chemicals. Every American, and every citizen on this Earth, relies on the ozone layer to block dangerous ultraviolet radiation that causes skin cancer, cataracts, immune disorders and other diseases. The treaty to protect the ozone layer, known as the Montreal Protocol, has enjoyed bipartisan support from five presidents beginning with Ronald Reagan. So have the ozone layer protection provisions of the Clean Air Act. They are saving literally millions of Americans, and tens of millions of people around the world, from death and disease. They are also preventing billions of dollars in UV-related crop losses and other economic damages.

Yet the ozone shield is still being weakened by ozone-depleting chemicals that increase our exposure to dangerous UV radiation. Millions of Americans – including farmers – must work everyday in the sun. Millions more – from school children to seniors – spend hours of their days out of doors. Millions of concerned parents check the UV Index and cover their kids with sunscreen before letting them go out in the sun.

That brings us to methyl bromide. Methyl bromide is the most powerful ozone-depleter still in widespread use. All of the other more potent ozone-destroying chemicals have been successfully

eliminated – worldwide. Methyl bromide is also highly toxic, with inhalation or dermal exposure causing a wide range of acute and chronic effects, including death.

Mr. Chairman, I will not mince words. You are considering a bill to further slow the snail-like pace of the transition from this dangerous chemical – a bill that will lead to more skin cancers, more cataracts, more immunological disease, and more crop losses due to ozone-destruction and UV radiation, as well as more illness from direct exposure. Contrary to the bill's grandiose title, this bill will not broadly benefit "the U.S. agricultural sector." Indeed, thousands of farmers growing other crops will suffer more UV-related crop losses as a result. Instead, this bill will benefit only a small sliver of strawberry growers and few others who have profited handsomely by abusing the "critical use exemption" for the better part of a decade.

No industry has had more time and more leeway to transition from dangerous ozone-destroying chemicals than this one. The auto industry replaced CFCs in car air conditioners in less than four years. The electronics industry replaced ozone-depleting solvents in circuit board manufacture in less time than that. The air conditioning and refrigeration industry and the fire protection industry got rid of their potent ozone-depleters in well under a decade. Indeed, some of these industries have gone through two rounds of transitions to safer chemicals in the last 20 years. And all of these industries have been able to produce better, more energy-efficient, and more profitable products.

But methyl bromide stands apart. The producer and the users of this chemical have dragged their feet on replacing this dangerous compound for two decades. Let's review:

The phase-out of methyl bromide was supposed to be completed by 2001 pursuant to the 1990 Clean Air Act Amendments. With a decade of lead-time, growers and other users should have invested in developing and field testing other agents and other agricultural practices, like every other industry did. Their effort was minimal. And their minimal effort was rewarded by pushing the deadline back to 2005, in conjunction with amendments to the Montreal Protocol to phase out methyl bromide world-

wide. An post-2005 exemption was allowed for so-called "critical uses," but all observers then thought this would be just a small percentage of historical ("baseline") methyl bromide use, just as the "essential use" exemptions for other ozone-destroying chemicals had been only a small fraction of their baselines.

Indeed, other countries with comparable agricultural conditions played by those rules, submitting critical use exemption requests, if any at all, that reflected small fractions of their historical methyl bromide use levels. Only the U.S. took a different tack. In 2003, U.S. growers and others sought exemptions totaling some 15,000 tons, more than 60 percent of country's baseline use in the early 1990s. The U.S. government requested more than 10,000 tons of exemptions, and nearly broke the back of the Montreal Protocol. For the first time in its history, the parties were unable to come to a consensus decision. For the first time, there was an impasse that could not be resolved without calling an extraordinary meeting of the parties.

For eight years running, the United States alone has requested more than 90 percent of all exemptions. Over this period, nearly every other developed nation has eliminated its need for methyl bromide. Specifically, every other strawberry- and tomato-growing country with Mediterranean-like growing conditions – including Italy, Spain, Greece, and Australia – has moved beyond use of methyl bromide. Even Mexico – the California strawberry growers' only competitor – is committed to end its use of methyl bromide this year.[1]

Throughout this period, and here again today, the California strawberry growers have led the pack in coming to Congress playing the hardship violin. In fact, however, California strawberry growers have done very well during the whole experience, according to a recent peer-reviewed economic study by Erin N. Mayfield and Catherine Shelley Norman, published in the *Journal of Environmental*

[1] "The Government of Mexico has committed to achieve the complete phase-out of MB by the end of 2012." United Nations Environment Programme, Executive Committee of the Multilateral Fund for the Implementation of the Montreal Protocol, Sixty-sixth Meeting, Montreal, 16-20 April 2012, "Project Proposal: Mexico, National methyl bromide phase-out plan (third tranche), ¶9, http://www.multilateralfund.org/66/English/1/6641.pdf.

Management.[2] They have expanded their strawberry acreage and increased their yields dramatically despite significant reductions in methyl bromide allocations: California strawberry acreage in 2010 had increased 83 percent over 1991 levels and 16 percent over 2004. Yields per acre in 2010 increased 29 percent over 1991 levels and 14 percent over 2004. California's share of U.S. production also increased during this period, from about 80 percent in 1991 to more than 90 percent in 2010. U.S. grower prices and total crop values adjusted for inflation also increased during the exemption years.

The expansion of the strawberry acreage treated with methyl bromide is extremely troubling because it breaks a commitment made by the U.S. government not to allow such expansion. For instance, the "National Management Strategy for Methyl Bromide, United States of America, December 2005" states: "An important way that the United States addresses the issue of avoiding increases in MeBr use is our policy to disallow any increases in acreage or throughput that CUE applicants might include in their CUE request."[3] This turns out to have been a hollow promise.

The growers' complaints often center on the claim of unfair competition from Mexico. Throughout this period, however, Mexican growers used less methyl bromide per acre than their California counterparts, and Mexico, as I mentioned, has committed to stop using methyl bromide this year. Mayfield and Norman note that although strawberry imports from Mexico increased as the overall U.S. strawberry market grew, Mexico's share of total U.S. consumption did not increase significantly, and U.S. growers' strawberry exports to Canada rose by almost as much as imports from Mexico.

Mayfield and Norman also note that the economic analysis supporting the critical use nomination for 2014 – an analysis prepared by the strawberry growers – indicates that a range of alternatives to methyl bromide are effective and available at comparable cost and without yield losses.

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[2] E. Mayfield & C. Norman, *Moving away from methyl bromide: Political economy of pesticide transition for California strawberries since 2004,* Journal of Environmental Management, Vol. 106, Pp. 93-101 (2012), available at http://www.sciencedirect.com/science/article/pii/S0301479712001909, and attached to this testimony.
[3] http://www.epa.gov/ozone/mbr/downloads/MeBrNatMgmtStrat.pdf, p. 4.

Notably, these results do not depend on methyl iodide, which was withdrawn from the market by its manufacturer earlier this year.

As it turns out, the industry is still sitting on a stockpile of methyl bromide made before 2005 and stored in railroad cars in various communities around the country. Believe me, tank cars of highly toxic methyl bromide baking in the sun on rail sidings are not something I'd want in my community, or rolling through my Congressional district, yet few people know if they enjoy that privilege. As of today, the stockpile still exceeds 1,200 tons – three time the U.S. critical use nomination for 2014.

Why is the stockpile important? Because the rules of the road under the treaty are that a country may request permission to manufacture new methyl bromide to serve critical use needs only if it has exhausted its stockpiles. The industry attempted to conceal that stockpile from both the public and the government, and this led to the U.S. government's initially misrepresenting to the other Montreal Protocol parties in 2003 that there would be no stockpile left in 2005. But the true stockpile, divulged only later in response to an NRDC lawsuit, was nearly 13,000 tons – more than the entire amount the U.S. claimed to need for 2005. The methyl bromide stockpile has been used – illegally, in our view – for crops that no longer qualify as critical uses, such as golf course turf grass, and to exceed the critical use limits on crops such as strawberries. Each year since 2004, the stockpile has been larger than the next year's total critical use request. That is true for 2013 and 2014. The deception over the stockpile, once revealed, almost caused the breakdown of the treaty process, and the existence of a continuing stockpile is still a major irritant between the parties today.

NRDC acknowledges that the amounts of U.S. critical use exemptions have been coming down, however belatedly. Many growers and other users have finally taken up alternative chemicals and alternative pest management practices, so that we have now come to the point where the only field use for which a critical use nomination is still being made in 2014 is California strawberries. Together with several structural and commodity uses, the total U.S. exemption request is down to slightly more than

400 tons, as compared to nearly 10,000 tons in 2005. This progress, though long delayed, is noteworthy and must continue. Further progress is possible even in the short run, through practices such as greater use of impermeable films (something other countries have already adopted) and by continued adoption of alternatives.

In short, the process is working. Now is not the time to tamper with the methyl bromide phase-out requirements under Montreal Protocol and the Clean Air Act. Mr. Chairman, the bill before you would pointlessly weaken curbs on this dangerous ozone-destroying chemical, threaten the recovery of the ozone layer, and further strain our relations with other countries that are already experienced with U.S. abuse of critical use exemptions. The bill does reckless damage in at least three major ways:

First, the bill would permanently define as "critical uses" all of the uses that were labeled critical in 2005, regardless of the fact that the vast majority of those crops and applications have successfully transitioned to alternatives and no longer even use methyl bromide. Absurdly, the bill would make golf course turf grass a "critical use," even though the Bush administration's agriculture department dropped it from the list in 2006. Why in the world does it make sense to revive and freeze into law an utterly out-dated list of "critical uses"?

Second, since growers and other applicants are seeking exemptions for a chemical that is otherwise already banned under both domestic and international law, and since they are in the best position to innovate and test alternatives, they quite properly now bear the burden of showing the need for methyl bromide and the absence of economically practical alternatives. But the bill would turn that burden around. It would allow applicants to submit their wish lists for exemptions without providing any data in support. Even though this chemical is already supposed to be banned, the bill would then require EPA to shoulder the burden of developing the data to support any reduction from the growers' or other applicants' requests. As the growers would be quick to point out, EPA does not run farms, and EPA does not run alternatives testing programs.

Absent the resources and access to data, EPA would have little choice but to forward the applicants' wish lists to the parties for consideration. Even from the growers' perspective, this would be a fool's errand. It is difficult enough for the U.S. to gain approval for its out-sized exemption requests when it can bring a reasonably robust case forward for technical scrutiny by the other parties. It actually helps the U.S. win approval for exemptions to have shown that the government has exercised some judgment and discipline in framing its requests, and that the U.S. is not asking for everything its domestic applicants may have wanted.

Third, the bill would blast an enormous new loophole into the Clean Air Act and our pesticide safety laws, by allowing any individual user to write his own ticket for up to 20 tons of methyl bromide simply by asserting the existence of an emergency. "Emergency" is conveniently defined to mean any situation where someone wants to use more methyl bromide than is available under a critical use exemption, and where he declares that there is no alternative. The bill would allow a hundred 20-ton emergency exemptions per year, up to a total of 2,000 tons per year (the amount of critical use exemptions in 2011). This would be a massive abuse of the emergency exemption provision under the Montreal Protocol, which has been invoked only twice so far (once by Australia and once by Canada) in genuine emergencies.

Imagine, Mr. Chairman, how cool it would be to be able to withdraw more cash from the bank than you have in your account, just by calling it an emergency. There's another name for that: bank robbery.

This is a bad bill, and an unneeded bill. It would harm public health, harm other farmers, and indeed even harm the farmers it is intended to help. The process is working. This Committee should let well enough alone.

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Moving away from methyl bromide: Political economy of pesticide transition for California strawberries since 2004

Erin N. Mayfield [a], Catherine Shelley Norman [a,b,*]

[a] Department of Geography and Environmental Engineering, The Johns Hopkins University, 3400 North Charles Street, Baltimore, MD 21218, USA
[b] Department of Economics, The Johns Hopkins University, 3400 North Charles Street, Baltimore, MD 21218, USA

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ABSTRACT

We examine the progress of the phaseout of the use of the pesticide methyl bromide in the production of California field strawberries. This phaseout is required under the Montreal Protocol and has been contentious in this sector, which receives exemptions from the schedule initially agreed under the treaty, and in international negotiations over the future of the Protocol. We examine the various ex ante predictions of the impacts on growers, consumers and trade patterns in light of several years of declining allocations under the Critical Use provisions of the Protocol and the 2010 approval of iodomethane for use in California and subsequent 2012 withdrawal of this alternative from the US market. We find that, contrary to ex ante industry claims, the years of declining methyl bromide use have been years of rising yields, acreage, exports, revenues and market share for California growers, even when faced with a global recession and increased imports from Mexican growers who retain the right to use the chemical under the Protocol. This has implications for the Protocol as a whole and for the remainder of the US phaseout of this chemical in particular.

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1. Introduction and background

US fruit and vegetable growers using the fumigant methyl bromide (MeBr), scheduled for phaseout under the Montreal Protocol on Substances that Deplete the Ozone Layer, faced uncertainty about the cost and effectiveness of alternative chemicals and practices, and many of them applied for exemptions allowing continued use after the planned elimination of MeBr. This process was controversial – so much so that the United States suggested that they might withdraw from the Montreal Protocol, up to that point considered a model of successful international environmental policy, if their nominations for exemptions were not granted (Gareau and DuPuis, 2009). In the exemption process, which allowed exceptions to the scheduled 2005 complete phaseout date, one of the most contested uses was for strawberry farming, especially in California where many alternatives are strictly regulated or disallowed. Growers argued that none of the alternatives met the 'economic and technical feasibility' conditions of the Critical Use Exemption (CUE) rules. DeCanio and Norman (2005) discuss possible interpretations of the feasibility criteria at length, emphasizing that it cannot mean that no changes in costs or agricultural practices are required of methyl bromide users, but there is not a consensus definition of precisely what standard must be met.

Currently, the majority of CUEs for methyl bromide are allocated to the United States.[1] The share of field (rather than nursery) strawberries in total exemption requests has also grown; the 2014 US field strawberries nomination was for over 93% of the total US allocation, and was exclusively for use in California, which produces 90% of US strawberries (ERS, 2011c). In 2007 the same share was only 13% and more geographically dispersed, including uses in the southeastern US as well as California (USDoS, 2010, 2005, ozone.unep.org). Substitutes have been slower to develop in California,

* Corresponding author. Department of Geography and Environmental Engineering, The Johns Hopkins University, 3400 North Charles Street, Baltimore, MD 21218, USA. Tel.: +1 410 516 5184; fax: +1 410 516 8996.
E-mail addresses: erin.noel.mayfield@gmail.com (E.N. Mayfield), norman@jhu.edu (C.S. Norman).

[1] For the last seven years reported, 2007 2013, approved US CUEs have been more than 75% of non-Article 5 exemptions approved globally, so US strawberry uses are a significant amount of remaining global use of MeBr. In the first year of the exemption process, US allowances were a bit over 40% of total non-Article 5 allocations. For 2013, the United States has received over 90% of approved CUE allowances. Article 5 parties, which are, roughly speaking, less developed countries, do not have to complete phaseout until 2015, but their total use peaked in 1998, and by 2010 total consumption in Article 5 and non-Article 5 countries were approximately equal (exclusive of quarantine and pre-shipment uses, which are regulated separately and excluded from the discussion throughout this paper) (ozone.unep.org).

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due to different farming practices and a relatively stringent regulatory climate that has slowed the approval of some MeBr alternatives. The California strawberry crop is worth more than $2 billion annually and is the 6th highest valued fruit crop in the state, so while the industry is small at the national level it is economically significant in the region.[2]

California growers and those negotiating the CUE process on their behalf were deeply concerned that the main source of US imports of fresh strawberries, Mexico, would not be required to eliminate the use of MeBr at the same time that California growers were scheduled to. The Montreal Protocol allows delays in the elimination of ozone depleting substances for less developed countries, and growers feared that lowered trade barriers under NAFTA would combine with a technological advantage to Mexican growers using the fumigant, leading to dramatically increased imports of fresh strawberries and reduced sales of and/or prices for domestic berries.

This work investigates how the process of phaseout has affected the California field strawberry industry and finds that management and regulatory decisions at the international, national, and state levels have allowed California growers to maintain and enhance their dominance in the domestic and North American market as the phaseout has progressed. The period between the beginning of the methyl bromide phaseout and the availability of iodomethane, the closest thing to a 'drop in' substitute yet developed, for use in the state has been characterized by slow elimination of MeBr, rising acreage, yields and consumption, improved balance of trade, increasing domestic market share, and rising or relatively stable prices. Iodomethane itself has recently been voluntarily withdrawn from the US market, and we consider how this might affect our assessment of the phaseout process to date.

2. Ex-ante analyses of economic effects and political factors influencing phaseout

Economic analyses earlier in the process did not reach a consensus regarding the likely impacts of phaseout. Norman (2005) relied heavily on data from nominations for CUEs and found that trends in demand growth for fresh strawberries[3] and significant pass through of cost increases to consumers were expected to outweigh the stated negative effects of production cost increases associated with use of alternative fumigants, even in the absence of direct government support, under fairly conservative assumptions, and that increased consumer costs per household would be minimal, even if they were substantial in aggregate.

Carpenter et al. (2000) simulated production, consumption, and crop prices for methyl bromide users (e.g., California) and direct competitors (e.g., Mexico) – prior to and after the 2005 MeBr ban using a spatial partial equilibrium model. To simulate post ban conditions, shifts in production technology and corresponding changes in production costs and monthly yields were assumed.[4] Model results suggested that following a ban, US consumers would pay higher prices for strawberries and consume fewer of them. The increased price of strawberries would outweigh increases in CA production costs for growers and, when coupled with increased acreage devoted to CA strawberry production, CA strawberry growers' gross and net revenues would increase and remain stable, respectively.

Goodhue et al. (2005) and Carter et al. (2005), on the other hand, suggested that MeBr phaseout could cause significant problems for US or California growers. The former included field trials to estimate weed control costs using MeBr and various available alternatives but were unable to estimate yield losses from the use of MeBr alternatives directly, and concluded that acreage and thus supply would have to decline significantly to raise market prices enough to eliminate the net losses to remaining growers. The latter note that a single annual demand elasticity parameterization obscures important variation in seasonal demand and supply functions and can bias estimates of losses downward, with the most significant losses accruing between mid May and early July. Their simulation results suggest full season losses of between 4 and 20% of revenue, with a point estimate of around 12%, excluding revenue realized from lower valued crops as acreage in strawberries decline. Neither study considered longer term trends in the fresh strawberry market.

The design of these studies reflected concerns that Mexico, which provided (and continues to provide) more than 99% of imported fresh strawberries to the US (ERS, 2010, Table 14), was an Article 5 country under the Montreal Protocol and thus not required to eliminate MeBr until 2015, at which point their MeBr use would also have to comply with CUE standards to be permitted. NAFTA rules would make it hard to shield US growers from Mexican competition. Rising costs to US producers forced to transition away from their preferred fumigant could make Mexican imports more competitive over more of the year, reducing market share and revenues to domestic growers. Carpenter, Gianessi, and Lynch (2000) projected that after the 2005 ban – exemptions notwithstanding – increased acreage in Mexico devoted to strawberry production would be observed, and in the absence of land and water constraints, Mexico would continue to increase acreage and displace acreage in California.

On the regulators side, there was concern that significant exemptions would slow the phaseout and increase lobbying efforts at the expense of efforts to develop and implement alternate fumigation strategies. Using even the lowest estimate of the cost burden of the elimination of MeBr for California strawberries growers from Norman (2005) of $51[5] ha/year suggests that diversion of funds to directly unproductive rent seeking around CUE rights could be significant; the 2011 industry survey indicates that 15,145 ha are planted in strawberries in California, and less than 5% of that land is devoted to organic production (CSC, 2011). This implies that delays in phaseout for conventionally grown berries could be worth more than $700,000 annually (15,145 × .95 × $51 $733,775), and any successful efforts to secure delays that cost less than this amount are profit maximizing for the industry as a whole.

The California Strawberry Commission (CSC), the most active industry group, doubled (nominal) federal lobbying expenditures from $40,000 in each of 2001–2007 to $80,000 in 2008, and expenditures have remained at that level through 2010 (Center for Responsive Politics, 2011). State nominal lobbying expenditures were about $30,000 for the 2001–2002 legislative session, as decisions about initial CUE applications were being made, and then dropped to around $3000 for the next session, rising for each subsequent legislature to a level of about $20,000 in 2009–2010 (CalAccess, 2011). It is likely, of course, that only some of these

[2] http://www.californiastrawberries.com.

[3] We focus on fresh berries throughout; in the US, frozen berries are largely a residual crop (ERS, 2011c), and as they are not perishable this market operates quite differently. Large increases in the share of production going for frozen or otherwise processed berries might suggest quality issues associated with various changes to fumigation processes, but we do not observe this in the data.

[4] The model assumes that the best alternative technology which is assumed to be the technology resulting in the highest yield per acre for the lowest cost per acre is selected. Given that the study was completed in 2000, the best technologies projected at the time do not entirely correspond to the alternatives actually employed during the phaseout.

[5] All figures converted to 2010 dollars using the CPI unless otherwise noted.

efforts were focused on preserving MeBr phaseout exemptions for growers. We were not able to find evidence of significant lobbying expenditures for strawberry growers in other regions. While lobbying expenditures are one indicator of lobbying efforts, the rapidity of regulatory movement – in this case, the reduction timeline – may also be suggestive. The reduction timeline in California has been much less aggressive than in other US regions, which no longer use MeBr for field strawberries, and more broadly, the reduction timeline in the US has been much less aggressive than other non Article 5 parties. Taken together, the lobbying expenditures and reduction timeline suggest that if lobbying has slowed the phaseout of methyl bromide for strawberries in CA, it has been a rational investment for the industry, even if the costs of using alternative pesticides are a relatively small fraction of revenues and profits.

The Critical Use Exemption process involves stakeholders who use the regulated chemical, national nominations, and recommendations or analysis by the Technology and Economic Assessment Panel (TEAP) of the Montreal Protocol, leading to final amounts which must be approved by the Parties to the Protocol at their annual meeting. In the US, the Environmental Protection Agency (EPA) solicits yearly applications with supporting information on use patterns and economic impacts from growers, and then the Department of State submits these as Critical Use Nominations (CUNs). For the last year for which data are available – the nominations and final decisions for 2012 exemptions – the CSC requested permits to treat 4454 ha, which were passed on to the Parties to the Montreal Protocol, who approved 4421 of those hectares, albeit at a lower application rate than was originally requested.[6] If this smaller amount receives the low estimate of value from continued use of MeBr, CA growers have gained about $225,000 in 2012 by securing the 2012 exemptions, as well as slowing further phaseout and broader price impacts until their chief competitor in the North American fresh strawberry industry completes their phaseout. At this point Mexican growers presumably lose any price advantage gained by ongoing MeBr use, and alternative pest control practices will be more established in California.

Interestingly, this approved MeBr fumigation allowance for about 30% of California acreage annually could mean use over the majority of the growing region on an intermittent basis. The CSC notes that "[m]ethyl bromide is often being used in rotation with alternative fumigants. Many growers will use alternative fumigants for 2–3 years then rotate back to methyl bromide to clean up emerging weed and disease problems" (California Strawberry Commission, 2008. *Request for a critical use exemption for methyl bromide on strawberries for the 2011 use season.* Cited in 2013 US Field Strawberries CUN). While a move towards using MeBr every 2–3 years rather than annually is certainly a substantial reduction in MeBr applications, it is not a reduction in the geographic area reliant on MeBr as part of strawberry production, and thus reflects less progress towards achieving a permanent phaseout than the reported reductions in acreage needing treatment would suggest. Unobserved cooperation within the industry to produce this outcome would undermine the intent of the Parties to the Protocol, particularly as it could allow the use of MeBr on fields put into production after the beginning of phaseout. In California, 2009 acreage represented an increase of 89%, or 7600 ha, over the 1991 'baseline' year established for MeBr under the Protocol (ERS, 2010, Table 4). It is not possible to determine if new acreage is using MeBr on the basis of allocations currently in use, as these are not broken out by sector or sub state geographic regions by the US EPA once exemptions are granted (Federal Register, 2011). While the United States did articulate a policy of not allowing growth in CUNs due to new acreage (UNEP, 2005), they did not specify that new acreage reliant on MeBr was not allowed even if it did not drive increasing total amounts of requested MeBr, and so the continued decline in CUNs for this sector seems to satisfy this domestic policy.

While lobbying efforts are ongoing, the CSC and other industry groups also work closely with farmers and researchers developing and testing MeBr free growing methods. CSC reports research expenditures of over ten million dollars to date toward this end, presumably beginning in the early to mid 1990s, which suggests that research expenditures are a substantial part of the CSC budget (calstrawberry.com). Additionally, within regional nomination applications, research expenditures and funding resources have historically been reported and used to substantiate nominations.[7] Sufficient data to elicit trends in those expenditures is not available. Overall, it seems reasonable to deduce that investment in new technology hedged by investment in lobbying for continued exemptions represents an effective risk management strategy for growers and has been an influential driver of industry and regulator decision making.

The political economic and sociological issues around agricultural exemptions to the MeBr phaseout have been studied extensively. Clark (2001) offers an early analysis of the relationship between growers, the state of California, and the Federal EPA. Badulescu and Baylis (2006) consider the harmonization of pesticide rules under NAFTA and the possibility that that process has favored US strawberry producers. Kent Monning (2007) raises concerns about the environmental justice implications of the use of the CUE process in California.

More recently, DuPuis and Gareau (2008); Gareau (2008, 2010, 2012) and Gareau and DuPuis (2009) argue in a series of papers that increasing pressure to provide market solutions rather than command and control ones – as evinced partly by the economic justification for exemptions to agreed phaseout schedules, which was not allowed for the previously established 'Essential Use Exemptions' granted for other ozone depleting substances in earlier stages of the Protocol – undermined the later stages of the Montreal Protocol. They further suggest that an emphasis on the credibility of estimates of private costs over estimates of public benefits will drive decision making about exemptions in the future, while in the past a precautionary principle approach to the human and environmental risks associated with ozone depleting substances was more important. Stakeholder processes have been 'captured' to a significant degree by industry groups rather than involving a broader group more focused on the welfare of civil society as a whole. That this mode of discourse is so dominant in US policymaking is thus offered as an explanation for the ongoing use of significant amounts of MeBr in the US when other countries granted early exemptions have completed phaseout.

[6] The 2013 nominations proved very contentious in 2011; additional bilateral (including with the CSC as well as with representatives of affected nations) and TEAP meetings were added to the schedule and multiple submissions were revised and new research offered during the process (UNEP, 2011a). The decision in the advance draft report of the 23rd Meeting of the Parties reflects the MBTOC (the Methyl Bromide Technical Options Committee, part of the TEAP) recommendation (a 2013 exemption of 461.186 metric tons for field strawberries) but not that of the minority report offered by several members of the MBTOC (UNEP, 2011a,b), which recommended granting the full nomination amount (531.737 metric tons). Application rates used to calculate CUNs and CUEs and the availability of alternative pesticides in specific California growing regions were disputed within the TEAP and among governmental and nongovernmental stakeholders.

[7] Publically reported research expenditure information is incomplete CSC has reported research expenditures as Confidential Business Information, and detailed expenditure data are not typically reported in regional nominations.

3. Progress and barriers in eliminating MeBr under the Montreal Protocol

For the first year of CUNs, 2005, 28 countries nominated critical uses. This number has declined steadily and most recently, four nominating parties (the US, Japan, Australia, and Canada) requested CUEs for 2013 (UNEP, 2011). Global CUEs for non Article 5 countries have decreased by 94% since 2005. Use in Article 5 countries has also declined, falling below total non Article 5 use for the first time in 2007. This decline is partly due to the support of phaseout programs paid for by the Protocol's Multilateral Fund, which is not available to non Article 5 countries. 2010 MeBr use in Article 5 countries was 5.2% of the 1991 baseline.

Nominations by the US and requests for nominations from the California Strawberry Commission between 2005 and 2014 are shown in Fig. 1. The US, which has had the slowest average annual rate of decrease in MeBr usage of non Article 5 countries using the CUE process, had nonetheless reduced CUN amounts by 78% from 2003 to 2013. Although the US has been accelerating the MeBr phaseout in recent years, with a large drop in the 2014 nomination, a complete phaseout has not been planned and it remains unclear when complete phaseout will be achieved.

Within the US, California is now the only state still requesting critical use exemptions for field strawberries. Porter et al. (2006) conducted a global meta analysis of strawberry yields based on hundreds of studies and found that many alternatives produce "statistically equivalent yields" to MeBr, and thus worked to undermine arguments for exemptions related to technical feasibility. The resistance to phaseout of MeBr in California has centered on technical issues but also on economic feasibility and uncertainties associated with the availability of alternative fumigants – namely iodomethane. Approval of iodomethane for use in California was predicted for 2003, and then 2005 (Carter et al., 2005), but it was not actually available for use until December 2010. The failure of California to permit the use of iodomethane was a key rationale for the ongoing exemption request in that state (UNEP, 2011); this is consistent with the US not decreasing its CUN request between the nominating years 2010 and 2011. Since the registration of iodomethane in the 2011 growing season, however, only one California strawberry grower has used it, and that usage was small in scale (Wozniacka et al., 2012).

The registration of iodomethane by the US Environmental Protection Agency and the California Department of Pesticide Regulation was controversial due to potential public and occupational health hazards resulting from its use in pre plant soil applications. After first denying registration of iodomethane in April 2006, the US EPA granted a one year registration in October 2007 and, by 2008, licensed iodomethane for sale and use in the US with some restrictions on its application. Most states – with California the most notable exception – quickly followed suit by registering the fumigant. California eventually did approve the sale and use of iodomethane, but with restrictions more stringent than those imposed by the US EPA and other states. Legal challenges to the approval of this fumigant are ongoing, and an ongoing dialogue with respect to concerns about the registration of iodomethane persists between the general public, the US EPA, the California state legislature, and the risk assessment community, including government scientists involved in assessing the risk of iodomethane, a neurotoxin and possible carcinogen (Urevich, 2011). In early 2012, while no legal ruling against the use of iodomethane was made, the manufacturer announced that, based on an internal review of the fumigant and its economic viability in the U.S. marketplace, they would no longer sell this alternative fumigant in the United States and withdrew its registration in California (Chawkins and Marcum, 2012; ALC, 2012).

4. California strawberries today

US strawberries had record production levels in 2009; production, real value per unit and the total real value of the fresh strawberry crop have risen every year since 2004 according to the USDA (ERS, 2010, Table 1). Real US cash receipts have risen in every year from 2005 to 2010, the last year reported (ERS, 2011a, Table A 8). As noted above, acreage in California has also increased according to each of several data series (California Agricultural Resource Directory, 2010 2011, CSC, 2011; ERS, 2010), contrary to the predictions of declining acreage in the Carter et al. (2005) work and consistent with Carpenter et al. (2000). The ERS data go back the farthest and show that harvested acres of California strawberries have increased steadily since 1970. An OLS linear regression of acreage on time for 2001–2009 data fits well and yields an estimated increase of 650 ha/year; regressions including the earlier decades also show positive and significant trends but do not fit the data as well, suggesting that the time trend alone is not as explanatory over longer periods. These data show acreage increases in every year since 1997, with the exception of 2007, when they declined by less than 1%. Additionally, the ERS data show that the share of California acres in US strawberry acreage has grown steadily over time, from less than a third of the total in the early eighties, to more than half by the mid 90s and rising over two thirds in 2006, where it remains.

Productivity of planted acres has also risen during this time period. ERS data on California yields from 1970 to 2009 show steadily increasing output per acre (ERS, 2010 Table 4). This trend continues for years subsequent to the onset of efforts to eliminate MeBr, though yields are, predictably, subject to weather and other conditions and thus more volatile than acreage. The share of California production in total domestic production has also grown over the time period covered, and has hovered around record highs of 88–89% since 2003. More recently, the Fruit and Tree Nuts report notes of 2010 that "last year, the increase in average yields per acre

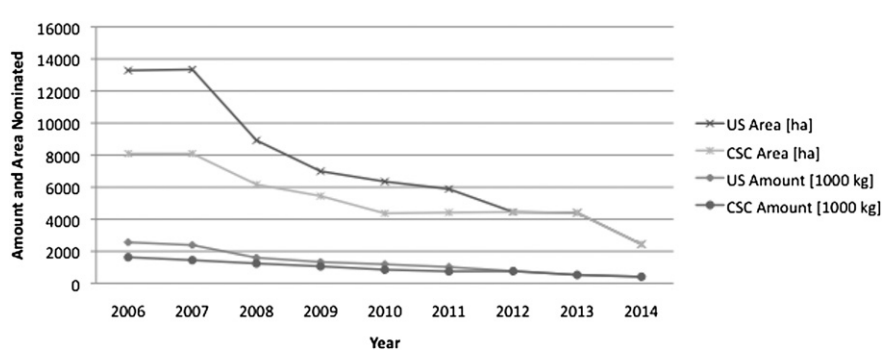

Fig. 1. US and California Critical Use Nominations, with MeBr requests and acreage.

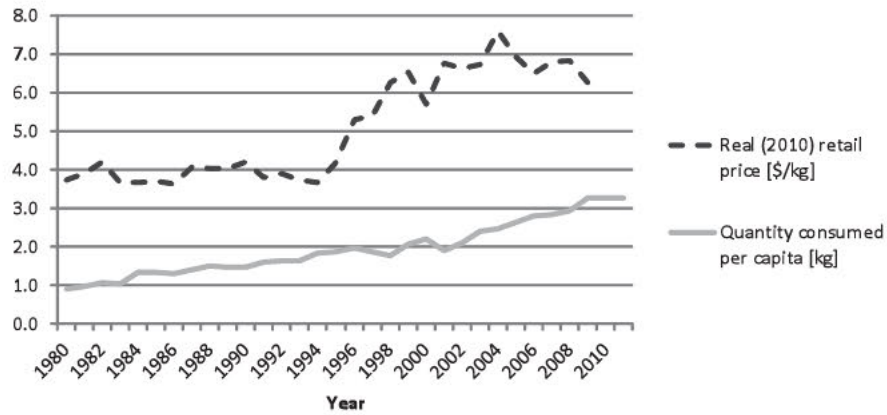

Fig. 2. US fresh strawberry prices and consumption.

in California (up 7 percent from 2009) more than made up for the decline in harvested acres (down 3 percent), resulting in a larger crop" (ERS, 2011c).

On the consumption side, we see that per capita consumption and total consumption of fresh and frozen strawberries continues to rise. In fact, per capita annual consumption of fresh strawberries has broken record levels in each year from 2003 to 2009 (ERS, 2011c; ERS, 2010, Table 12) even as real retail prices have stayed relatively stable or declined slightly. The most recent figures suggest an increase of 48% in per capita consumption of fresh berries since 2002, the last year covered in Norman (2005); with population growth that has amounted to a 67% increase in total US consumption over the same period. The continuing increase in per capita consumption as well as trends in real retail prices can be seen in Fig. 2.

We examine seasonal patterns in retail prices to evaluate hypotheses about patterns of trade raised in some of the ex ante studies discussed above. Real retail prices in June, the period identified by Carter et al. (2005) as most vulnerable to losses in a MeBr phaseout, rose in 5 of the 10 most recent years for which data are available (2000–2009). The average of real June retail prices from 2005 to 2009 was 1% higher than for 2000–2004, suggesting no significant change in the trend over time as a driver of this observation. Looking more closely, however, and in contrast with all but 3 of the preceding 24 years of available data, we note that for 2004–2008 May retail prices were higher than April prices, reversing again in 2009. Grower prices confirm this trend; for 2005–2011, May prices to growers for fresh berries were higher than April prices in 5 years and lower in two years (http://quickstats.nass.usda.gov).

While farming is subject to significant variability from year to year, both in the various growing regions domestically and abroad, this is suggestive of an increasingly competitive market in North America. Norman (2005) predicted that the pre 2005 gap between higher April prices and lower May prices was likely to decrease in size in the absence of methyl bromide. Ex post, we see that the gap has not just diminished but has reversed, while significant MeBr use continues. In the past, imports from Mexico peaked in April and domestic deliveries peaked in May or June. The historic drop in prices as domestic berries hit the markets in bulk suggested that exporting costs were high enough for Mexican growers that expanding exports during this period was relatively unattractive. In recent years, we have not observed a significant shift in strawberry acreage away from northern California growing areas, which deliver strawberries later in the season, and towards southern regions, where strawberries come in earlier (CSC, 2011), which might offer a domestic explanation for this shift in the pattern of relative prices throughout the year, so the currently observed pattern of relatively lower April prices is consistent with the US market becoming more attractive for Mexican growers wishing to export for more of the season or US growers facing rising costs in their peak production periods. It could also be that unobserved changes in crop timing associated with the use of MeBr alternatives have shifted the timing of peak deliveries in some parts of the state.

Investigating trends in imports and exports of fresh strawberries in more detail, however, does not provide strong supporting evidence for the hypothesis that increased Mexican imports are driving intra year changes in relative prices. Imports of fresh strawberries to the United States, almost exclusively from Mexico, have indeed grown substantially, continuing a trend observed well before MeBr restrictions began. They have more than doubled since 2004 (ERS, 2011b and Table G 1, ERS, 2011a). The share of Mexican imports in domestic consumption has changed less, however, trending slowly upward since the mid 1980s and now around 8%.[8] This may reflect increasing retail availability and consumption in the off seasons for domestic strawberries as well as increased April exports from Mexico.

United States exports also grew during this time, rising more than 50% from 2004 to 2010 (Table G 2, ERS, 2011a). The bulk of these exports go to Canada, which consumes considerably more strawberries than are produced there. The increase in tonnage of exports to Canada is very similar to the increase in imports from Mexico, suggesting that changing price patterns over time cannot be cleanly ascribed to trade advantages for Mexican growers selling in the United States. Domestic exports could well increase the scarcity of domestic berries at peak periods, driving domestic prices up. Strawberry exports do peak in May (ERS, 2011a, Tables G6–G8). Unfortunately, import and export data by month are only available for a few years, making it difficult to discern trends over time with confidence.

Also affecting trade patterns in North America may be the promulgation of Country of Origin Labeling (COOL) regulations in the United States (http://www.ams.usda.gov/AMSv1.0/COOL). For the 2009 and subsequent seasons all fresh strawberries sold in the United States were required to carry labels indicating where they were grown and packed. One expectation of supporters of this policy was that consumers would prefer domestic products over imports, and this may have reduced the vulnerability of California growers to cheaper imports from Mexico in particular. Carter and Zwane (2003) argue that this was in essence a (costly) protectionist policy. Van Ittersum et al. (2007) note that consumers may prefer domestic or local region products both because they believe them to be better or safer, or because they have a preference for

[8] Calculations based on ERS (2011b) yield slightly different shares than those given in ERS (October 2010, Table F-14).

supporting growers in geographic regions that they identify with. Either of these would help California growers and hurt Mexican exporters in the domestic market. While we cannot isolate any impact of this over the short period since the rules have been established, it remains clear that the majority of the US market continues to be served by domestic growers.

The MeBr alternative iodomethane has been approved for use in Mexico and a commercial launch there is planned for 2012 (ALC, 2010). As an Article 5 country, Mexico has until 2015 to phaseout MeBr under the Montreal Protocol; however, the government of Mexico has committed to completely phaseout methyl bromide by 2012 (UNEP, 2010),[9] by which point it seems likely that growers there will be able to use iodomethane and California growers will use continuing allocations of MeBr and any of several alternatives which show little to no yield changes in current research (summarized in USDoS, 2012). Costs for various production inputs and growing conditions will of course vary and be drivers of comparative advantage in international trade as with any commodity. It is unlikely that changes in land use in California or Mexico have been driven by an expectation of continued MeBr use in Mexico after it is curtailed in the United States.

Additionally, increases in imports may reflect changing trade advantages unrelated to MeBr phaseout in the United States. From 2002 to 2009, imports of Mexican lemons increased from negligible to a major trade commodity, increasing to 54 times initial levels. Avocados increased eleven fold, raspberries increased eight fold, pineapples were up 250%, and pecans and cocoanut meat also increased more rapidly than fresh strawberries. Tangerine, lime, and mango imports grew more slowly than strawberries but still rose significantly (ERS, 2011a, Table G 1). Trade changes driven by NAFTA or other drivers of increased globalization should not be ascribed to the ongoing MeBr phaseout without more substantial evidence than we are able to find.

5. California strawberry production cost estimates

Looking at the various sample budgets available from Cooperative Extension in California (UC Cooperative Extension, 2001a–c, 2004a–d, 2006, 2010, 2011a–b), we do not observe clear links between decreasing availability of MeBr and costs or profits. 2010 and earlier reports note that alternatives to MeBr are available and in use, but the sample budgets assume fumigation with MeBr and chloropicrin (or 'Pic'); Pic allows for significantly lower rates of MeBr application in areas where MeBr had previously been used alone. Of the two 2011 reports one notes that methyl bromide availability is limited and does not specify a fumigant in the line item budgets and the other uses Pic alone.

In the geographically central of the three largest growing regions, fumigation costs as a share of total costs were 2.4% in the 2001 sample budget, 3.7% in 2004, 3.5% in 2006 and 2.9% in 2011. For the same 3 years estimated net returns were 1.6, 14.2, 7.6, and 3.2% of total costs. In the main growing region to the south we have budgets for 2001, 2004, and 2011 which show a decline in fumigation costs as a share of the total, from 6.0 to 5.7 to 3.1%, while net returns increased from 9.5 to 13.4% and then dropped to 2.2%. In the northernmost growing region, budgets for 2001, 2004 and 2010 show increasing fumigation costs (5.2, 5.4 and 6.9% of total costs, respectively) and fluctuating net returns (6.6, 9.4 and 4.0%). These numbers offer some insights into input and production costs, in particular suggesting weakly declining fumigation costs and yielding some evidence of declining net revenues in the most recent years, but we note that the sample budgets are designed to offer a general understanding of costs and revenues using current methods rather than to support rigorous economic analysis.

Critical Use Nominations themselves are another source of data on trends in production costs and revenues. The nominations through 2013 give a baseline yield rate for fumigation with 100% methyl bromide and discount it by some fraction for each alternative pest control regime. While detailed budgets are not provided, annual CUNs for CUEs also include estimates of the economic impacts of MeBr as compared to alternatives.[10] These estimates are developed to support the case that additional exemptions to use MeBr in California are needed to avoid 'significant market disruption,' which is a key part of the standard established in Decision IX/6 of the Montreal Protocol to define a use as critical. Alternatives are shown with associated yield estimates and implied costs to producers facing changed yields and other practices. For 2006–2013 CUNs, the baseline MeBr yield estimates fluctuate a bit, dropping by around 15% from 2006 to 2008 levels in 2009–2010 and then rising again for 2011–2013 nominations. Reported yields per hectare are well below those reported in the sample budgets referenced above, typically around 40–50,000 kg/ha in recent CUNs, with some alternatives in the 30–40,000 range in earlier nominations, while first year strawberry yields in the sample budgets are around 60–80,000 kg/ha and the most recent second year yield reported is over 50,000 kg/ha (UC Cooperative Extension, 2011c). The yield loss associated with moving from MeBr to a mixture of 1,3 dichloropropene (1,3 D) and chloropicrin is steady at 14% throughout, suggesting that the loss rate estimate was not revised over time but simply applied to the MeBr number for a given year. This alternative is the only one included in every nomination[11]; metam sodium (MS) and a mixture of Pic and MS were excluded from 2010 to 2009, respectively, and a mixture of Pic and MeBr was not added until the 2010 nomination. Iodomethane is included for the first time in the 2013 nomination.

Projected strawberry prices drop by about 30% from 2010 to the 2011 nomination estimates, and they remain at this low level through the 2013 nomination. This price, $1.37/kilogram,[12] is well below current and recent reported grower receipts (ERS, 2010); it is not clear why recent nominations have used such a low baseline price. This price drop helps explain why the estimated value of MeBr use as opposed to 1,3 D+Pic can be relatively stable, ranging between $43–68 per kilogram for 2006–2013 nominations, while the figure for "percentage loss in net revenues" swings up to 1269% in 2011 and subsequent years, after previously being estimated at 55 and 87%. While the loss to net revenue is appealing as a proxy for disruption suffered by growers, the nominations note that the

[9] In 2008, Mexico's MeBr consumption was below consumption allowed under the Montreal Protocol. As of 2010, those implementing the National Methyl Bromide Phase-Out Plan for Mexico (the United Nations Industrial Development Organization (UNIDO) along with the governments of Italy, Spain, and Canada) intended to eliminate the remaining MeBr (approximately 900 ODP tonnes) by 2012, provided requested monies from the Multilateral Fund were received. The plan initially proposed that the strawberry sector convert near the end of the phaseout because "strawberry growers were reluctant to reduce MB consumption" (UNEP, 2010, p. 5). However, Mexico's strawberry growers have since requested immediate assistance in order to accelerate completion of the phaseout.

[10] These figures are all reported in nominal dollars, as the requests are filed a few years in advance of the proposed use, and do not specify nominal or real figures. Additionally, many of the numbers do not change from year to year, suggesting that the precision of the estimates is not such that deflating them should drive conclusions.

[11] It is worth noting that the 1,3-D mix is not available to all growers, as many California townships restrict 1,3-D use (Carpenter et al., 2001) and some counties restrict Pic application. This may be why the extension service budgets above exclude it, and this may also make it difficult to draw statewide conclusions on the basis of variation in yield estimates between 1,3-D alone and in combination and MeBr.

[12] The CUN itself reports 'units'; we believe these to be kilograms based on matching with previous California nominations.

required gross revenues less operating costs are "difficult to measure and verify" (USDoS, 2004–2011). Net revenues are sensitive to the implied change in gross revenues of much lower strawberry prices even in the absence of significant cost shifts, and smaller net revenues produce bigger percentage changes for a given nominal cost increase or yield decrease.

As this article was being finalized for publication, the 2014 Critical Use Nomination for field strawberries in California was made public. It requests 415 metric tonnes of MeBr for field strawberries, a bit over a 20% decline from the request for 2013. The drop in requested acreage to be treated is about 50%, suggesting decreasing use of MeBr in combination with other chemicals and thus at higher rates, while the baseline fumigant in the economic impact table is now a mixture of MeBr and Pic rather than MeBr alone. The economic impact analysis shows no yield losses for any alternative, a substantially higher output price for growers of $2.51 per unit, a roughly 60% increase in reported yields to nearly 80,000 kg/ha, and greatly reduced or even negative loss measures. The estimated loss or gain as a percentage of net revenue ranges from 9% (for an alternative using iodomethane) to 5% across all reported alternatives (USDoS, 2012). Chloropicrin alone yields an increase in net revenue of 2% relative to the baseline. Thus the key driver of the request is now the limited access in some specific areas to use of some of the alternative fumigants, or the requirement for buffer zones around schools and residential areas. However, the township caps that limit 1,3 D are being reached in regions where strawberry acreage has grown substantially since the US agreement to phaseout methyl bromide. It is difficult to argue that a sub state regulatory decision that limits the amount of acreage in all crops that can be treated with certain pesticides represents a substantial disruption of the California strawberry market due to the elimination of methyl bromide.

It is interesting to note that with the exception of the 2006–2008 nominations the economic impact estimates in the CUNs assume no price gap per unit produced using MeBr and using alternatives. Wolverton (2012) indicates that in 2006–2008 the change in prices was used to reflect anticipated planting delays and subsequent later deliveries of crops to market for growers using alternative fumigation practices rather than broader market impacts. Constant output prices across alternatives with significantly differing yields suggest that these economic impact estimates assume no market price responses to significant supply swings (including projected yield losses of up to 30% for California growers, which would certainly affect the domestic and North American markets), and thus do not account for the significant amount of any cost increase that will be passed along to consumers as the market reaches a new equilibrium price (see Norman, 2005 for detailed discussion of the impact of relatively inelastic consumer demand for fresh strawberries on market prices and the distribution of the burden of rising production costs). If all acres not receiving exemptions were using alternatives with substantially lower yields and similar or increased costs, we would expect market prices to rise and moderate reductions in profits.

While we do not observe profits directly in the way that we do acreage and revenues, it is difficult to reconcile the history of CUN figures for California yields and costs using alternatives with the increasing use of alternatives and the increasing yields per acre and increases in total acreage noted above. The continued expansion in acres noted above is not consistent with an industry facing large losses as the phaseout continues; basic economics tells us that rising profits attract entry into an industry and falling profits drive exit, as more remunerative investments are sought for the land and capital previously employed in the failing sector. It seems likely that modifications of farming practices in concert with the use of non iodomethane MeBr alternatives have been increasingly successful at preserving yields in those areas that are doing without MeBr either altogether or at least in some years. Input substitution as the price of fumigation relative to other inputs into the strawberry growing process rises – altered weeding practices or schedules, perhaps, or alternate cultivars or crop rotations – would be expected to lower the costs of compliance with the phaseout process. We have found no evidence suggesting zero input substitution characterizes this industry, and any substitutability across inputs will reduce cost burdens on growers. Learning by doing should also lower costs and gaps in yields across different pest control strategies over time, as growers and fumigation contractors become accustomed to using alternatives. Further and perhaps most significantly, it seems that the calculations used to support the granting of CUEs in this sector do not allow for the ability of growers to share cost increases with consumers, who may by their numbers and relatively inelastic demand bear the majority of any remaining burden without individually experiencing price increases as economically disruptive.

6. Additional drivers of change and trends

While per capita consumption of fresh berries by Americans has continued to rise since 2004, it is not obvious that this is driven by rising per capita incomes as earlier data suggested to Norman (2005). Mean and median household and per capita income trends were disrupted by the global recession, with US median household income falling in 2008, 2009 and 2010, mean household income falling in 2007, 2008, 2009 and 2010, and per capita income falling in 2009 and 2010 (Historical income tables, www.census.gov). With a relatively short data period to contend with and a lack of detailed information about changes in income distribution

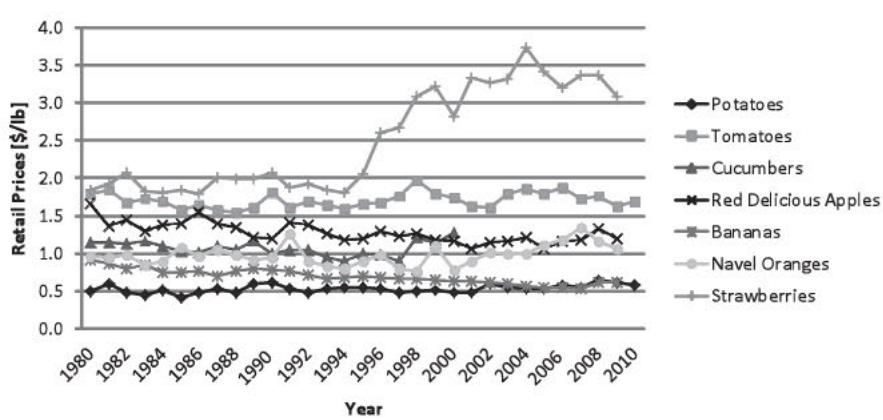

Fig. 3. US fruit and vegetable real retail prices.

and the relationship between income and strawberry consumption, disentangling trends in prices, consumption, and income to estimate relationships is imprecise.

One thing we do note in this market is that while prices of many fresh fruits and vegetables, including strawberries, have trended slightly downwards since 2008 (ERS, 2010 Table 12 and October 2011 Table A 7), over a longer time horizon, we observe a marked difference in fresh strawberry prices, which have increased by 85% from 1994 to 2008, compared to the prices of some other fruits and vegetables, which have largely been stable or increased to a much lesser extent (Fig. 3). Per capita consumption of fruits overall remained constant from 1994 to 2008, while per capita vegetable consumption initially increased from the mid 90s to 2000 but declined subsequently. This suggests that significantly increased strawberry consumption in the face of rising or stable prices in recent years is not likely to be driven by a decline in the price of strawberries relative to substitute fruits and vegetables. Changes in income, tastes, and preferences as well as the increased availability of strawberries at all times of the year are combining to support increased per capita and total strawberry consumption.

7. Conclusion

We offer an ex post analysis of the impact of the mandated phaseout process for methyl bromide on California strawberry growers to date. Ex ante estimates of the economic impact of the elimination of MeBr were required by and influential in the CUN and CUE processes, in contrast with either a benefit cost approach including public health and environmental protection gains, as required by many of the domestic environmental policies of Parties to the Montreal Protocol, or with the Essential Use Exemption process used for other ozone depleting substances eliminated earlier in the ozone protection regime. While this is not an ex post analysis of the originally expected complete phaseout, and thus cannot be directly compared with ex ante predictions based on the complete elimination of MeBr use, it does offer insight into the gap between predictions and outcomes of a strawberry industry moving away from this ozone depleting pesticide while facing import competition from a major trading partner with a more lenient phaseout schedule.

Contrary to many ex ante predictions and concerns expressed by stakeholders, California strawberry growers have thrived in recent years relative to both domestic and foreign competitors. They have successfully worked to ensure that MeBr has been available for significant fractions of their significantly expanded acreage, increased exports, and continued to enjoy rising yields and revenues as well as increased demand from consumers. The interim years between the planned elimination of MeBr and the increasing success of alternatives as detailed in the 2014 CUN and other reports have been years of expansion in the face of global recession and increased imports from Mexico, and successful navigation of technical and regulatory changes. Industry data suggests that the real burdens associated with changing agricultural practices have not kept this sector from profitability and growth in a challenging economic environment, though we cannot know how much faster growth might have been if MeBr use had continued unabated.

Alarming numbers in the CUNs sent to the Parties to the Montreal Protocol are not consistent with the success of California strawberry growers in aggregate as use of MeBr has been reduced. Nor are they consistent with basic economics. The 'economic disruption' standard of the CUE process was not intended to require the Parties to permit application of MeBr on new acreage to allow limitless expansion of a given industry using MeBr, and it is difficult to justify ongoing exemptions to support expansion rather than protect existing growers and growing regions. If all the new acres in production since 2005 are being managed profitably without MeBr, and existing acres are using less MeBr less often while overall and per acre yields and revenues rise steadily, it seems we have reached a point where alternatives are demonstrating successes for field strawberries in California.

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NATURAL RESOURCES DEFENSE COUNCIL

Testimony of David D. Doniger
Policy Director and Senior Attorney, Climate and Clean Air Program
Natural Resources Defense Council

Hearing on the U.S. Agricultural Sector Relief Act of 2012

Subcommittee on Energy and Power
Committee on Energy and Commerce
House of Representatives
July 18, 2012

Summary

- Protection of the ozone layer is a huge bi-partisan public health success story. The phase-out of ozone-destroying chemicals, including methyl bromide, is saving literally millions of Americans, and tens of millions of people around the world, from death and disease, from skin cancer, cataracts, and immune diseases. It is also saving farmers billions of dollars in UV-related crop losses.

- Now is not the time to tamper with the Montreal Protocol and the Clean Air Act. By slowing or even reversing the transition away from methyl bromide, "The U.S. Agricultural Sector Relief Act" will lead to more skin cancers, more cataracts, more immunological disease. It will benefit strawberry growers and others who have profited by abusing the "critical use exemption" for almost a decade. Thousands of other farmers growing other crops will suffer more UV-related crop losses as a result.

- Methyl bromide suppliers and users have dragged their feet on replacing this dangerous compound for two decades. No other industry has had more time and more leeway to transition from dangerous ozone-destroying chemicals.

- The United States is responsible for more than 90 percent of all methyl bromide exemptions. Every other strawberry- and tomato-growing country with California-like growing conditions – including Italy, Spain, Greece, and Australia – has ended use of methyl bromide. Mexican growers use less methyl bromide per acre than their California counterparts, and Mexico will end methyl bromide use entirely this year.

- California strawberry growers have done very well during the whole experience, according to a recent peer-reviewed economic study. Strawberry acreage is up 16% and yields are up 14% since 2004 despite significant reductions in methyl bromide allocations. So are U.S. grower prices and total crop values.

- U.S. critical use exemptions have been coming down. California strawberries are now the only field use for which the U.S. is still seeking critical use exemptions. Together with several structural and commodity uses, the total U.S. exemption request for 2014 is down to slightly more than 400 tons.

- The bill would do reckless damage in three major ways: First, it would permanently define as "critical uses" all of the uses that were labeled critical in 2005, even though the vast majority no longer even use methyl bromide. Absurdly, the bill would make even golf course turf grass a "critical use." It makes no sense to freeze into law an utterly out-dated list of "critical uses."

- Second, the bill relieves applicants of the need to show why they need exemptions. They could just submit their exemption wish lists without any supporting data. EPA then would bear the burden of gathering the data to support any reduction. Absent resources and data, EPA would have little choice but to forward the applicants' unsupported wish lists to the parties. This would be foolish even from the growers' perspective. It actually helps the U.S. government win approval for exemptions to have shown that it has exercised judgment and discipline in framing its requests, and has is not mechanically asked for everything its domestic applicants may have wanted.

- Third, the bill would blast an enormous new loophole into the Clean Air Act and our pesticide safety laws, by allowing any individual user to write his own ticket for up to 20 tons of methyl bromide

simply by asserting the existence of an "emergency." There could be a hundreds of emergency exemptions per year, totaling up to 2,000 tons per year (the 2011 critical use amount).

- This is a bad and unneeded bill. It would harm public health, harm other farmers, and indeed even harm the farmers it is intended to help. The process is working. This Committee should let well enough alone.

Thank you Chairman Whitfield and Ranking Member Rush for the opportunity to testify on behalf of the Natural Resources Defense Council on the proposed "U.S. Agricultural Sector Relief Act of 2012." Founded in 1970, NRDC is a national nonprofit environmental organization of scientist, lawyers, and environmental specialists with more than 1.3 million members and online activists, served from offices in New York, Washington, Chicago, San Francisco, Los Angeles, and Beijing. I am policy director of NRDC's Climate and Clean Air Program. I have been with NRDC twice, from 1978 through 1992 and from 2001 to the present. In the 1990's I served as director of climate change policy in the EPA Office of Air and Radiation. Relevant to the topic of today's hearing, I have worked on the phase-out of ozone-destroying chemicals for more than a quarter century.

There are few greater success stories than the global effort to phase out the ozone-damaging chemicals. Every American, and every citizen on this Earth, relies on the ozone layer to block dangerous ultraviolet radiation that causes skin cancer, cataracts, immune disorders and other diseases. The treaty to protect the ozone layer, known as the Montreal Protocol, has enjoyed bipartisan support from five presidents beginning with Ronald Reagan. So have the ozone layer protection provisions of the Clean Air Act. They are saving literally millions of Americans, and tens of millions of people around the world, from death and disease. They are also preventing billions of dollars in UV-related crop losses and other economic damages.

Yet the ozone shield is still being weakened by ozone-depleting chemicals that increase our exposure to dangerous UV radiation. Millions of Americans – including farmers – must work everyday in the sun. Millions more – from school children to seniors – spend hours of their days out of doors. Millions of concerned parents check the UV Index and cover their kids with sunscreen before letting them go out in the sun.

That brings us to methyl bromide. Methyl bromide is the most powerful ozone-depleter still in widespread use. All of the other more potent ozone-destroying chemicals have been successfully

eliminated – worldwide. Methyl bromide is also highly toxic, with inhalation or dermal exposure causing a wide range of acute and chronic effects, including death.

Mr. Chairman, I will not mince words. You are considering a bill to further slow the snail-like pace of the transition from this dangerous chemical – a bill that will lead to more skin cancers, more cataracts, more immunological disease, and more crop losses due to ozone-destruction and UV radiation, as well as more illness from direct exposure. Contrary to the bill's grandiose title, this bill will not broadly benefit "the U.S. agricultural sector." Indeed, thousands of farmers growing other crops will suffer more UV-related crop losses as a result. Instead, this bill will benefit only a small sliver of strawberry growers and few others who have profited handsomely by abusing the "critical use exemption" for the better part of a decade.

No industry has had more time and more leeway to transition from dangerous ozone-destroying chemicals than this one. The auto industry replaced CFCs in car air conditioners in less than four years. The electronics industry replaced ozone-depleting solvents in circuit board manufacture in less time than that. The air conditioning and refrigeration industry and the fire protection industry got rid of their potent ozone-depleters in well under a decade. Indeed, some of these industries have gone through two rounds of transitions to safer chemicals in the last 20 years. And all of these industries have been able to produce better, more energy-efficient, and more profitable products.

But methyl bromide stands apart. The producer and the users of this chemical have dragged their feet on replacing this dangerous compound for two decades. Let's review:

The phase-out of methyl bromide was supposed to be completed by 2001 pursuant to the 1990 Clean Air Act Amendments. With a decade of lead-time, growers and other users should have invested in developing and field testing other agents and other agricultural practices, like every other industry did. Their effort was minimal. And their minimal effort was rewarded by pushing the deadline back to 2005, in conjunction with amendments to the Montreal Protocol to phase out methyl bromide world-

wide. An post-2005 exemption was allowed for so-called "critical uses," but all observers then thought this would be just a small percentage of historical ("baseline") methyl bromide use, just as the "essential use" exemptions for other ozone-destroying chemicals had been only a small fraction of their baselines.

Indeed, other countries with comparable agricultural conditions played by those rules, submitting critical use exemption requests, if any at all, that reflected small fractions of their historical methyl bromide use levels. Only the U.S. took a different tack. In 2003, U.S. growers and others sought exemptions totaling some 15,000 tons, more than 60 percent of country's baseline use in the early 1990s. The U.S. government requested more than 10,000 tons of exemptions, and nearly broke the back of the Montreal Protocol. For the first time in its history, the parties were unable to come to a consensus decision. For the first time, there was an impasse that could not be resolved without calling an extraordinary meeting of the parties.

For eight years running, the United States alone has requested more than 90 percent of all exemptions. Over this period, nearly every other developed nation has eliminated its need for methyl bromide. Specifically, every other strawberry- and tomato-growing country with Mediterranean-like growing conditions – including Italy, Spain, Greece, and Australia – has moved beyond use of methyl bromide. Even Mexico – the California strawberry growers' only competitor – is committed to end its use of methyl bromide this year.[1]

Throughout this period, and here again today, the California strawberry growers have led the pack in coming to Congress playing the hardship violin. In fact, however, California strawberry growers have done very well during the whole experience, according to a recent peer-reviewed economic study by Erin N. Mayfield and Catherine Shelley Norman, published in the *Journal of Environmental*

[1] "The Government of Mexico has committed to achieve the complete phase-out of MB by the end of 2012." United Nations Environment Programme, Executive Committee of the Multilateral Fund for the Implementation of the Montreal Protocol, Sixty-sixth Meeting, Montreal, 16-20 April 2012, "Project Proposal: Mexico, National methyl bromide phase-out plan (third tranche), ¶9, http://www.multilateralfund.org/66/English/1/6641.pdf.

Management.[2] They have expanded their strawberry acreage and increased their yields dramatically despite significant reductions in methyl bromide allocations: California strawberry acreage in 2010 had increased 83 percent over 1991 levels and 16 percent over 2004. Yields per acre in 2010 increased 29 percent over 1991 levels and 14 percent over 2004. California's share of U.S. production also increased during this period, from about 80 percent in 1991 to more than 90 percent in 2010. U.S. grower prices and total crop values adjusted for inflation also increased during the exemption years.

The expansion of the strawberry acreage treated with methyl bromide is extremely troubling because it breaks a commitment made by the U.S. government not to allow such expansion. For instance, the "National Management Strategy for Methyl Bromide, United States of America, December 2005" states: "An important way that the United States addresses the issue of avoiding increases in MeBr use is our policy to disallow any increases in acreage or throughput that CUE applicants might include in their CUE request."[3] This turns out to have been a hollow promise.

The growers' complaints often center on the claim of unfair competition from Mexico. Throughout this period, however, Mexican growers used less methyl bromide per acre than their California counterparts, and Mexico, as I mentioned, has committed to stop using methyl bromide this year. Mayfield and Norman note that although strawberry imports from Mexico increased as the overall U.S. strawberry market grew, Mexico's share of total U.S. consumption did not increase significantly, and U.S. growers' strawberry exports to Canada rose by almost as much as imports from Mexico.

Mayfield and Norman also note that the economic analysis supporting the critical use nomination for 2014 – an analysis prepared by the strawberry growers – indicates that a range of alternatives to methyl bromide are effective and available at comparable cost and without yield losses.

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[2] E. Mayfield & C. Norman, *Moving away from methyl bromide: Political economy of pesticide transition for California strawberries since 2004,* Journal of Environmental Management, Vol. 106, Pp. 93-101 (2012), available at http://www.sciencedirect.com/science/article/pii/S0301479712001909, and attached to this testimony.
[3] http://www.epa.gov/ozone/mbr/downloads/MeBrNatMgmtStrat.pdf, p. 4.

Notably, these results do not depend on methyl iodide, which was withdrawn from the market by its manufacturer earlier this year.

As it turns out, the industry is still sitting on a stockpile of methyl bromide made before 2005 and stored in railroad cars in various communities around the country. Believe me, tank cars of highly toxic methyl bromide baking in the sun on rail sidings are not something I'd want in my community, or rolling through my Congressional district, yet few people know if they enjoy that privilege. As of today, the stockpile still exceeds 1,200 tons – three time the U.S. critical use nomination for 2014.

Why is the stockpile important? Because the rules of the road under the treaty are that a country may request permission to manufacture new methyl bromide to serve critical use needs only if it has exhausted its stockpiles. The industry attempted to conceal that stockpile from both the public and the government, and this led to the U.S. government's initially misrepresenting to the other Montreal Protocol parties in 2003 that there would be no stockpile left in 2005. But the true stockpile, divulged only later in response to an NRDC lawsuit, was nearly 13,000 tons – more than the entire amount the U.S. claimed to need for 2005. The methyl bromide stockpile has been used – illegally, in our view – for crops that no longer qualify as critical uses, such as golf course turf grass, and to exceed the critical use limits on crops such as strawberries. Each year since 2004, the stockpile has been larger than the next year's total critical use request. That is true for 2013 and 2014. The deception over the stockpile, once revealed, almost caused the breakdown of the treaty process, and the existence of a continuing stockpile is still a major irritant between the parties today.

NRDC acknowledges that the amounts of U.S. critical use exemptions have been coming down, however belatedly. Many growers and other users have finally taken up alternative chemicals and alternative pest management practices, so that we have now come to the point where the only field use for which a critical use nomination is still being made in 2014 is California strawberries. Together with several structural and commodity uses, the total U.S. exemption request is down to slightly more than

400 tons, as compared to nearly 10,000 tons in 2005. This progress, though long delayed, is noteworthy and must continue. Further progress is possible even in the short run, through practices such as greater use of impermeable films (something other countries have already adopted) and by continued adoption of alternatives.

In short, the process is working. Now is not the time to tamper with the methyl bromide phase-out requirements under Montreal Protocol and the Clean Air Act. Mr. Chairman, the bill before you would pointlessly weaken curbs on this dangerous ozone-destroying chemical, threaten the recovery of the ozone layer, and further strain our relations with other countries that are already experienced with U.S. abuse of critical use exemptions. The bill does reckless damage in at least three major ways:

First, the bill would permanently define as "critical uses" all of the uses that were labeled critical in 2005, regardless of the fact that the vast majority of those crops and applications have successfully transitioned to alternatives and no longer even use methyl bromide. Absurdly, the bill would make golf course turf grass a "critical use," even though the Bush administration's agriculture department dropped it from the list in 2006. Why in the world does it make sense to revive and freeze into law an utterly out-dated list of "critical uses"?

Second, since growers and other applicants are seeking exemptions for a chemical that is otherwise already banned under both domestic and international law, and since they are in the best position to innovate and test alternatives, they quite properly now bear the burden of showing the need for methyl bromide and the absence of economically practical alternatives. But the bill would turn that burden around. It would allow applicants to submit their wish lists for exemptions without providing any data in support. Even though this chemical is already supposed to be banned, the bill would then require EPA to shoulder the burden of developing the data to support any reduction from the growers' or other applicants' requests. As the growers would be quick to point out, EPA does not run farms, and EPA does not run alternatives testing programs.

Absent the resources and access to data, EPA would have little choice but to forward the applicants' wish lists to the parties for consideration. Even from the growers' perspective, this would be a fool's errand. It is difficult enough for the U.S. to gain approval for its out-sized exemption requests when it can bring a reasonably robust case forward for technical scrutiny by the other parties. It actually helps the U.S. win approval for exemptions to have shown that the government has exercised some judgment and discipline in framing its requests, and that the U.S. is not asking for everything its domestic applicants may have wanted.

Third, the bill would blast an enormous new loophole into the Clean Air Act and our pesticide safety laws, by allowing any individual user to write his own ticket for up to 20 tons of methyl bromide simply by asserting the existence of an emergency. "Emergency" is conveniently defined to mean any situation where someone wants to use more methyl bromide than is available under a critical use exemption, and where he declares that there is no alternative. The bill would allow a hundred 20-ton emergency exemptions per year, up to a total of 2,000 tons per year (the amount of critical use exemptions in 2011). This would be a massive abuse of the emergency exemption provision under the Montreal Protocol, which has been invoked only twice so far (once by Australia and once by Canada) in genuine emergencies.

Imagine, Mr. Chairman, how cool it would be to be able to withdraw more cash from the bank than you have in your account, just by calling it an emergency. There's another name for that: bank robbery.

This is a bad bill, and an unneeded bill. It would harm public health, harm other farmers, and indeed even harm the farmers it is intended to help. The process is working. This Committee should let well enough alone.

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Moving away from methyl bromide: Political economy of pesticide transition for California strawberries since 2004

Erin N. Mayfield [a], Catherine Shelley Norman [a,b,*]

[a] Department of Geography and Environmental Engineering, The Johns Hopkins University, 3400 North Charles Street, Baltimore, MD 21218, USA
[b] Department of Economics, The Johns Hopkins University, 3400 North Charles Street, Baltimore, MD 21218, USA

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ABSTRACT

We examine the progress of the phaseout of the use of the pesticide methyl bromide in the production of California field strawberries. This phaseout is required under the Montreal Protocol and has been contentious in this sector, which receives exemptions from the schedule initially agreed under the treaty, and in international negotiations over the future of the Protocol. We examine the various ex ante predictions of the impacts on growers, consumers and trade patterns in light of several years of declining allocations under the Critical Use provisions of the Protocol and the 2010 approval of iodomethane for use in California and subsequent 2012 withdrawal of this alternative from the US market. We find that, contrary to ex ante industry claims, the years of declining methyl bromide use have been years of rising yields, acreage, exports, revenues and market share for California growers, even when faced with a global recession and increased imports from Mexican growers who retain the right to use the chemical under the Protocol. This has implications for the Protocol as a whole and for the remainder of the US phaseout of this chemical in particular.

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1. Introduction and background

US fruit and vegetable growers using the fumigant methyl bromide (MeBr), scheduled for phaseout under the Montreal Protocol on Substances that Deplete the Ozone Layer, faced uncertainty about the cost and effectiveness of alternative chemicals and practices, and many of them applied for exemptions allowing continued use after the planned elimination of MeBr. This process was controversial – so much so that the United States suggested that they might withdraw from the Montreal Protocol, up to that point considered a model of successful international environmental policy, if their nominations for exemptions were not granted (Gareau and DuPuis, 2009). In the exemption process, which allowed exceptions to the scheduled 2005 complete phaseout date, one of the most contested uses was for strawberry farming, especially in California where many alternatives are strictly regulated or disallowed. Growers argued that none of the alternatives met the 'economic and technical feasibility' conditions of the Critical Use Exemption (CUE) rules. DeCanio and Norman (2005) discuss possible interpretations of the feasibility criteria at length, emphasizing that it cannot mean that no changes in costs or agricultural practices are required of methyl bromide users, but there is not a consensus definition of precisely what standard must be met.

Currently, the majority of CUEs for methyl bromide are allocated to the United States.[1] The share of field (rather than nursery) strawberries in total exemption requests has also grown; the 2014 US field strawberries nomination was for over 93% of the total US allocation, and was exclusively for use in California, which produces 90% of US strawberries (ERS, 2011c). In 2007 the same share was only 13% and more geographically dispersed, including uses in the southeastern US as well as California (USDoS, 2010, 2005, ozone.unep.org). Substitutes have been slower to develop in California,

* Corresponding author. Department of Geography and Environmental Engineering, The Johns Hopkins University, 3400 North Charles Street, Baltimore, MD 21218, USA. Tel.: +1 410 516 5184; fax: +1 410 516 8996.
E-mail addresses: erin.noel.mayfield@gmail.com (E.N. Mayfield), norman@jhu.edu (C.S. Norman).

[1] For the last seven years reported, 2007 2013, approved US CUEs have been more than 75% of non-Article 5 exemptions approved globally, so US strawberry uses are a significant amount of remaining global use of MeBr. In the first year of the exemption process, US allowances were a bit over 40% of total non-Article 5 allocations. For 2013, the United States has received over 90% of approved CUE allowances. Article 5 parties, which are, roughly speaking, less developed countries, do not have to complete phaseout until 2015, but their total use peaked in 1998, and by 2010 total consumption in Article 5 and non-Article 5 countries were approximately equal (exclusive of quarantine and pre-shipment uses, which are regulated separately and excluded from the discussion throughout this paper) (ozone.unep.org).

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due to different farming practices and a relatively stringent regulatory climate that has slowed the approval of some MeBr alternatives. The California strawberry crop is worth more than $2 billion annually and is the 6th highest valued fruit crop in the state, so while the industry is small at the national level it is economically significant in the region.[2]

California growers and those negotiating the CUE process on their behalf were deeply concerned that the main source of US imports of fresh strawberries, Mexico, would not be required to eliminate the use of MeBr at the same time that California growers were scheduled to. The Montreal Protocol allows delays in the elimination of ozone depleting substances for less developed countries, and growers feared that lowered trade barriers under NAFTA would combine with a technological advantage to Mexican growers using the fumigant, leading to dramatically increased imports of fresh strawberries and reduced sales of and/or prices for domestic berries.

This work investigates how the process of phaseout has affected the California field strawberry industry and finds that management and regulatory decisions at the international, national, and state levels have allowed California growers to maintain and enhance their dominance in the domestic and North American market as the phaseout has progressed. The period between the beginning of the methyl bromide phaseout and the availability of iodomethane, the closest thing to a 'drop in' substitute yet developed, for use in the state has been characterized by slow elimination of MeBr, rising acreage, yields and consumption, improved balance of trade, increasing domestic market share, and rising or relatively stable prices. Iodomethane itself has recently been voluntarily withdrawn from the US market, and we consider how this might affect our assessment of the phaseout process to date.

2. Ex-ante analyses of economic effects and political factors influencing phaseout

Economic analyses earlier in the process did not reach a consensus regarding the likely impacts of phaseout. Norman (2005) relied heavily on data from nominations for CUEs and found that trends in demand growth for fresh strawberries[3] and significant pass through of cost increases to consumers were expected to outweigh the stated negative effects of production cost increases associated with use of alternative fumigants, even in the absence of direct government support, under fairly conservative assumptions, and that increased consumer costs per household would be minimal, even if they were substantial in aggregate.

Carpenter et al. (2000) simulated production, consumption, and crop prices for methyl bromide users (e.g., California) and direct competitors (e.g., Mexico) – prior to and after the 2005 MeBr ban using a spatial partial equilibrium model. To simulate post ban conditions, shifts in production technology and corresponding changes in production costs and monthly yields were assumed.[4] Model results suggested that following a ban, US consumers would pay higher prices for strawberries and consume fewer of them. The increased price of strawberries would outweigh increases in CA production costs for growers and, when coupled with increased acreage devoted to CA strawberry production, CA strawberry growers' gross and net revenues would increase and remain stable, respectively.

Goodhue et al. (2005) and Carter et al. (2005), on the other hand, suggested that MeBr phaseout could cause significant problems for US or California growers. The former included field trials to estimate weed control costs using MeBr and various available alternatives but were unable to estimate yield losses from the use of MeBr alternatives directly, and concluded that acreage and thus supply would have to decline significantly to raise market prices enough to eliminate the net losses to remaining growers. The latter note that a single annual demand elasticity parameterization obscures important variation in seasonal demand and supply functions and can bias estimates of losses downward, with the most significant losses accruing between mid May and early July. Their simulation results suggest full season losses of between 4 and 20% of revenue, with a point estimate of around 12%, excluding revenue realized from lower valued crops as acreage in strawberries decline. Neither study considered longer term trends in the fresh strawberry market.

The design of these studies reflected concerns that Mexico, which provided (and continues to provide) more than 99% of imported fresh strawberries to the US (ERS, 2010, Table 14), was an Article 5 country under the Montreal Protocol and thus not required to eliminate MeBr until 2015, at which point their MeBr use would also have to comply with CUE standards to be permitted. NAFTA rules would make it hard to shield US growers from Mexican competition. Rising costs to US producers forced to transition away from their preferred fumigant could make Mexican imports more competitive over more of the year, reducing market share and revenues to domestic growers. Carpenter, Gianessi, and Lynch (2000) projected that after the 2005 ban – exemptions notwithstanding – increased acreage in Mexico devoted to strawberry production would be observed, and in the absence of land and water constraints, Mexico would continue to increase acreage and displace acreage in California.

On the regulators side, there was concern that significant exemptions would slow the phaseout and increase lobbying efforts at the expense of efforts to develop and implement alternate fumigation strategies. Using even the lowest estimate of the cost burden of the elimination of MeBr for California strawberries growers from Norman (2005) of $51[5] ha/year suggests that diversion of funds to directly unproductive rent seeking around CUE rights could be significant; the 2011 industry survey indicates that 15,145 ha are planted in strawberries in California, and less than 5% of that land is devoted to organic production (CSC, 2011). This implies that delays in phaseout for conventionally grown berries could be worth more than $700,000 annually (15,145 × .95 × $51 $733,775), and any successful efforts to secure delays that cost less than this amount are profit maximizing for the industry as a whole.

The California Strawberry Commission (CSC), the most active industry group, doubled (nominal) federal lobbying expenditures from $40,000 in each of 2001–2007 to $80,000 in 2008, and expenditures have remained at that level through 2010 (Center for Responsive Politics, 2011). State nominal lobbying expenditures were about $30,000 for the 2001–2002 legislative session, as decisions about initial CUE applications were being made, and then dropped to around $3000 for the next session, rising for each subsequent legislature to a level of about $20,000 in 2009–2010 (CalAccess, 2011). It is likely, of course, that only some of these

[2] http://www.californiastrawberries.com.

[3] We focus on fresh berries throughout; in the US, frozen berries are largely a residual crop (ERS, 2011c), and as they are not perishable this market operates quite differently. Large increases in the share of production going for frozen or otherwise processed berries might suggest quality issues associated with various changes to fumigation processes, but we do not observe this in the data.

[4] The model assumes that the best alternative technology which is assumed to be the technology resulting in the highest yield per acre for the lowest cost per acre is selected. Given that the study was completed in 2000, the best technologies projected at the time do not entirely correspond to the alternatives actually employed during the phaseout.

[5] All figures converted to 2010 dollars using the CPI unless otherwise noted.

efforts were focused on preserving MeBr phaseout exemptions for growers. We were not able to find evidence of significant lobbying expenditures for strawberry growers in other regions. While lobbying expenditures are one indicator of lobbying efforts, the rapidity of regulatory movement – in this case, the reduction timeline – may also be suggestive. The reduction timeline in California has been much less aggressive than in other US regions, which no longer use MeBr for field strawberries, and more broadly, the reduction timeline in the US has been much less aggressive than other non Article 5 parties. Taken together, the lobbying expenditures and reduction timeline suggest that if lobbying has slowed the phaseout of methyl bromide for strawberries in CA, it has been a rational investment for the industry, even if the costs of using alternative pesticides are a relatively small fraction of revenues and profits.

The Critical Use Exemption process involves stakeholders who use the regulated chemical, national nominations, and recommendations or analysis by the Technology and Economic Assessment Panel (TEAP) of the Montreal Protocol, leading to final amounts which must be approved by the Parties to the Protocol at their annual meeting. In the US, the Environmental Protection Agency (EPA) solicits yearly applications with supporting information on use patterns and economic impacts from growers, and then the Department of State submits these as Critical Use Nominations (CUNs). For the last year for which data are available – the nominations and final decisions for 2012 exemptions – the CSC requested permits to treat 4454 ha, which were passed on to the Parties to the Montreal Protocol, who approved 4421 of those hectares, albeit at a lower application rate than was originally requested.[6] If this smaller amount receives the low estimate of value from continued use of MeBr, CA growers have gained about $225,000 in 2012 by securing the 2012 exemptions, as well as slowing further phaseout and broader price impacts until their chief competitor in the North American fresh strawberry industry completes their phaseout. At this point Mexican growers presumably lose any price advantage gained by ongoing MeBr use, and alternative pest control practices will be more established in California.

Interestingly, this approved MeBr fumigation allowance for about 30% of California acreage annually could mean use over the majority of the growing region on an intermittent basis. The CSC notes that "[m]ethyl bromide is often being used in rotation with alternative fumigants. Many growers will use alternative fumigants for 2–3 years then rotate back to methyl bromide to clean up emerging weed and disease problems" (California Strawberry Commission, 2008. *Request for a critical use exemption for methyl bromide on strawberries for the 2011 use season.* Cited in 2013 US Field Strawberries CUN). While a move towards using MeBr every 2–3 years rather than annually is certainly a substantial reduction in MeBr applications, it is not a reduction in the geographic area reliant on MeBr as part of strawberry production, and thus reflects less progress towards achieving a permanent phaseout than the reported reductions in acreage needing treatment would suggest. Unobserved cooperation within the industry to produce this outcome would undermine the intent of the Parties to the Protocol, particularly as it could allow the use of MeBr on fields put into production after the beginning of phaseout. In California, 2009 acreage represented an increase of 89%, or 7600 ha, over the 1991 'baseline' year established for MeBr under the Protocol (ERS, 2010, Table 4). It is not possible to determine if new acreage is using MeBr on the basis of allocations currently in use, as these are not broken out by sector or sub state geographic regions by the US EPA once exemptions are granted (Federal Register, 2011). While the United States did articulate a policy of not allowing growth in CUNs due to new acreage (UNEP, 2005), they did not specify that new acreage reliant on MeBr was not allowed even if it did not drive increasing total amounts of requested MeBr, and so the continued decline in CUNs for this sector seems to satisfy this domestic policy.

While lobbying efforts are ongoing, the CSC and other industry groups also work closely with farmers and researchers developing and testing MeBr free growing methods. CSC reports research expenditures of over ten million dollars to date toward this end, presumably beginning in the early to mid 1990s, which suggests that research expenditures are a substantial part of the CSC budget (calstrawberry.com). Additionally, within regional nomination applications, research expenditures and funding resources have historically been reported and used to substantiate nominations.[7] Sufficient data to elicit trends in those expenditures is not available. Overall, it seems reasonable to deduce that investment in new technology hedged by investment in lobbying for continued exemptions represents an effective risk management strategy for growers and has been an influential driver of industry and regulator decision making.

The political economic and sociological issues around agricultural exemptions to the MeBr phaseout have been studied extensively. Clark (2001) offers an early analysis of the relationship between growers, the state of California, and the Federal EPA. Badulescu and Baylis (2006) consider the harmonization of pesticide rules under NAFTA and the possibility that that process has favored US strawberry producers. Kent Monning (2007) raises concerns about the environmental justice implications of the use of the CUE process in California.

More recently, DuPuis and Gareau (2008); Gareau (2008, 2010, 2012) and Gareau and DuPuis (2009) argue in a series of papers that increasing pressure to provide market solutions rather than command and control ones – as evinced partly by the economic justification for exemptions to agreed phaseout schedules, which was not allowed for the previously established 'Essential Use Exemptions' granted for other ozone depleting substances in earlier stages of the Protocol – undermined the later stages of the Montreal Protocol. They further suggest that an emphasis on the credibility of estimates of private costs over estimates of public benefits will drive decision making about exemptions in the future, while in the past a precautionary principle approach to the human and environmental risks associated with ozone depleting substances was more important. Stakeholder processes have been 'captured' to a significant degree by industry groups rather than involving a broader group more focused on the welfare of civil society as a whole. That this mode of discourse is so dominant in US policymaking is thus offered as an explanation for the ongoing use of significant amounts of MeBr in the US when other countries granted early exemptions have completed phaseout.

[6] The 2013 nominations proved very contentious in 2011; additional bilateral (including with the CSC as well as with representatives of affected nations) and TEAP meetings were added to the schedule and multiple submissions were revised and new research offered during the process (UNEP, 2011a). The decision in the advance draft report of the 23rd Meeting of the Parties reflects the MBTOC (the Methyl Bromide Technical Options Committee, part of the TEAP) recommendation (a 2013 exemption of 461.186 metric tons for field strawberries) but not that of the minority report offered by several members of the MBTOC (UNEP, 2011a,b), which recommended granting the full nomination amount (531.737 metric tons). Application rates used to calculate CUNs and CUEs and the availability of alternative pesticides in specific California growing regions were disputed within the TEAP and among governmental and nongovernmental stakeholders.

[7] Publically reported research expenditure information is incomplete CSC has reported research expenditures as Confidential Business Information, and detailed expenditure data are not typically reported in regional nominations.

3. Progress and barriers in eliminating MeBr under the Montreal Protocol

For the first year of CUNs, 2005, 28 countries nominated critical uses. This number has declined steadily and most recently, four nominating parties (the US, Japan, Australia, and Canada) requested CUEs for 2013 (UNEP, 2011). Global CUEs for non Article 5 countries have decreased by 94% since 2005. Use in Article 5 countries has also declined, falling below total non Article 5 use for the first time in 2007. This decline is partly due to the support of phaseout programs paid for by the Protocol's Multilateral Fund, which is not available to non Article 5 countries. 2010 MeBr use in Article 5 countries was 5.2% of the 1991 baseline.

Nominations by the US and requests for nominations from the California Strawberry Commission between 2005 and 2014 are shown in Fig. 1. The US, which has had the slowest average annual rate of decrease in MeBr usage of non Article 5 countries using the CUE process, had nonetheless reduced CUN amounts by 78% from 2003 to 2013. Although the US has been accelerating the MeBr phaseout in recent years, with a large drop in the 2014 nomination, a complete phaseout has not been planned and it remains unclear when complete phaseout will be achieved.

Within the US, California is now the only state still requesting critical use exemptions for field strawberries. Porter et al. (2006) conducted a global meta analysis of strawberry yields based on hundreds of studies and found that many alternatives produce "statistically equivalent yields" to MeBr, and thus worked to undermine arguments for exemptions related to technical feasibility. The resistance to phaseout of MeBr in California has centered on technical issues but also on economic feasibility and uncertainties associated with the availability of alternative fumigants – namely iodomethane. Approval of iodomethane for use in California was predicted for 2003, and then 2005 (Carter et al., 2005), but it was not actually available for use until December 2010. The failure of California to permit the use of iodomethane was a key rationale for the ongoing exemption request in that state (UNEP, 2011); this is consistent with the US not decreasing its CUN request between the nominating years 2010 and 2011. Since the registration of iodomethane in the 2011 growing season, however, only one California strawberry grower has used it, and that usage was small in scale (Wozniacka et al., 2012).

The registration of iodomethane by the US Environmental Protection Agency and the California Department of Pesticide Regulation was controversial due to potential public and occupational health hazards resulting from its use in pre plant soil applications. After first denying registration of iodomethane in April 2006, the US EPA granted a one year registration in October 2007 and, by 2008, licensed iodomethane for sale and use in the US with some restrictions on its application. Most states – with California the most notable exception – quickly followed suit by registering the fumigant. California eventually did approve the sale and use of iodomethane, but with restrictions more stringent than those imposed by the US EPA and other states. Legal challenges to the approval of this fumigant are ongoing, and an ongoing dialogue with respect to concerns about the registration of iodomethane persists between the general public, the US EPA, the California state legislature, and the risk assessment community, including government scientists involved in assessing the risk of iodomethane, a neurotoxin and possible carcinogen (Urevich, 2011). In early 2012, while no legal ruling against the use of iodomethane was made, the manufacturer announced that, based on an internal review of the fumigant and its economic viability in the U.S. marketplace, they would no longer sell this alternative fumigant in the United States and withdrew its registration in California (Chawkins and Marcum, 2012; ALC, 2012).

4. California strawberries today

US strawberries had record production levels in 2009; production, real value per unit and the total real value of the fresh strawberry crop have risen every year since 2004 according to the USDA (ERS, 2010, Table 1). Real US cash receipts have risen in every year from 2005 to 2010, the last year reported (ERS, 2011a, Table A 8). As noted above, acreage in California has also increased according to each of several data series (California Agricultural Resource Directory, 2010 2011, CSC, 2011; ERS, 2010), contrary to the predictions of declining acreage in the Carter et al. (2005) work and consistent with Carpenter et al. (2000). The ERS data go back the farthest and show that harvested acres of California strawberries have increased steadily since 1970. An OLS linear regression of acreage on time for 2001–2009 data fits well and yields an estimated increase of 650 ha/year; regressions including the earlier decades also show positive and significant trends but do not fit the data as well, suggesting that the time trend alone is not as explanatory over longer periods. These data show acreage increases in every year since 1997, with the exception of 2007, when they declined by less than 1%. Additionally, the ERS data show that the share of California acres in US strawberry acreage has grown steadily over time, from less than a third of the total in the early eighties, to more than half by the mid 90s and rising over two thirds in 2006, where it remains.

Productivity of planted acres has also risen during this time period. ERS data on California yields from 1970 to 2009 show steadily increasing output per acre (ERS, 2010 Table 4). This trend continues for years subsequent to the onset of efforts to eliminate MeBr, though yields are, predictably, subject to weather and other conditions and thus more volatile than acreage. The share of California production in total domestic production has also grown over the time period covered, and has hovered around record highs of 88–89% since 2003. More recently, the Fruit and Tree Nuts report notes of 2010 that "last year, the increase in average yields per acre

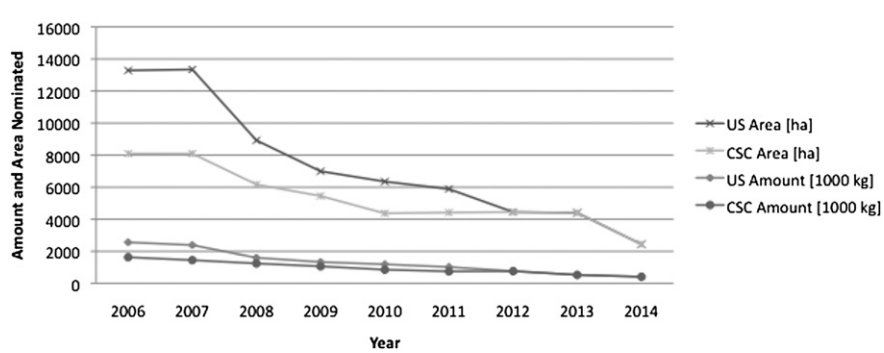

Fig. 1. US and California Critical Use Nominations, with MeBr requests and acreage.

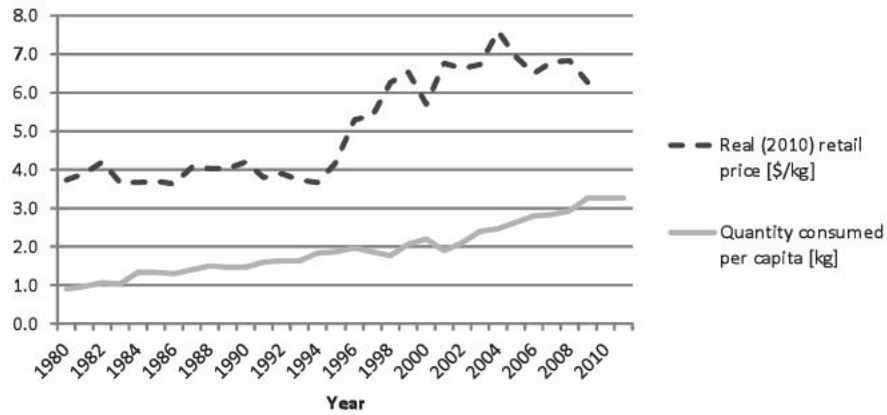

Fig. 2. US fresh strawberry prices and consumption.

in California (up 7 percent from 2009) more than made up for the decline in harvested acres (down 3 percent), resulting in a larger crop" (ERS, 2011c).

On the consumption side, we see that per capita consumption and total consumption of fresh and frozen strawberries continues to rise. In fact, per capita annual consumption of fresh strawberries has broken record levels in each year from 2003 to 2009 (ERS, 2011c; ERS, 2010, Table 12) even as real retail prices have stayed relatively stable or declined slightly. The most recent figures suggest an increase of 48% in per capita consumption of fresh berries since 2002, the last year covered in Norman (2005); with population growth that has amounted to a 67% increase in total US consumption over the same period. The continuing increase in per capita consumption as well as trends in real retail prices can be seen in Fig. 2.

We examine seasonal patterns in retail prices to evaluate hypotheses about patterns of trade raised in some of the ex ante studies discussed above. Real retail prices in June, the period identified by Carter et al. (2005) as most vulnerable to losses in a MeBr phaseout, rose in 5 of the 10 most recent years for which data are available (2000–2009). The average of real June retail prices from 2005 to 2009 was 1% higher than for 2000–2004, suggesting no significant change in the trend over time as a driver of this observation. Looking more closely, however, and in contrast with all but 3 of the preceding 24 years of available data, we note that for 2004–2008 May retail prices were higher than April prices, reversing again in 2009. Grower prices confirm this trend; for 2005–2011, May prices to growers for fresh berries were higher than April prices in 5 years and lower in two years (http://quickstats.nass.usda.gov).

While farming is subject to significant variability from year to year, both in the various growing regions domestically and abroad, this is suggestive of an increasingly competitive market in North America. Norman (2005) predicted that the pre 2005 gap between higher April prices and lower May prices was likely to decrease in size in the absence of methyl bromide. Ex post, we see that the gap has not just diminished but has reversed, while significant MeBr use continues. In the past, imports from Mexico peaked in April and domestic deliveries peaked in May or June. The historic drop in prices as domestic berries hit the markets in bulk suggested that exporting costs were high enough for Mexican growers that expanding exports during this period was relatively unattractive. In recent years, we have not observed a significant shift in strawberry acreage away from northern California growing areas, which deliver strawberries later in the season, and towards southern regions, where strawberries come in earlier (CSC, 2011), which might offer a domestic explanation for this shift in the pattern of relative prices throughout the year, so the currently observed pattern of relatively lower April prices is consistent with the US market becoming more attractive for Mexican growers wishing to export for more of the season or US growers facing rising costs in their peak production periods. It could also be that unobserved changes in crop timing associated with the use of MeBr alternatives have shifted the timing of peak deliveries in some parts of the state.

Investigating trends in imports and exports of fresh strawberries in more detail, however, does not provide strong supporting evidence for the hypothesis that increased Mexican imports are driving intra year changes in relative prices. Imports of fresh strawberries to the United States, almost exclusively from Mexico, have indeed grown substantially, continuing a trend observed well before MeBr restrictions began. They have more than doubled since 2004 (ERS, 2011b and Table G 1, ERS, 2011a). The share of Mexican imports in domestic consumption has changed less, however, trending slowly upward since the mid 1980s and now around 8%.[8] This may reflect increasing retail availability and consumption in the off seasons for domestic strawberries as well as increased April exports from Mexico.

United States exports also grew during this time, rising more than 50% from 2004 to 2010 (Table G 2, ERS, 2011a). The bulk of these exports go to Canada, which consumes considerably more strawberries than are produced there. The increase in tonnage of exports to Canada is very similar to the increase in imports from Mexico, suggesting that changing price patterns over time cannot be cleanly ascribed to trade advantages for Mexican growers selling in the United States. Domestic exports could well increase the scarcity of domestic berries at peak periods, driving domestic prices up. Strawberry exports do peak in May (ERS, 2011a, Tables G6–G8). Unfortunately, import and export data by month are only available for a few years, making it difficult to discern trends over time with confidence.

Also affecting trade patterns in North America may be the promulgation of Country of Origin Labeling (COOL) regulations in the United States (http://www.ams.usda.gov/AMSv1.0/COOL). For the 2009 and subsequent seasons all fresh strawberries sold in the United States were required to carry labels indicating where they were grown and packed. One expectation of supporters of this policy was that consumers would prefer domestic products over imports, and this may have reduced the vulnerability of California growers to cheaper imports from Mexico in particular. Carter and Zwane (2003) argue that this was in essence a (costly) protectionist policy. Van Ittersum et al. (2007) note that consumers may prefer domestic or local region products both because they believe them to be better or safer, or because they have a preference for

[8] Calculations based on ERS (2011b) yield slightly different shares than those given in ERS (October 2010, Table F-14).

supporting growers in geographic regions that they identify with. Either of these would help California growers and hurt Mexican exporters in the domestic market. While we cannot isolate any impact of this over the short period since the rules have been established, it remains clear that the majority of the US market continues to be served by domestic growers.

The MeBr alternative iodomethane has been approved for use in Mexico and a commercial launch there is planned for 2012 (ALC, 2010). As an Article 5 country, Mexico has until 2015 to phaseout MeBr under the Montreal Protocol; however, the government of Mexico has committed to completely phaseout methyl bromide by 2012 (UNEP, 2010),[9] by which point it seems likely that growers there will be able to use iodomethane and California growers will use continuing allocations of MeBr and any of several alternatives which show little to no yield changes in current research (summarized in USDoS, 2012). Costs for various production inputs and growing conditions will of course vary and be drivers of comparative advantage in international trade as with any commodity. It is unlikely that changes in land use in California or Mexico have been driven by an expectation of continued MeBr use in Mexico after it is curtailed in the United States.

Additionally, increases in imports may reflect changing trade advantages unrelated to MeBr phaseout in the United States. From 2002 to 2009, imports of Mexican lemons increased from negligible to a major trade commodity, increasing to 54 times initial levels. Avocados increased eleven fold, raspberries increased eight fold, pineapples were up 250%, and pecans and cocoanut meat also increased more rapidly than fresh strawberries. Tangerine, lime, and mango imports grew more slowly than strawberries but still rose significantly (ERS, 2011a, Table G 1). Trade changes driven by NAFTA or other drivers of increased globalization should not be ascribed to the ongoing MeBr phaseout without more substantial evidence than we are able to find.

5. California strawberry production cost estimates

Looking at the various sample budgets available from Cooperative Extension in California (UC Cooperative Extension, 2001a–c, 2004a–d, 2006, 2010, 2011a–b), we do not observe clear links between decreasing availability of MeBr and costs or profits. 2010 and earlier reports note that alternatives to MeBr are available and in use, but the sample budgets assume fumigation with MeBr and chloropicrin (or 'Pic'); Pic allows for significantly lower rates of MeBr application in areas where MeBr had previously been used alone. Of the two 2011 reports one notes that methyl bromide availability is limited and does not specify a fumigant in the line item budgets and the other uses Pic alone.

In the geographically central of the three largest growing regions, fumigation costs as a share of total costs were 2.4% in the 2001 sample budget, 3.7% in 2004, 3.5% in 2006 and 2.9% in 2011. For the same 3 years estimated net returns were 1.6, 14.2, 7.6, and 3.2% of total costs. In the main growing region to the south we have budgets for 2001, 2004, and 2011 which show a decline in fumigation costs as a share of the total, from 6.0 to 5.7 to 3.1%, while net returns increased from 9.5 to 13.4% and then dropped to 2.2%. In the northernmost growing region, budgets for 2001, 2004 and 2010 show increasing fumigation costs (5.2, 5.4 and 6.9% of total costs, respectively) and fluctuating net returns (6.6, 9.4 and 4.0%). These numbers offer some insights into input and production costs, in particular suggesting weakly declining fumigation costs and yielding some evidence of declining net revenues in the most recent years, but we note that the sample budgets are designed to offer a general understanding of costs and revenues using current methods rather than to support rigorous economic analysis.

Critical Use Nominations themselves are another source of data on trends in production costs and revenues. The nominations through 2013 give a baseline yield rate for fumigation with 100% methyl bromide and discount it by some fraction for each alternative pest control regime. While detailed budgets are not provided, annual CUNs for CUEs also include estimates of the economic impacts of MeBr as compared to alternatives.[10] These estimates are developed to support the case that additional exemptions to use MeBr in California are needed to avoid 'significant market disruption,' which is a key part of the standard established in Decision IX/6 of the Montreal Protocol to define a use as critical. Alternatives are shown with associated yield estimates and implied costs to producers facing changed yields and other practices. For 2006–2013 CUNs, the baseline MeBr yield estimates fluctuate a bit, dropping by around 15% from 2006 to 2008 levels in 2009–2010 and then rising again for 2011–2013 nominations. Reported yields per hectare are well below those reported in the sample budgets referenced above, typically around 40–50,000 kg/ha in recent CUNs, with some alternatives in the 30–40,000 range in earlier nominations, while first year strawberry yields in the sample budgets are around 60–80,000 kg/ha and the most recent second year yield reported is over 50,000 kg/ha (UC Cooperative Extension, 2011c). The yield loss associated with moving from MeBr to a mixture of 1,3 dichloropropene (1,3 D) and chloropicrin is steady at 14% throughout, suggesting that the loss rate estimate was not revised over time but simply applied to the MeBr number for a given year. This alternative is the only one included in every nomination[11]; metam sodium (MS) and a mixture of Pic and MS were excluded from 2010 to 2009, respectively, and a mixture of Pic and MeBr was not added until the 2010 nomination. Iodomethane is included for the first time in the 2013 nomination.

Projected strawberry prices drop by about 30% from 2010 to the 2011 nomination estimates, and they remain at this low level through the 2013 nomination. This price, $1.37/kilogram,[12] is well below current and recent reported grower receipts (ERS, 2010); it is not clear why recent nominations have used such a low baseline price. This price drop helps explain why the estimated value of MeBr use as opposed to 1,3 D+Pic can be relatively stable, ranging between $43–68 per kilogram for 2006–2013 nominations, while the figure for "percentage loss in net revenues" swings up to 1269% in 2011 and subsequent years, after previously being estimated at 55 and 87%. While the loss to net revenue is appealing as a proxy for disruption suffered by growers, the nominations note that the

[9] In 2008, Mexico's MeBr consumption was below consumption allowed under the Montreal Protocol. As of 2010, those implementing the National Methyl Bromide Phase-Out Plan for Mexico (the United Nations Industrial Development Organization (UNIDO) along with the governments of Italy, Spain, and Canada) intended to eliminate the remaining MeBr (approximately 900 ODP tonnes) by 2012, provided requested monies from the Multilateral Fund were received. The plan initially proposed that the strawberry sector convert near the end of the phaseout because "strawberry growers were reluctant to reduce MB consumption" (UNEP, 2010, p. 5). However, Mexico's strawberry growers have since requested immediate assistance in order to accelerate completion of the phaseout.

[10] These figures are all reported in nominal dollars, as the requests are filed a few years in advance of the proposed use, and do not specify nominal or real figures. Additionally, many of the numbers do not change from year to year, suggesting that the precision of the estimates is not such that deflating them should drive conclusions.

[11] It is worth noting that the 1,3-D mix is not available to all growers, as many California townships restrict 1,3-D use (Carpenter et al., 2001) and some counties restrict Pic application. This may be why the extension service budgets above exclude it, and this may also make it difficult to draw statewide conclusions on the basis of variation in yield estimates between 1,3-D alone and in combination and MeBr.

[12] The CUN itself reports 'units'; we believe these to be kilograms based on matching with previous California nominations.

required gross revenues less operating costs are "difficult to measure and verify" (USDoS, 2004–2011). Net revenues are sensitive to the implied change in gross revenues of much lower strawberry prices even in the absence of significant cost shifts, and smaller net revenues produce bigger percentage changes for a given nominal cost increase or yield decrease.

As this article was being finalized for publication, the 2014 Critical Use Nomination for field strawberries in California was made public. It requests 415 metric tonnes of MeBr for field strawberries, a bit over a 20% decline from the request for 2013. The drop in requested acreage to be treated is about 50%, suggesting decreasing use of MeBr in combination with other chemicals and thus at higher rates, while the baseline fumigant in the economic impact table is now a mixture of MeBr and Pic rather than MeBr alone. The economic impact analysis shows no yield losses for any alternative, a substantially higher output price for growers of $2.51 per unit, a roughly 60% increase in reported yields to nearly 80,000 kg/ha, and greatly reduced or even negative loss measures. The estimated loss or gain as a percentage of net revenue ranges from 9% (for an alternative using iodomethane) to 5% across all reported alternatives (USDoS, 2012). Chloropicrin alone yields an increase in net revenue of 2% relative to the baseline. Thus the key driver of the request is now the limited access in some specific areas to use of some of the alternative fumigants, or the requirement for buffer zones around schools and residential areas. However, the township caps that limit 1,3 D are being reached in regions where strawberry acreage has grown substantially since the US agreement to phaseout methyl bromide. It is difficult to argue that a sub state regulatory decision that limits the amount of acreage in all crops that can be treated with certain pesticides represents a substantial disruption of the California strawberry market due to the elimination of methyl bromide.

It is interesting to note that with the exception of the 2006–2008 nominations the economic impact estimates in the CUNs assume no price gap per unit produced using MeBr and using alternatives. Wolverton (2012) indicates that in 2006–2008 the change in prices was used to reflect anticipated planting delays and subsequent later deliveries of crops to market for growers using alternative fumigation practices rather than broader market impacts. Constant output prices across alternatives with significantly differing yields suggest that these economic impact estimates assume no market price responses to significant supply swings (including projected yield losses of up to 30% for California growers, which would certainly affect the domestic and North American markets), and thus do not account for the significant amount of any cost increase that will be passed along to consumers as the market reaches a new equilibrium price (see Norman, 2005 for detailed discussion of the impact of relatively inelastic consumer demand for fresh strawberries on market prices and the distribution of the burden of rising production costs). If all acres not receiving exemptions were using alternatives with substantially lower yields and similar or increased costs, we would expect market prices to rise and moderate reductions in profits.

While we do not observe profits directly in the way that we do acreage and revenues, it is difficult to reconcile the history of CUN figures for California yields and costs using alternatives with the increasing use of alternatives and the increasing yields per acre and increases in total acreage noted above. The continued expansion in acres noted above is not consistent with an industry facing large losses as the phaseout continues; basic economics tells us that rising profits attract entry into an industry and falling profits drive exit, as more remunerative investments are sought for the land and capital previously employed in the failing sector. It seems likely that modifications of farming practices in concert with the use of non iodomethane MeBr alternatives have been increasingly successful at preserving yields in those areas that are doing without MeBr either altogether or at least in some years. Input substitution as the price of fumigation relative to other inputs into the strawberry growing process rises – altered weeding practices or schedules, perhaps, or alternate cultivars or crop rotations – would be expected to lower the costs of compliance with the phaseout process. We have found no evidence suggesting zero input substitution characterizes this industry, and any substitutability across inputs will reduce cost burdens on growers. Learning by doing should also lower costs and gaps in yields across different pest control strategies over time, as growers and fumigation contractors become accustomed to using alternatives. Further and perhaps most significantly, it seems that the calculations used to support the granting of CUEs in this sector do not allow for the ability of growers to share cost increases with consumers, who may by their numbers and relatively inelastic demand bear the majority of any remaining burden without individually experiencing price increases as economically disruptive.

6. Additional drivers of change and trends

While per capita consumption of fresh berries by Americans has continued to rise since 2004, it is not obvious that this is driven by rising per capita incomes as earlier data suggested to Norman (2005). Mean and median household and per capita income trends were disrupted by the global recession, with US median household income falling in 2008, 2009 and 2010, mean household income falling in 2007, 2008, 2009 and 2010, and per capita income falling in 2009 and 2010 (Historical income tables, www.census.gov). With a relatively short data period to contend with and a lack of detailed information about changes in income distribution

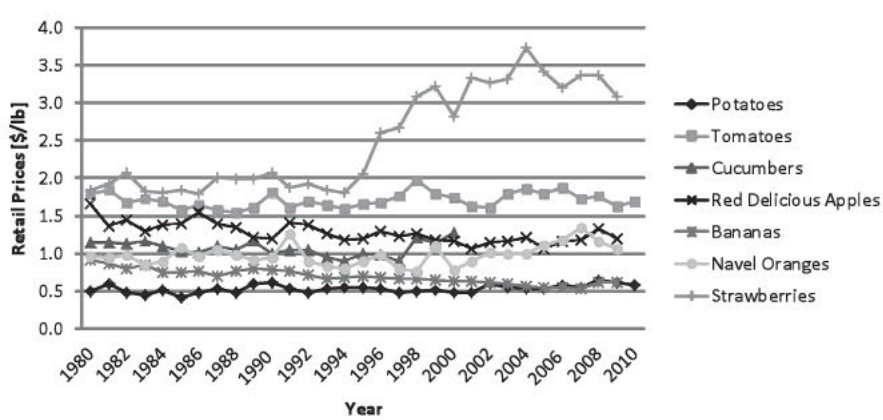

Fig. 3. US fruit and vegetable real retail prices.

and the relationship between income and strawberry consumption, disentangling trends in prices, consumption, and income to estimate relationships is imprecise.

One thing we do note in this market is that while prices of many fresh fruits and vegetables, including strawberries, have trended slightly downwards since 2008 (ERS, 2010 Table 12 and October 2011 Table A 7), over a longer time horizon, we observe a marked difference in fresh strawberry prices, which have increased by 85% from 1994 to 2008, compared to the prices of some other fruits and vegetables, which have largely been stable or increased to a much lesser extent (Fig. 3). Per capita consumption of fruits overall remained constant from 1994 to 2008, while per capita vegetable consumption initially increased from the mid 90s to 2000 but declined subsequently. This suggests that significantly increased strawberry consumption in the face of rising or stable prices in recent years is not likely to be driven by a decline in the price of strawberries relative to substitute fruits and vegetables. Changes in income, tastes, and preferences as well as the increased availability of strawberries at all times of the year are combining to support increased per capita and total strawberry consumption.

7. Conclusion

We offer an ex post analysis of the impact of the mandated phaseout process for methyl bromide on California strawberry growers to date. Ex ante estimates of the economic impact of the elimination of MeBr were required by and influential in the CUN and CUE processes, in contrast with either a benefit cost approach including public health and environmental protection gains, as required by many of the domestic environmental policies of Parties to the Montreal Protocol, or with the Essential Use Exemption process used for other ozone depleting substances eliminated earlier in the ozone protection regime. While this is not an ex post analysis of the originally expected complete phaseout, and thus cannot be directly compared with ex ante predictions based on the complete elimination of MeBr use, it does offer insight into the gap between predictions and outcomes of a strawberry industry moving away from this ozone depleting pesticide while facing import competition from a major trading partner with a more lenient phaseout schedule.

Contrary to many ex ante predictions and concerns expressed by stakeholders, California strawberry growers have thrived in recent years relative to both domestic and foreign competitors. They have successfully worked to ensure that MeBr has been available for significant fractions of their significantly expanded acreage, increased exports, and continued to enjoy rising yields and revenues as well as increased demand from consumers. The interim years between the planned elimination of MeBr and the increasing success of alternatives as detailed in the 2014 CUN and other reports have been years of expansion in the face of global recession and increased imports from Mexico, and successful navigation of technical and regulatory changes. Industry data suggests that the real burdens associated with changing agricultural practices have not kept this sector from profitability and growth in a challenging economic environment, though we cannot know how much faster growth might have been if MeBr use had continued unabated.

Alarming numbers in the CUNs sent to the Parties to the Montreal Protocol are not consistent with the success of California strawberry growers in aggregate as use of MeBr has been reduced. Nor are they consistent with basic economics. The 'economic disruption' standard of the CUE process was not intended to require the Parties to permit application of MeBr on new acreage to allow limitless expansion of a given industry using MeBr, and it is difficult to justify ongoing exemptions to support expansion rather than protect existing growers and growing regions. If all the new acres in production since 2005 are being managed profitably without MeBr, and existing acres are using less MeBr less often while overall and per acre yields and revenues rise steadily, it seems we have reached a point where alternatives are demonstrating successes for field strawberries in California.

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NATURAL RESOURCES DEFENSE COUNCIL

Testimony of David D. Doniger
Policy Director and Senior Attorney, Climate and Clean Air Program
Natural Resources Defense Council

Hearing on the U.S. Agricultural Sector Relief Act of 2012

Subcommittee on Energy and Power
Committee on Energy and Commerce
House of Representatives
July 18, 2012

Summary

- Protection of the ozone layer is a huge bi-partisan public health success story. The phase-out of ozone-destroying chemicals, including methyl bromide, is saving literally millions of Americans, and tens of millions of people around the world, from death and disease, from skin cancer, cataracts, and immune diseases. It is also saving farmers billions of dollars in UV-related crop losses.

- Now is not the time to tamper with the Montreal Protocol and the Clean Air Act. By slowing or even reversing the transition away from methyl bromide, "The U.S. Agricultural Sector Relief Act" will lead to more skin cancers, more cataracts, more immunological disease. It will benefit strawberry growers and others who have profited by abusing the "critical use exemption" for almost a decade. Thousands of other farmers growing other crops will suffer more UV-related crop losses as a result.

- Methyl bromide suppliers and users have dragged their feet on replacing this dangerous compound for two decades. No other industry has had more time and more leeway to transition from dangerous ozone-destroying chemicals.

- The United States is responsible for more than 90 percent of all methyl bromide exemptions. Every other strawberry- and tomato-growing country with California-like growing conditions – including Italy, Spain, Greece, and Australia – has ended use of methyl bromide. Mexican growers use less methyl bromide per acre than their California counterparts, and Mexico will end methyl bromide use entirely this year.

- California strawberry growers have done very well during the whole experience, according to a recent peer-reviewed economic study. Strawberry acreage is up 16% and yields are up 14% since 2004 despite significant reductions in methyl bromide allocations. So are U.S. grower prices and total crop values.

- U.S. critical use exemptions have been coming down. California strawberries are now the only field use for which the U.S. is still seeking critical use exemptions. Together with several structural and commodity uses, the total U.S. exemption request for 2014 is down to slightly more than 400 tons.

- The bill would do reckless damage in three major ways: First, it would permanently define as "critical uses" all of the uses that were labeled critical in 2005, even though the vast majority no longer even use methyl bromide. Absurdly, the bill would make even golf course turf grass a "critical use." It makes no sense to freeze into law an utterly out-dated list of "critical uses."

- Second, the bill relieves applicants of the need to show why they need exemptions. They could just submit their exemption wish lists without any supporting data. EPA then would bear the burden of gathering the data to support any reduction. Absent resources and data, EPA would have little choice but to forward the applicants' unsupported wish lists to the parties. This would be foolish even from the growers' perspective. It actually helps the U.S. government win approval for exemptions to have shown that it has exercised judgment and discipline in framing its requests, and has is not mechanically asked for everything its domestic applicants may have wanted.

- Third, the bill would blast an enormous new loophole into the Clean Air Act and our pesticide safety laws, by allowing any individual user to write his own ticket for up to 20 tons of methyl bromide

simply by asserting the existence of an "emergency." There could be a hundreds of emergency exemptions per year, totaling up to 2,000 tons per year (the 2011 critical use amount).

- This is a bad and unneeded bill. It would harm public health, harm other farmers, and indeed even harm the farmers it is intended to help. The process is working. This Committee should let well enough alone.

Thank you Chairman Whitfield and Ranking Member Rush for the opportunity to testify on behalf of the Natural Resources Defense Council on the proposed "U.S. Agricultural Sector Relief Act of 2012." Founded in 1970, NRDC is a national nonprofit environmental organization of scientist, lawyers, and environmental specialists with more than 1.3 million members and online activists, served from offices in New York, Washington, Chicago, San Francisco, Los Angeles, and Beijing. I am policy director of NRDC's Climate and Clean Air Program. I have been with NRDC twice, from 1978 through 1992 and from 2001 to the present. In the 1990's I served as director of climate change policy in the EPA Office of Air and Radiation. Relevant to the topic of today's hearing, I have worked on the phase-out of ozone-destroying chemicals for more than a quarter century.

There are few greater success stories than the global effort to phase out the ozone-damaging chemicals. Every American, and every citizen on this Earth, relies on the ozone layer to block dangerous ultraviolet radiation that causes skin cancer, cataracts, immune disorders and other diseases. The treaty to protect the ozone layer, known as the Montreal Protocol, has enjoyed bipartisan support from five presidents beginning with Ronald Reagan. So have the ozone layer protection provisions of the Clean Air Act. They are saving literally millions of Americans, and tens of millions of people around the world, from death and disease. They are also preventing billions of dollars in UV-related crop losses and other economic damages.

Yet the ozone shield is still being weakened by ozone-depleting chemicals that increase our exposure to dangerous UV radiation. Millions of Americans – including farmers – must work everyday in the sun. Millions more – from school children to seniors – spend hours of their days out of doors. Millions of concerned parents check the UV Index and cover their kids with sunscreen before letting them go out in the sun.

That brings us to methyl bromide. Methyl bromide is the most powerful ozone-depleter still in widespread use. All of the other more potent ozone-destroying chemicals have been successfully

eliminated – worldwide. Methyl bromide is also highly toxic, with inhalation or dermal exposure causing a wide range of acute and chronic effects, including death.

Mr. Chairman, I will not mince words. You are considering a bill to further slow the snail-like pace of the transition from this dangerous chemical – a bill that will lead to more skin cancers, more cataracts, more immunological disease, and more crop losses due to ozone-destruction and UV radiation, as well as more illness from direct exposure. Contrary to the bill's grandiose title, this bill will not broadly benefit "the U.S. agricultural sector." Indeed, thousands of farmers growing other crops will suffer more UV-related crop losses as a result. Instead, this bill will benefit only a small sliver of strawberry growers and few others who have profited handsomely by abusing the "critical use exemption" for the better part of a decade.

No industry has had more time and more leeway to transition from dangerous ozone-destroying chemicals than this one. The auto industry replaced CFCs in car air conditioners in less than four years. The electronics industry replaced ozone-depleting solvents in circuit board manufacture in less time than that. The air conditioning and refrigeration industry and the fire protection industry got rid of their potent ozone-depleters in well under a decade. Indeed, some of these industries have gone through two rounds of transitions to safer chemicals in the last 20 years. And all of these industries have been able to produce better, more energy-efficient, and more profitable products.

But methyl bromide stands apart. The producer and the users of this chemical have dragged their feet on replacing this dangerous compound for two decades. Let's review:

The phase-out of methyl bromide was supposed to be completed by 2001 pursuant to the 1990 Clean Air Act Amendments. With a decade of lead-time, growers and other users should have invested in developing and field testing other agents and other agricultural practices, like every other industry did. Their effort was minimal. And their minimal effort was rewarded by pushing the deadline back to 2005, in conjunction with amendments to the Montreal Protocol to phase out methyl bromide world-

wide. An post-2005 exemption was allowed for so-called "critical uses," but all observers then thought this would be just a small percentage of historical ("baseline") methyl bromide use, just as the "essential use" exemptions for other ozone-destroying chemicals had been only a small fraction of their baselines.

Indeed, other countries with comparable agricultural conditions played by those rules, submitting critical use exemption requests, if any at all, that reflected small fractions of their historical methyl bromide use levels. Only the U.S. took a different tack. In 2003, U.S. growers and others sought exemptions totaling some 15,000 tons, more than 60 percent of country's baseline use in the early 1990s. The U.S. government requested more than 10,000 tons of exemptions, and nearly broke the back of the Montreal Protocol. For the first time in its history, the parties were unable to come to a consensus decision. For the first time, there was an impasse that could not be resolved without calling an extraordinary meeting of the parties.

For eight years running, the United States alone has requested more than 90 percent of all exemptions. Over this period, nearly every other developed nation has eliminated its need for methyl bromide. Specifically, every other strawberry- and tomato-growing country with Mediterranean-like growing conditions – including Italy, Spain, Greece, and Australia – has moved beyond use of methyl bromide. Even Mexico – the California strawberry growers' only competitor – is committed to end its use of methyl bromide this year.[1]

Throughout this period, and here again today, the California strawberry growers have led the pack in coming to Congress playing the hardship violin. In fact, however, California strawberry growers have done very well during the whole experience, according to a recent peer-reviewed economic study by Erin N. Mayfield and Catherine Shelley Norman, published in the *Journal of Environmental*

[1] "The Government of Mexico has committed to achieve the complete phase-out of MB by the end of 2012." United Nations Environment Programme, Executive Committee of the Multilateral Fund for the Implementation of the Montreal Protocol, Sixty-sixth Meeting, Montreal, 16-20 April 2012, "Project Proposal: Mexico, National methyl bromide phase-out plan (third tranche), ¶9, http://www.multilateralfund.org/66/English/1/6641.pdf.

Management.[2] They have expanded their strawberry acreage and increased their yields dramatically despite significant reductions in methyl bromide allocations: California strawberry acreage in 2010 had increased 83 percent over 1991 levels and 16 percent over 2004. Yields per acre in 2010 increased 29 percent over 1991 levels and 14 percent over 2004. California's share of U.S. production also increased during this period, from about 80 percent in 1991 to more than 90 percent in 2010. U.S. grower prices and total crop values adjusted for inflation also increased during the exemption years.

The expansion of the strawberry acreage treated with methyl bromide is extremely troubling because it breaks a commitment made by the U.S. government not to allow such expansion. For instance, the "National Management Strategy for Methyl Bromide, United States of America, December 2005" states: "An important way that the United States addresses the issue of avoiding increases in MeBr use is our policy to disallow any increases in acreage or throughput that CUE applicants might include in their CUE request."[3] This turns out to have been a hollow promise.

The growers' complaints often center on the claim of unfair competition from Mexico. Throughout this period, however, Mexican growers used less methyl bromide per acre than their California counterparts, and Mexico, as I mentioned, has committed to stop using methyl bromide this year. Mayfield and Norman note that although strawberry imports from Mexico increased as the overall U.S. strawberry market grew, Mexico's share of total U.S. consumption did not increase significantly, and U.S. growers' strawberry exports to Canada rose by almost as much as imports from Mexico.

Mayfield and Norman also note that the economic analysis supporting the critical use nomination for 2014 – an analysis prepared by the strawberry growers – indicates that a range of alternatives to methyl bromide are effective and available at comparable cost and without yield losses.

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[2] E. Mayfield & C. Norman, *Moving away from methyl bromide: Political economy of pesticide transition for California strawberries since 2004,* Journal of Environmental Management, Vol. 106, Pp. 93-101 (2012), available at http://www.sciencedirect.com/science/article/pii/S0301479712001909, and attached to this testimony.
[3] http://www.epa.gov/ozone/mbr/downloads/MeBrNatMgmtStrat.pdf, p. 4.

Notably, these results do not depend on methyl iodide, which was withdrawn from the market by its manufacturer earlier this year.

As it turns out, the industry is still sitting on a stockpile of methyl bromide made before 2005 and stored in railroad cars in various communities around the country. Believe me, tank cars of highly toxic methyl bromide baking in the sun on rail sidings are not something I'd want in my community, or rolling through my Congressional district, yet few people know if they enjoy that privilege. As of today, the stockpile still exceeds 1,200 tons – three time the U.S. critical use nomination for 2014.

Why is the stockpile important? Because the rules of the road under the treaty are that a country may request permission to manufacture new methyl bromide to serve critical use needs only if it has exhausted its stockpiles. The industry attempted to conceal that stockpile from both the public and the government, and this led to the U.S. government's initially misrepresenting to the other Montreal Protocol parties in 2003 that there would be no stockpile left in 2005. But the true stockpile, divulged only later in response to an NRDC lawsuit, was nearly 13,000 tons – more than the entire amount the U.S. claimed to need for 2005. The methyl bromide stockpile has been used – illegally, in our view – for crops that no longer qualify as critical uses, such as golf course turf grass, and to exceed the critical use limits on crops such as strawberries. Each year since 2004, the stockpile has been larger than the next year's total critical use request. That is true for 2013 and 2014. The deception over the stockpile, once revealed, almost caused the breakdown of the treaty process, and the existence of a continuing stockpile is still a major irritant between the parties today.

NRDC acknowledges that the amounts of U.S. critical use exemptions have been coming down, however belatedly. Many growers and other users have finally taken up alternative chemicals and alternative pest management practices, so that we have now come to the point where the only field use for which a critical use nomination is still being made in 2014 is California strawberries. Together with several structural and commodity uses, the total U.S. exemption request is down to slightly more than

400 tons, as compared to nearly 10,000 tons in 2005. This progress, though long delayed, is noteworthy and must continue. Further progress is possible even in the short run, through practices such as greater use of impermeable films (something other countries have already adopted) and by continued adoption of alternatives.

In short, the process is working. Now is not the time to tamper with the methyl bromide phase-out requirements under Montreal Protocol and the Clean Air Act. Mr. Chairman, the bill before you would pointlessly weaken curbs on this dangerous ozone-destroying chemical, threaten the recovery of the ozone layer, and further strain our relations with other countries that are already experienced with U.S. abuse of critical use exemptions. The bill does reckless damage in at least three major ways:

First, the bill would permanently define as "critical uses" all of the uses that were labeled critical in 2005, regardless of the fact that the vast majority of those crops and applications have successfully transitioned to alternatives and no longer even use methyl bromide. Absurdly, the bill would make golf course turf grass a "critical use," even though the Bush administration's agriculture department dropped it from the list in 2006. Why in the world does it make sense to revive and freeze into law an utterly out-dated list of "critical uses"?

Second, since growers and other applicants are seeking exemptions for a chemical that is otherwise already banned under both domestic and international law, and since they are in the best position to innovate and test alternatives, they quite properly now bear the burden of showing the need for methyl bromide and the absence of economically practical alternatives. But the bill would turn that burden around. It would allow applicants to submit their wish lists for exemptions without providing any data in support. Even though this chemical is already supposed to be banned, the bill would then require EPA to shoulder the burden of developing the data to support any reduction from the growers' or other applicants' requests. As the growers would be quick to point out, EPA does not run farms, and EPA does not run alternatives testing programs.

Absent the resources and access to data, EPA would have little choice but to forward the applicants' wish lists to the parties for consideration. Even from the growers' perspective, this would be a fool's errand. It is difficult enough for the U.S. to gain approval for its out-sized exemption requests when it can bring a reasonably robust case forward for technical scrutiny by the other parties. It actually helps the U.S. win approval for exemptions to have shown that the government has exercised some judgment and discipline in framing its requests, and that the U.S. is not asking for everything its domestic applicants may have wanted.

Third, the bill would blast an enormous new loophole into the Clean Air Act and our pesticide safety laws, by allowing any individual user to write his own ticket for up to 20 tons of methyl bromide simply by asserting the existence of an emergency. "Emergency" is conveniently defined to mean any situation where someone wants to use more methyl bromide than is available under a critical use exemption, and where he declares that there is no alternative. The bill would allow a hundred 20-ton emergency exemptions per year, up to a total of 2,000 tons per year (the amount of critical use exemptions in 2011). This would be a massive abuse of the emergency exemption provision under the Montreal Protocol, which has been invoked only twice so far (once by Australia and once by Canada) in genuine emergencies.

Imagine, Mr. Chairman, how cool it would be to be able to withdraw more cash from the bank than you have in your account, just by calling it an emergency. There's another name for that: bank robbery.

This is a bad bill, and an unneeded bill. It would harm public health, harm other farmers, and indeed even harm the farmers it is intended to help. The process is working. This Committee should let well enough alone.

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Moving away from methyl bromide: Political economy of pesticide transition for California strawberries since 2004

Erin N. Mayfield [a], Catherine Shelley Norman [a,b,*]

[a] Department of Geography and Environmental Engineering, The Johns Hopkins University, 3400 North Charles Street, Baltimore, MD 21218, USA
[b] Department of Economics, The Johns Hopkins University, 3400 North Charles Street, Baltimore, MD 21218, USA

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ABSTRACT

We examine the progress of the phaseout of the use of the pesticide methyl bromide in the production of California field strawberries. This phaseout is required under the Montreal Protocol and has been contentious in this sector, which receives exemptions from the schedule initially agreed under the treaty, and in international negotiations over the future of the Protocol. We examine the various ex ante predictions of the impacts on growers, consumers and trade patterns in light of several years of declining allocations under the Critical Use provisions of the Protocol and the 2010 approval of iodomethane for use in California and subsequent 2012 withdrawal of this alternative from the US market. We find that, contrary to ex ante industry claims, the years of declining methyl bromide use have been years of rising yields, acreage, exports, revenues and market share for California growers, even when faced with a global recession and increased imports from Mexican growers who retain the right to use the chemical under the Protocol. This has implications for the Protocol as a whole and for the remainder of the US phaseout of this chemical in particular.

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1. Introduction and background

US fruit and vegetable growers using the fumigant methyl bromide (MeBr), scheduled for phaseout under the Montreal Protocol on Substances that Deplete the Ozone Layer, faced uncertainty about the cost and effectiveness of alternative chemicals and practices, and many of them applied for exemptions allowing continued use after the planned elimination of MeBr. This process was controversial – so much so that the United States suggested that they might withdraw from the Montreal Protocol, up to that point considered a model of successful international environmental policy, if their nominations for exemptions were not granted (Gareau and DuPuis, 2009). In the exemption process, which allowed exceptions to the scheduled 2005 complete phaseout date, one of the most contested uses was for strawberry farming, especially in California where many alternatives are strictly regulated or disallowed. Growers argued that none of the alternatives met the 'economic and technical feasibility' conditions of the Critical Use Exemption (CUE) rules. DeCanio and Norman (2005) discuss possible interpretations of the feasibility criteria at length, emphasizing that it cannot mean that no changes in costs or agricultural practices are required of methyl bromide users, but there is not a consensus definition of precisely what standard must be met.

Currently, the majority of CUEs for methyl bromide are allocated to the United States.[1] The share of field (rather than nursery) strawberries in total exemption requests has also grown; the 2014 US field strawberries nomination was for over 93% of the total US allocation, and was exclusively for use in California, which produces 90% of US strawberries (ERS, 2011c). In 2007 the same share was only 13% and more geographically dispersed, including uses in the southeastern US as well as California (USDoS, 2010, 2005, ozone.unep.org). Substitutes have been slower to develop in California,

* Corresponding author. Department of Geography and Environmental Engineering, The Johns Hopkins University, 3400 North Charles Street, Baltimore, MD 21218, USA. Tel.: +1 410 516 5184; fax: +1 410 516 8996.
E-mail addresses: erin.noel.mayfield@gmail.com (E.N. Mayfield), norman@jhu.edu (C.S. Norman).

[1] For the last seven years reported, 2007 2013, approved US CUEs have been more than 75% of non-Article 5 exemptions approved globally, so US strawberry uses are a significant amount of remaining global use of MeBr. In the first year of the exemption process, US allowances were a bit over 40% of total non-Article 5 allocations. For 2013, the United States has received over 90% of approved CUE allowances. Article 5 parties, which are, roughly speaking, less developed countries, do not have to complete phaseout until 2015, but their total use peaked in 1998, and by 2010 total consumption in Article 5 and non-Article 5 countries were approximately equal (exclusive of quarantine and pre-shipment uses, which are regulated separately and excluded from the discussion throughout this paper) (ozone.unep.org).

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due to different farming practices and a relatively stringent regulatory climate that has slowed the approval of some MeBr alternatives. The California strawberry crop is worth more than $2 billion annually and is the 6th highest valued fruit crop in the state, so while the industry is small at the national level it is economically significant in the region.[2]

California growers and those negotiating the CUE process on their behalf were deeply concerned that the main source of US imports of fresh strawberries, Mexico, would not be required to eliminate the use of MeBr at the same time that California growers were scheduled to. The Montreal Protocol allows delays in the elimination of ozone depleting substances for less developed countries, and growers feared that lowered trade barriers under NAFTA would combine with a technological advantage to Mexican growers using the fumigant, leading to dramatically increased imports of fresh strawberries and reduced sales of and/or prices for domestic berries.

This work investigates how the process of phaseout has affected the California field strawberry industry and finds that management and regulatory decisions at the international, national, and state levels have allowed California growers to maintain and enhance their dominance in the domestic and North American market as the phaseout has progressed. The period between the beginning of the methyl bromide phaseout and the availability of iodomethane, the closest thing to a 'drop in' substitute yet developed, for use in the state has been characterized by slow elimination of MeBr, rising acreage, yields and consumption, improved balance of trade, increasing domestic market share, and rising or relatively stable prices. Iodomethane itself has recently been voluntarily withdrawn from the US market, and we consider how this might affect our assessment of the phaseout process to date.

2. Ex-ante analyses of economic effects and political factors influencing phaseout

Economic analyses earlier in the process did not reach a consensus regarding the likely impacts of phaseout. Norman (2005) relied heavily on data from nominations for CUEs and found that trends in demand growth for fresh strawberries[3] and significant pass through of cost increases to consumers were expected to outweigh the stated negative effects of production cost increases associated with use of alternative fumigants, even in the absence of direct government support, under fairly conservative assumptions, and that increased consumer costs per household would be minimal, even if they were substantial in aggregate.

Carpenter et al. (2000) simulated production, consumption, and crop prices for methyl bromide users (e.g., California) and direct competitors (e.g., Mexico) – prior to and after the 2005 MeBr ban using a spatial partial equilibrium model. To simulate post ban conditions, shifts in production technology and corresponding changes in production costs and monthly yields were assumed.[4] Model results suggested that following a ban, US consumers would pay higher prices for strawberries and consume fewer of them. The increased price of strawberries would outweigh increases in CA production costs for growers and, when coupled with increased acreage devoted to CA strawberry production, CA strawberry growers' gross and net revenues would increase and remain stable, respectively.

Goodhue et al. (2005) and Carter et al. (2005), on the other hand, suggested that MeBr phaseout could cause significant problems for US or California growers. The former included field trials to estimate weed control costs using MeBr and various available alternatives but were unable to estimate yield losses from the use of MeBr alternatives directly, and concluded that acreage and thus supply would have to decline significantly to raise market prices enough to eliminate the net losses to remaining growers. The latter note that a single annual demand elasticity parameterization obscures important variation in seasonal demand and supply functions and can bias estimates of losses downward, with the most significant losses accruing between mid May and early July. Their simulation results suggest full season losses of between 4 and 20% of revenue, with a point estimate of around 12%, excluding revenue realized from lower valued crops as acreage in strawberries decline. Neither study considered longer term trends in the fresh strawberry market.

The design of these studies reflected concerns that Mexico, which provided (and continues to provide) more than 99% of imported fresh strawberries to the US (ERS, 2010, Table 14), was an Article 5 country under the Montreal Protocol and thus not required to eliminate MeBr until 2015, at which point their MeBr use would also have to comply with CUE standards to be permitted. NAFTA rules would make it hard to shield US growers from Mexican competition. Rising costs to US producers forced to transition away from their preferred fumigant could make Mexican imports more competitive over more of the year, reducing market share and revenues to domestic growers. Carpenter, Gianessi, and Lynch (2000) projected that after the 2005 ban – exemptions notwithstanding – increased acreage in Mexico devoted to strawberry production would be observed, and in the absence of land and water constraints, Mexico would continue to increase acreage and displace acreage in California.

On the regulators side, there was concern that significant exemptions would slow the phaseout and increase lobbying efforts at the expense of efforts to develop and implement alternate fumigation strategies. Using even the lowest estimate of the cost burden of the elimination of MeBr for California strawberries growers from Norman (2005) of $51[5] ha/year suggests that diversion of funds to directly unproductive rent seeking around CUE rights could be significant; the 2011 industry survey indicates that 15,145 ha are planted in strawberries in California, and less than 5% of that land is devoted to organic production (CSC, 2011). This implies that delays in phaseout for conventionally grown berries could be worth more than $700,000 annually (15,145 × .95 × $51 $733,775), and any successful efforts to secure delays that cost less than this amount are profit maximizing for the industry as a whole.

The California Strawberry Commission (CSC), the most active industry group, doubled (nominal) federal lobbying expenditures from $40,000 in each of 2001–2007 to $80,000 in 2008, and expenditures have remained at that level through 2010 (Center for Responsive Politics, 2011). State nominal lobbying expenditures were about $30,000 for the 2001–2002 legislative session, as decisions about initial CUE applications were being made, and then dropped to around $3000 for the next session, rising for each subsequent legislature to a level of about $20,000 in 2009–2010 (CalAccess, 2011). It is likely, of course, that only some of these

[2] http://www.californiastrawberries.com.

[3] We focus on fresh berries throughout; in the US, frozen berries are largely a residual crop (ERS, 2011c), and as they are not perishable this market operates quite differently. Large increases in the share of production going for frozen or otherwise processed berries might suggest quality issues associated with various changes to fumigation processes, but we do not observe this in the data.

[4] The model assumes that the best alternative technology which is assumed to be the technology resulting in the highest yield per acre for the lowest cost per acre is selected. Given that the study was completed in 2000, the best technologies projected at the time do not entirely correspond to the alternatives actually employed during the phaseout.

[5] All figures converted to 2010 dollars using the CPI unless otherwise noted.

efforts were focused on preserving MeBr phaseout exemptions for growers. We were not able to find evidence of significant lobbying expenditures for strawberry growers in other regions. While lobbying expenditures are one indicator of lobbying efforts, the rapidity of regulatory movement – in this case, the reduction timeline – may also be suggestive. The reduction timeline in California has been much less aggressive than in other US regions, which no longer use MeBr for field strawberries, and more broadly, the reduction timeline in the US has been much less aggressive than other non Article 5 parties. Taken together, the lobbying expenditures and reduction timeline suggest that if lobbying has slowed the phaseout of methyl bromide for strawberries in CA, it has been a rational investment for the industry, even if the costs of using alternative pesticides are a relatively small fraction of revenues and profits.

The Critical Use Exemption process involves stakeholders who use the regulated chemical, national nominations, and recommendations or analysis by the Technology and Economic Assessment Panel (TEAP) of the Montreal Protocol, leading to final amounts which must be approved by the Parties to the Protocol at their annual meeting. In the US, the Environmental Protection Agency (EPA) solicits yearly applications with supporting information on use patterns and economic impacts from growers, and then the Department of State submits these as Critical Use Nominations (CUNs). For the last year for which data are available – the nominations and final decisions for 2012 exemptions – the CSC requested permits to treat 4454 ha, which were passed on to the Parties to the Montreal Protocol, who approved 4421 of those hectares, albeit at a lower application rate than was originally requested.[6] If this smaller amount receives the low estimate of value from continued use of MeBr, CA growers have gained about $225,000 in 2012 by securing the 2012 exemptions, as well as slowing further phaseout and broader price impacts until their chief competitor in the North American fresh strawberry industry completes their phaseout. At this point Mexican growers presumably lose any price advantage gained by ongoing MeBr use, and alternative pest control practices will be more established in California.

Interestingly, this approved MeBr fumigation allowance for about 30% of California acreage annually could mean use over the majority of the growing region on an intermittent basis. The CSC notes that "[m]ethyl bromide is often being used in rotation with alternative fumigants. Many growers will use alternative fumigants for 2–3 years then rotate back to methyl bromide to clean up emerging weed and disease problems" (California Strawberry Commission, 2008. *Request for a critical use exemption for methyl bromide on strawberries for the 2011 use season.* Cited in 2013 US Field Strawberries CUN). While a move towards using MeBr every 2–3 years rather than annually is certainly a substantial reduction in MeBr applications, it is not a reduction in the geographic area reliant on MeBr as part of strawberry production, and thus reflects less progress towards achieving a permanent phaseout than the reported reductions in acreage needing treatment would suggest. Unobserved cooperation within the industry to produce this outcome would undermine the intent of the Parties to the Protocol, particularly as it could allow the use of MeBr on fields put into production after the beginning of phaseout. In California, 2009 acreage represented an increase of 89%, or 7600 ha, over the 1991 'baseline' year established for MeBr under the Protocol (ERS, 2010, Table 4). It is not possible to determine if new acreage is using MeBr on the basis of allocations currently in use, as these are not broken out by sector or sub state geographic regions by the US EPA once exemptions are granted (Federal Register, 2011). While the United States did articulate a policy of not allowing growth in CUNs due to new acreage (UNEP, 2005), they did not specify that new acreage reliant on MeBr was not allowed even if it did not drive increasing total amounts of requested MeBr, and so the continued decline in CUNs for this sector seems to satisfy this domestic policy.

While lobbying efforts are ongoing, the CSC and other industry groups also work closely with farmers and researchers developing and testing MeBr free growing methods. CSC reports research expenditures of over ten million dollars to date toward this end, presumably beginning in the early to mid 1990s, which suggests that research expenditures are a substantial part of the CSC budget (calstrawberry.com). Additionally, within regional nomination applications, research expenditures and funding resources have historically been reported and used to substantiate nominations.[7] Sufficient data to elicit trends in those expenditures is not available. Overall, it seems reasonable to deduce that investment in new technology hedged by investment in lobbying for continued exemptions represents an effective risk management strategy for growers and has been an influential driver of industry and regulator decision making.

The political economic and sociological issues around agricultural exemptions to the MeBr phaseout have been studied extensively. Clark (2001) offers an early analysis of the relationship between growers, the state of California, and the Federal EPA. Badulescu and Baylis (2006) consider the harmonization of pesticide rules under NAFTA and the possibility that that process has favored US strawberry producers. Kent Monning (2007) raises concerns about the environmental justice implications of the use of the CUE process in California.

More recently, DuPuis and Gareau (2008); Gareau (2008, 2010, 2012) and Gareau and DuPuis (2009) argue in a series of papers that increasing pressure to provide market solutions rather than command and control ones – as evinced partly by the economic justification for exemptions to agreed phaseout schedules, which was not allowed for the previously established 'Essential Use Exemptions' granted for other ozone depleting substances in earlier stages of the Protocol – undermined the later stages of the Montreal Protocol. They further suggest that an emphasis on the credibility of estimates of private costs over estimates of public benefits will drive decision making about exemptions in the future, while in the past a precautionary principle approach to the human and environmental risks associated with ozone depleting substances was more important. Stakeholder processes have been 'captured' to a significant degree by industry groups rather than involving a broader group more focused on the welfare of civil society as a whole. That this mode of discourse is so dominant in US policymaking is thus offered as an explanation for the ongoing use of significant amounts of MeBr in the US when other countries granted early exemptions have completed phaseout.

[6] The 2013 nominations proved very contentious in 2011; additional bilateral (including with the CSC as well as with representatives of affected nations) and TEAP meetings were added to the schedule and multiple submissions were revised and new research offered during the process (UNEP, 2011a). The decision in the advance draft report of the 23rd Meeting of the Parties reflects the MBTOC (the Methyl Bromide Technical Options Committee, part of the TEAP) recommendation (a 2013 exemption of 461.186 metric tons for field strawberries) but not that of the minority report offered by several members of the MBTOC (UNEP, 2011a,b), which recommended granting the full nomination amount (531.737 metric tons). Application rates used to calculate CUNs and CUEs and the availability of alternative pesticides in specific California growing regions were disputed within the TEAP and among governmental and nongovernmental stakeholders.

[7] Publically reported research expenditure information is incomplete CSC has reported research expenditures as Confidential Business Information, and detailed expenditure data are not typically reported in regional nominations.

3. Progress and barriers in eliminating MeBr under the Montreal Protocol

For the first year of CUNs, 2005, 28 countries nominated critical uses. This number has declined steadily and most recently, four nominating parties (the US, Japan, Australia, and Canada) requested CUEs for 2013 (UNEP, 2011). Global CUEs for non Article 5 countries have decreased by 94% since 2005. Use in Article 5 countries has also declined, falling below total non Article 5 use for the first time in 2007. This decline is partly due to the support of phaseout programs paid for by the Protocol's Multilateral Fund, which is not available to non Article 5 countries. 2010 MeBr use in Article 5 countries was 5.2% of the 1991 baseline.

Nominations by the US and requests for nominations from the California Strawberry Commission between 2005 and 2014 are shown in Fig. 1. The US, which has had the slowest average annual rate of decrease in MeBr usage of non Article 5 countries using the CUE process, had nonetheless reduced CUN amounts by 78% from 2003 to 2013. Although the US has been accelerating the MeBr phaseout in recent years, with a large drop in the 2014 nomination, a complete phaseout has not been planned and it remains unclear when complete phaseout will be achieved.

Within the US, California is now the only state still requesting critical use exemptions for field strawberries. Porter et al. (2006) conducted a global meta analysis of strawberry yields based on hundreds of studies and found that many alternatives produce "statistically equivalent yields" to MeBr, and thus worked to undermine arguments for exemptions related to technical feasibility. The resistance to phaseout of MeBr in California has centered on technical issues but also on economic feasibility and uncertainties associated with the availability of alternative fumigants – namely iodomethane. Approval of iodomethane for use in California was predicted for 2003, and then 2005 (Carter et al., 2005), but it was not actually available for use until December 2010. The failure of California to permit the use of iodomethane was a key rationale for the ongoing exemption request in that state (UNEP, 2011); this is consistent with the US not decreasing its CUN request between the nominating years 2010 and 2011. Since the registration of iodomethane in the 2011 growing season, however, only one California strawberry grower has used it, and that usage was small in scale (Wozniacka et al., 2012).

The registration of iodomethane by the US Environmental Protection Agency and the California Department of Pesticide Regulation was controversial due to potential public and occupational health hazards resulting from its use in pre plant soil applications. After first denying registration of iodomethane in April 2006, the US EPA granted a one year registration in October 2007 and, by 2008, licensed iodomethane for sale and use in the US with some restrictions on its application. Most states – with California the most notable exception – quickly followed suit by registering the fumigant. California eventually did approve the sale and use of iodomethane, but with restrictions more stringent than those imposed by the US EPA and other states. Legal challenges to the approval of this fumigant are ongoing, and an ongoing dialogue with respect to concerns about the registration of iodomethane persists between the general public, the US EPA, the California state legislature, and the risk assessment community, including government scientists involved in assessing the risk of iodomethane, a neurotoxin and possible carcinogen (Urevich, 2011). In early 2012, while no legal ruling against the use of iodomethane was made, the manufacturer announced that, based on an internal review of the fumigant and its economic viability in the U.S. marketplace, they would no longer sell this alternative fumigant in the United States and withdrew its registration in California (Chawkins and Marcum, 2012; ALC, 2012).

4. California strawberries today

US strawberries had record production levels in 2009; production, real value per unit and the total real value of the fresh strawberry crop have risen every year since 2004 according to the USDA (ERS, 2010, Table 1). Real US cash receipts have risen in every year from 2005 to 2010, the last year reported (ERS, 2011a, Table A 8). As noted above, acreage in California has also increased according to each of several data series (California Agricultural Resource Directory, 2010 2011, CSC, 2011; ERS, 2010), contrary to the predictions of declining acreage in the Carter et al. (2005) work and consistent with Carpenter et al. (2000). The ERS data go back the farthest and show that harvested acres of California strawberries have increased steadily since 1970. An OLS linear regression of acreage on time for 2001–2009 data fits well and yields an estimated increase of 650 ha/year; regressions including the earlier decades also show positive and significant trends but do not fit the data as well, suggesting that the time trend alone is not as explanatory over longer periods. These data show acreage increases in every year since 1997, with the exception of 2007, when they declined by less than 1%. Additionally, the ERS data show that the share of California acres in US strawberry acreage has grown steadily over time, from less than a third of the total in the early eighties, to more than half by the mid 90s and rising over two thirds in 2006, where it remains.

Productivity of planted acres has also risen during this time period. ERS data on California yields from 1970 to 2009 show steadily increasing output per acre (ERS, 2010 Table 4). This trend continues for years subsequent to the onset of efforts to eliminate MeBr, though yields are, predictably, subject to weather and other conditions and thus more volatile than acreage. The share of California production in total domestic production has also grown over the time period covered, and has hovered around record highs of 88–89% since 2003. More recently, the Fruit and Tree Nuts report notes of 2010 that "last year, the increase in average yields per acre

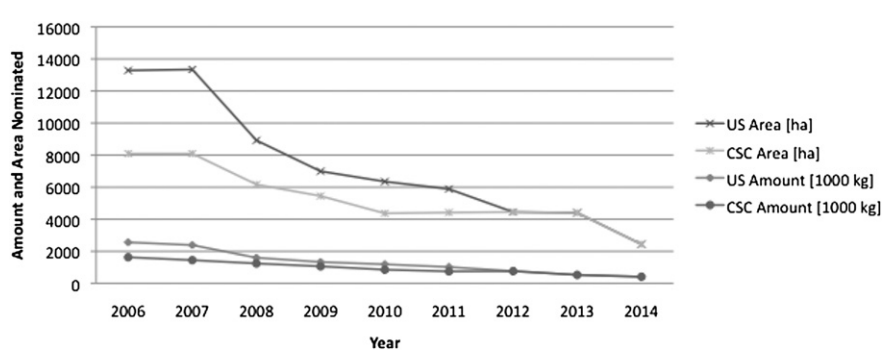

Fig. 1. US and California Critical Use Nominations, with MeBr requests and acreage.

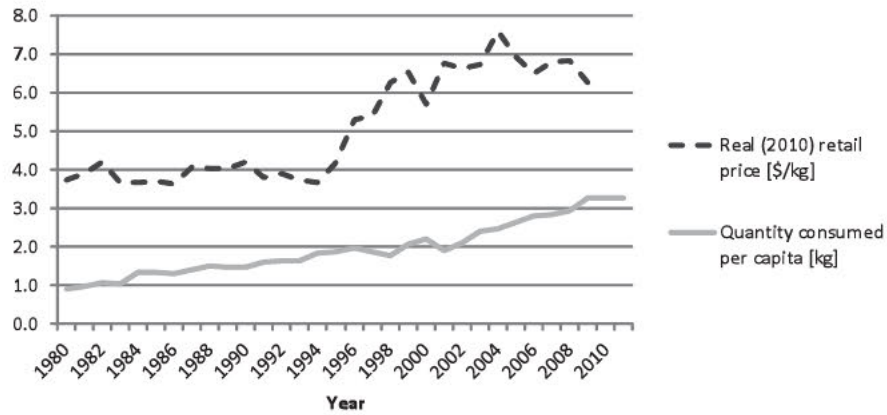

Fig. 2. US fresh strawberry prices and consumption.

in California (up 7 percent from 2009) more than made up for the decline in harvested acres (down 3 percent), resulting in a larger crop" (ERS, 2011c).

On the consumption side, we see that per capita consumption and total consumption of fresh and frozen strawberries continues to rise. In fact, per capita annual consumption of fresh strawberries has broken record levels in each year from 2003 to 2009 (ERS, 2011c; ERS, 2010, Table 12) even as real retail prices have stayed relatively stable or declined slightly. The most recent figures suggest an increase of 48% in per capita consumption of fresh berries since 2002, the last year covered in Norman (2005); with population growth that has amounted to a 67% increase in total US consumption over the same period. The continuing increase in per capita consumption as well as trends in real retail prices can be seen in Fig. 2.

We examine seasonal patterns in retail prices to evaluate hypotheses about patterns of trade raised in some of the ex ante studies discussed above. Real retail prices in June, the period identified by Carter et al. (2005) as most vulnerable to losses in a MeBr phaseout, rose in 5 of the 10 most recent years for which data are available (2000–2009). The average of real June retail prices from 2005 to 2009 was 1% higher than for 2000–2004, suggesting no significant change in the trend over time as a driver of this observation. Looking more closely, however, and in contrast with all but 3 of the preceding 24 years of available data, we note that for 2004–2008 May retail prices were higher than April prices, reversing again in 2009. Grower prices confirm this trend; for 2005–2011, May prices to growers for fresh berries were higher than April prices in 5 years and lower in two years (http://quickstats.nass.usda.gov).

While farming is subject to significant variability from year to year, both in the various growing regions domestically and abroad, this is suggestive of an increasingly competitive market in North America. Norman (2005) predicted that the pre 2005 gap between higher April prices and lower May prices was likely to decrease in size in the absence of methyl bromide. Ex post, we see that the gap has not just diminished but has reversed, while significant MeBr use continues. In the past, imports from Mexico peaked in April and domestic deliveries peaked in May or June. The historic drop in prices as domestic berries hit the markets in bulk suggested that exporting costs were high enough for Mexican growers that expanding exports during this period was relatively unattractive. In recent years, we have not observed a significant shift in strawberry acreage away from northern California growing areas, which deliver strawberries later in the season, and towards southern regions, where strawberries come in earlier (CSC, 2011), which might offer a domestic explanation for this shift in the pattern of relative prices throughout the year, so the currently observed pattern of relatively lower April prices is consistent with the US market becoming more attractive for Mexican growers wishing to export for more of the season or US growers facing rising costs in their peak production periods. It could also be that unobserved changes in crop timing associated with the use of MeBr alternatives have shifted the timing of peak deliveries in some parts of the state.

Investigating trends in imports and exports of fresh strawberries in more detail, however, does not provide strong supporting evidence for the hypothesis that increased Mexican imports are driving intra year changes in relative prices. Imports of fresh strawberries to the United States, almost exclusively from Mexico, have indeed grown substantially, continuing a trend observed well before MeBr restrictions began. They have more than doubled since 2004 (ERS, 2011b and Table G 1, ERS, 2011a). The share of Mexican imports in domestic consumption has changed less, however, trending slowly upward since the mid 1980s and now around 8%.[8] This may reflect increasing retail availability and consumption in the off seasons for domestic strawberries as well as increased April exports from Mexico.

United States exports also grew during this time, rising more than 50% from 2004 to 2010 (Table G 2, ERS, 2011a). The bulk of these exports go to Canada, which consumes considerably more strawberries than are produced there. The increase in tonnage of exports to Canada is very similar to the increase in imports from Mexico, suggesting that changing price patterns over time cannot be cleanly ascribed to trade advantages for Mexican growers selling in the United States. Domestic exports could well increase the scarcity of domestic berries at peak periods, driving domestic prices up. Strawberry exports do peak in May (ERS, 2011a, Tables G6–G8). Unfortunately, import and export data by month are only available for a few years, making it difficult to discern trends over time with confidence.

Also affecting trade patterns in North America may be the promulgation of Country of Origin Labeling (COOL) regulations in the United States (http://www.ams.usda.gov/AMSv1.0/COOL). For the 2009 and subsequent seasons all fresh strawberries sold in the United States were required to carry labels indicating where they were grown and packed. One expectation of supporters of this policy was that consumers would prefer domestic products over imports, and this may have reduced the vulnerability of California growers to cheaper imports from Mexico in particular. Carter and Zwane (2003) argue that this was in essence a (costly) protectionist policy. Van Ittersum et al. (2007) note that consumers may prefer domestic or local region products both because they believe them to be better or safer, or because they have a preference for

[8] Calculations based on ERS (2011b) yield slightly different shares than those given in ERS (October 2010, Table F-14).

supporting growers in geographic regions that they identify with. Either of these would help California growers and hurt Mexican exporters in the domestic market. While we cannot isolate any impact of this over the short period since the rules have been established, it remains clear that the majority of the US market continues to be served by domestic growers.

The MeBr alternative iodomethane has been approved for use in Mexico and a commercial launch there is planned for 2012 (ALC, 2010). As an Article 5 country, Mexico has until 2015 to phaseout MeBr under the Montreal Protocol; however, the government of Mexico has committed to completely phaseout methyl bromide by 2012 (UNEP, 2010),[9] by which point it seems likely that growers there will be able to use iodomethane and California growers will use continuing allocations of MeBr and any of several alternatives which show little to no yield changes in current research (summarized in USDoS, 2012). Costs for various production inputs and growing conditions will of course vary and be drivers of comparative advantage in international trade as with any commodity. It is unlikely that changes in land use in California or Mexico have been driven by an expectation of continued MeBr use in Mexico after it is curtailed in the United States.

Additionally, increases in imports may reflect changing trade advantages unrelated to MeBr phaseout in the United States. From 2002 to 2009, imports of Mexican lemons increased from negligible to a major trade commodity, increasing to 54 times initial levels. Avocados increased eleven fold, raspberries increased eight fold, pineapples were up 250%, and pecans and cocoanut meat also increased more rapidly than fresh strawberries. Tangerine, lime, and mango imports grew more slowly than strawberries but still rose significantly (ERS, 2011a, Table G 1). Trade changes driven by NAFTA or other drivers of increased globalization should not be ascribed to the ongoing MeBr phaseout without more substantial evidence than we are able to find.

5. California strawberry production cost estimates

Looking at the various sample budgets available from Cooperative Extension in California (UC Cooperative Extension, 2001a–c, 2004a–d, 2006, 2010, 2011a–b), we do not observe clear links between decreasing availability of MeBr and costs or profits. 2010 and earlier reports note that alternatives to MeBr are available and in use, but the sample budgets assume fumigation with MeBr and chloropicrin (or 'Pic'); Pic allows for significantly lower rates of MeBr application in areas where MeBr had previously been used alone. Of the two 2011 reports one notes that methyl bromide availability is limited and does not specify a fumigant in the line item budgets and the other uses Pic alone.

In the geographically central of the three largest growing regions, fumigation costs as a share of total costs were 2.4% in the 2001 sample budget, 3.7% in 2004, 3.5% in 2006 and 2.9% in 2011. For the same 3 years estimated net returns were 1.6, 14.2, 7.6, and 3.2% of total costs. In the main growing region to the south we have budgets for 2001, 2004, and 2011 which show a decline in fumigation costs as a share of the total, from 6.0 to 5.7 to 3.1%, while net returns increased from 9.5 to 13.4% and then dropped to 2.2%. In the northernmost growing region, budgets for 2001, 2004 and 2010 show increasing fumigation costs (5.2, 5.4 and 6.9% of total costs, respectively) and fluctuating net returns (6.6, 9.4 and 4.0%). These numbers offer some insights into input and production costs, in particular suggesting weakly declining fumigation costs and yielding some evidence of declining net revenues in the most recent years, but we note that the sample budgets are designed to offer a general understanding of costs and revenues using current methods rather than to support rigorous economic analysis.

Critical Use Nominations themselves are another source of data on trends in production costs and revenues. The nominations through 2013 give a baseline yield rate for fumigation with 100% methyl bromide and discount it by some fraction for each alternative pest control regime. While detailed budgets are not provided, annual CUNs for CUEs also include estimates of the economic impacts of MeBr as compared to alternatives.[10] These estimates are developed to support the case that additional exemptions to use MeBr in California are needed to avoid 'significant market disruption,' which is a key part of the standard established in Decision IX/6 of the Montreal Protocol to define a use as critical. Alternatives are shown with associated yield estimates and implied costs to producers facing changed yields and other practices. For 2006–2013 CUNs, the baseline MeBr yield estimates fluctuate a bit, dropping by around 15% from 2006 to 2008 levels in 2009–2010 and then rising again for 2011–2013 nominations. Reported yields per hectare are well below those reported in the sample budgets referenced above, typically around 40–50,000 kg/ha in recent CUNs, with some alternatives in the 30–40,000 range in earlier nominations, while first year strawberry yields in the sample budgets are around 60–80,000 kg/ha and the most recent second year yield reported is over 50,000 kg/ha (UC Cooperative Extension, 2011c). The yield loss associated with moving from MeBr to a mixture of 1,3 dichloropropene (1,3 D) and chloropicrin is steady at 14% throughout, suggesting that the loss rate estimate was not revised over time but simply applied to the MeBr number for a given year. This alternative is the only one included in every nomination[11]; metam sodium (MS) and a mixture of Pic and MS were excluded from 2010 to 2009, respectively, and a mixture of Pic and MeBr was not added until the 2010 nomination. Iodomethane is included for the first time in the 2013 nomination.

Projected strawberry prices drop by about 30% from 2010 to the 2011 nomination estimates, and they remain at this low level through the 2013 nomination. This price, $1.37/kilogram,[12] is well below current and recent reported grower receipts (ERS, 2010); it is not clear why recent nominations have used such a low baseline price. This price drop helps explain why the estimated value of MeBr use as opposed to 1,3 D+Pic can be relatively stable, ranging between $43–68 per kilogram for 2006–2013 nominations, while the figure for "percentage loss in net revenues" swings up to 1269% in 2011 and subsequent years, after previously being estimated at 55 and 87%. While the loss to net revenue is appealing as a proxy for disruption suffered by growers, the nominations note that the

[9] In 2008, Mexico's MeBr consumption was below consumption allowed under the Montreal Protocol. As of 2010, those implementing the National Methyl Bromide Phase-Out Plan for Mexico (the United Nations Industrial Development Organization (UNIDO) along with the governments of Italy, Spain, and Canada) intended to eliminate the remaining MeBr (approximately 900 ODP tonnes) by 2012, provided requested monies from the Multilateral Fund were received. The plan initially proposed that the strawberry sector convert near the end of the phaseout because "strawberry growers were reluctant to reduce MB consumption" (UNEP, 2010, p. 5). However, Mexico's strawberry growers have since requested immediate assistance in order to accelerate completion of the phaseout.

[10] These figures are all reported in nominal dollars, as the requests are filed a few years in advance of the proposed use, and do not specify nominal or real figures. Additionally, many of the numbers do not change from year to year, suggesting that the precision of the estimates is not such that deflating them should drive conclusions.

[11] It is worth noting that the 1,3-D mix is not available to all growers, as many California townships restrict 1,3-D use (Carpenter et al., 2001) and some counties restrict Pic application. This may be why the extension service budgets above exclude it, and this may also make it difficult to draw statewide conclusions on the basis of variation in yield estimates between 1,3-D alone and in combination and MeBr.

[12] The CUN itself reports 'units'; we believe these to be kilograms based on matching with previous California nominations.

required gross revenues less operating costs are "difficult to measure and verify" (USDoS, 2004–2011). Net revenues are sensitive to the implied change in gross revenues of much lower strawberry prices even in the absence of significant cost shifts, and smaller net revenues produce bigger percentage changes for a given nominal cost increase or yield decrease.

As this article was being finalized for publication, the 2014 Critical Use Nomination for field strawberries in California was made public. It requests 415 metric tonnes of MeBr for field strawberries, a bit over a 20% decline from the request for 2013. The drop in requested acreage to be treated is about 50%, suggesting decreasing use of MeBr in combination with other chemicals and thus at higher rates, while the baseline fumigant in the economic impact table is now a mixture of MeBr and Pic rather than MeBr alone. The economic impact analysis shows no yield losses for any alternative, a substantially higher output price for growers of $2.51 per unit, a roughly 60% increase in reported yields to nearly 80,000 kg/ha, and greatly reduced or even negative loss measures. The estimated loss or gain as a percentage of net revenue ranges from 9% (for an alternative using iodomethane) to 5% across all reported alternatives (USDoS, 2012). Chloropicrin alone yields an increase in net revenue of 2% relative to the baseline. Thus the key driver of the request is now the limited access in some specific areas to use of some of the alternative fumigants, or the requirement for buffer zones around schools and residential areas. However, the township caps that limit 1,3 D are being reached in regions where strawberry acreage has grown substantially since the US agreement to phaseout methyl bromide. It is difficult to argue that a sub state regulatory decision that limits the amount of acreage in all crops that can be treated with certain pesticides represents a substantial disruption of the California strawberry market due to the elimination of methyl bromide.

It is interesting to note that with the exception of the 2006–2008 nominations the economic impact estimates in the CUNs assume no price gap per unit produced using MeBr and using alternatives. Wolverton (2012) indicates that in 2006–2008 the change in prices was used to reflect anticipated planting delays and subsequent later deliveries of crops to market for growers using alternative fumigation practices rather than broader market impacts. Constant output prices across alternatives with significantly differing yields suggest that these economic impact estimates assume no market price responses to significant supply swings (including projected yield losses of up to 30% for California growers, which would certainly affect the domestic and North American markets), and thus do not account for the significant amount of any cost increase that will be passed along to consumers as the market reaches a new equilibrium price (see Norman, 2005 for detailed discussion of the impact of relatively inelastic consumer demand for fresh strawberries on market prices and the distribution of the burden of rising production costs). If all acres not receiving exemptions were using alternatives with substantially lower yields and similar or increased costs, we would expect market prices to rise and moderate reductions in profits.

While we do not observe profits directly in the way that we do acreage and revenues, it is difficult to reconcile the history of CUN figures for California yields and costs using alternatives with the increasing use of alternatives and the increasing yields per acre and increases in total acreage noted above. The continued expansion in acres noted above is not consistent with an industry facing large losses as the phaseout continues; basic economics tells us that rising profits attract entry into an industry and falling profits drive exit, as more remunerative investments are sought for the land and capital previously employed in the failing sector. It seems likely that modifications of farming practices in concert with the use of non iodomethane MeBr alternatives have been increasingly successful at preserving yields in those areas that are doing without MeBr either altogether or at least in some years. Input substitution as the price of fumigation relative to other inputs into the strawberry growing process rises – altered weeding practices or schedules, perhaps, or alternate cultivars or crop rotations – would be expected to lower the costs of compliance with the phaseout process. We have found no evidence suggesting zero input substitution characterizes this industry, and any substitutability across inputs will reduce cost burdens on growers. Learning by doing should also lower costs and gaps in yields across different pest control strategies over time, as growers and fumigation contractors become accustomed to using alternatives. Further and perhaps most significantly, it seems that the calculations used to support the granting of CUEs in this sector do not allow for the ability of growers to share cost increases with consumers, who may by their numbers and relatively inelastic demand bear the majority of any remaining burden without individually experiencing price increases as economically disruptive.

6. Additional drivers of change and trends

While per capita consumption of fresh berries by Americans has continued to rise since 2004, it is not obvious that this is driven by rising per capita incomes as earlier data suggested to Norman (2005). Mean and median household and per capita income trends were disrupted by the global recession, with US median household income falling in 2008, 2009 and 2010, mean household income falling in 2007, 2008, 2009 and 2010, and per capita income falling in 2009 and 2010 (Historical income tables, www.census.gov). With a relatively short data period to contend with and a lack of detailed information about changes in income distribution

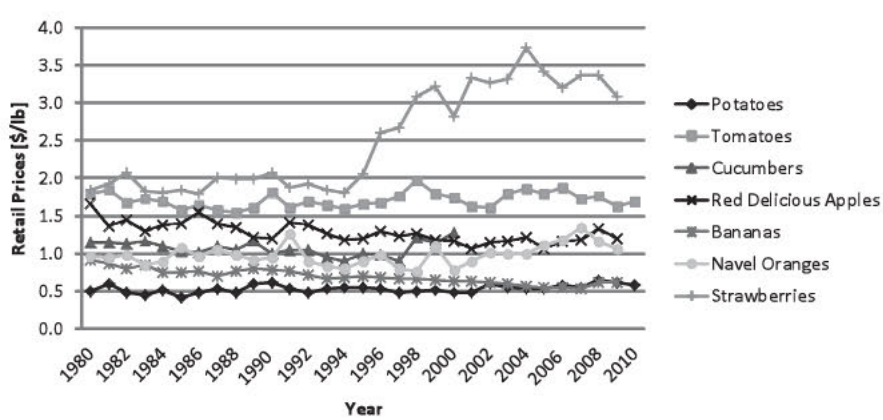

Fig. 3. US fruit and vegetable real retail prices.

and the relationship between income and strawberry consumption, disentangling trends in prices, consumption, and income to estimate relationships is imprecise.

One thing we do note in this market is that while prices of many fresh fruits and vegetables, including strawberries, have trended slightly downwards since 2008 (ERS, 2010 Table 12 and October 2011 Table A 7), over a longer time horizon, we observe a marked difference in fresh strawberry prices, which have increased by 85% from 1994 to 2008, compared to the prices of some other fruits and vegetables, which have largely been stable or increased to a much lesser extent (Fig. 3). Per capita consumption of fruits overall remained constant from 1994 to 2008, while per capita vegetable consumption initially increased from the mid 90s to 2000 but declined subsequently. This suggests that significantly increased strawberry consumption in the face of rising or stable prices in recent years is not likely to be driven by a decline in the price of strawberries relative to substitute fruits and vegetables. Changes in income, tastes, and preferences as well as the increased availability of strawberries at all times of the year are combining to support increased per capita and total strawberry consumption.

7. Conclusion

We offer an ex post analysis of the impact of the mandated phaseout process for methyl bromide on California strawberry growers to date. Ex ante estimates of the economic impact of the elimination of MeBr were required by and influential in the CUN and CUE processes, in contrast with either a benefit cost approach including public health and environmental protection gains, as required by many of the domestic environmental policies of Parties to the Montreal Protocol, or with the Essential Use Exemption process used for other ozone depleting substances eliminated earlier in the ozone protection regime. While this is not an ex post analysis of the originally expected complete phaseout, and thus cannot be directly compared with ex ante predictions based on the complete elimination of MeBr use, it does offer insight into the gap between predictions and outcomes of a strawberry industry moving away from this ozone depleting pesticide while facing import competition from a major trading partner with a more lenient phaseout schedule.

Contrary to many ex ante predictions and concerns expressed by stakeholders, California strawberry growers have thrived in recent years relative to both domestic and foreign competitors. They have successfully worked to ensure that MeBr has been available for significant fractions of their significantly expanded acreage, increased exports, and continued to enjoy rising yields and revenues as well as increased demand from consumers. The interim years between the planned elimination of MeBr and the increasing success of alternatives as detailed in the 2014 CUN and other reports have been years of expansion in the face of global recession and increased imports from Mexico, and successful navigation of technical and regulatory changes. Industry data suggests that the real burdens associated with changing agricultural practices have not kept this sector from profitability and growth in a challenging economic environment, though we cannot know how much faster growth might have been if MeBr use had continued unabated.

Alarming numbers in the CUNs sent to the Parties to the Montreal Protocol are not consistent with the success of California strawberry growers in aggregate as use of MeBr has been reduced. Nor are they consistent with basic economics. The 'economic disruption' standard of the CUE process was not intended to require the Parties to permit application of MeBr on new acreage to allow limitless expansion of a given industry using MeBr, and it is difficult to justify ongoing exemptions to support expansion rather than protect existing growers and growing regions. If all the new acres in production since 2005 are being managed profitably without MeBr, and existing acres are using less MeBr less often while overall and per acre yields and revenues rise steadily, it seems we have reached a point where alternatives are demonstrating successes for field strawberries in California.

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NATURAL RESOURCES DEFENSE COUNCIL

Testimony of David D. Doniger
Policy Director and Senior Attorney, Climate and Clean Air Program
Natural Resources Defense Council

Hearing on the U.S. Agricultural Sector Relief Act of 2012

Subcommittee on Energy and Power
Committee on Energy and Commerce
House of Representatives
July 18, 2012

Summary

- Protection of the ozone layer is a huge bi-partisan public health success story. The phase-out of ozone-destroying chemicals, including methyl bromide, is saving literally millions of Americans, and tens of millions of people around the world, from death and disease, from skin cancer, cataracts, and immune diseases. It is also saving farmers billions of dollars in UV-related crop losses.

- Now is not the time to tamper with the Montreal Protocol and the Clean Air Act. By slowing or even reversing the transition away from methyl bromide, "The U.S. Agricultural Sector Relief Act" will lead to more skin cancers, more cataracts, more immunological disease. It will benefit strawberry growers and others who have profited by abusing the "critical use exemption" for almost a decade. Thousands of other farmers growing other crops will suffer more UV-related crop losses as a result.

- Methyl bromide suppliers and users have dragged their feet on replacing this dangerous compound for two decades. No other industry has had more time and more leeway to transition from dangerous ozone-destroying chemicals.

- The United States is responsible for more than 90 percent of all methyl bromide exemptions. Every other strawberry- and tomato-growing country with California-like growing conditions – including Italy, Spain, Greece, and Australia – has ended use of methyl bromide. Mexican growers use less methyl bromide per acre than their California counterparts, and Mexico will end methyl bromide use entirely this year.

- California strawberry growers have done very well during the whole experience, according to a recent peer-reviewed economic study. Strawberry acreage is up 16% and yields are up 14% since 2004 despite significant reductions in methyl bromide allocations. So are U.S. grower prices and total crop values.

- U.S. critical use exemptions have been coming down. California strawberries are now the only field use for which the U.S. is still seeking critical use exemptions. Together with several structural and commodity uses, the total U.S. exemption request for 2014 is down to slightly more than 400 tons.

- The bill would do reckless damage in three major ways: First, it would permanently define as "critical uses" all of the uses that were labeled critical in 2005, even though the vast majority no longer even use methyl bromide. Absurdly, the bill would make even golf course turf grass a "critical use." It makes no sense to freeze into law an utterly out-dated list of "critical uses."

- Second, the bill relieves applicants of the need to show why they need exemptions. They could just submit their exemption wish lists without any supporting data. EPA then would bear the burden of gathering the data to support any reduction. Absent resources and data, EPA would have little choice but to forward the applicants' unsupported wish lists to the parties. This would be foolish even from the growers' perspective. It actually helps the U.S. government win approval for exemptions to have shown that it has exercised judgment and discipline in framing its requests, and has is not mechanically asked for everything its domestic applicants may have wanted.

- Third, the bill would blast an enormous new loophole into the Clean Air Act and our pesticide safety laws, by allowing any individual user to write his own ticket for up to 20 tons of methyl bromide

simply by asserting the existence of an "emergency." There could be a hundreds of emergency exemptions per year, totaling up to 2,000 tons per year (the 2011 critical use amount).

- This is a bad and unneeded bill. It would harm public health, harm other farmers, and indeed even harm the farmers it is intended to help. The process is working. This Committee should let well enough alone.

Thank you Chairman Whitfield and Ranking Member Rush for the opportunity to testify on behalf of the Natural Resources Defense Council on the proposed "U.S. Agricultural Sector Relief Act of 2012." Founded in 1970, NRDC is a national nonprofit environmental organization of scientist, lawyers, and environmental specialists with more than 1.3 million members and online activists, served from offices in New York, Washington, Chicago, San Francisco, Los Angeles, and Beijing. I am policy director of NRDC's Climate and Clean Air Program. I have been with NRDC twice, from 1978 through 1992 and from 2001 to the present. In the 1990's I served as director of climate change policy in the EPA Office of Air and Radiation. Relevant to the topic of today's hearing, I have worked on the phase-out of ozone-destroying chemicals for more than a quarter century.

There are few greater success stories than the global effort to phase out the ozone-damaging chemicals. Every American, and every citizen on this Earth, relies on the ozone layer to block dangerous ultraviolet radiation that causes skin cancer, cataracts, immune disorders and other diseases. The treaty to protect the ozone layer, known as the Montreal Protocol, has enjoyed bipartisan support from five presidents beginning with Ronald Reagan. So have the ozone layer protection provisions of the Clean Air Act. They are saving literally millions of Americans, and tens of millions of people around the world, from death and disease. They are also preventing billions of dollars in UV-related crop losses and other economic damages.

Yet the ozone shield is still being weakened by ozone-depleting chemicals that increase our exposure to dangerous UV radiation. Millions of Americans – including farmers – must work everyday in the sun. Millions more – from school children to seniors – spend hours of their days out of doors. Millions of concerned parents check the UV Index and cover their kids with sunscreen before letting them go out in the sun.

That brings us to methyl bromide. Methyl bromide is the most powerful ozone-depleter still in widespread use. All of the other more potent ozone-destroying chemicals have been successfully

eliminated – worldwide. Methyl bromide is also highly toxic, with inhalation or dermal exposure causing a wide range of acute and chronic effects, including death.

Mr. Chairman, I will not mince words. You are considering a bill to further slow the snail-like pace of the transition from this dangerous chemical – a bill that will lead to more skin cancers, more cataracts, more immunological disease, and more crop losses due to ozone-destruction and UV radiation, as well as more illness from direct exposure. Contrary to the bill's grandiose title, this bill will not broadly benefit "the U.S. agricultural sector." Indeed, thousands of farmers growing other crops will suffer more UV-related crop losses as a result. Instead, this bill will benefit only a small sliver of strawberry growers and few others who have profited handsomely by abusing the "critical use exemption" for the better part of a decade.

No industry has had more time and more leeway to transition from dangerous ozone-destroying chemicals than this one. The auto industry replaced CFCs in car air conditioners in less than four years. The electronics industry replaced ozone-depleting solvents in circuit board manufacture in less time than that. The air conditioning and refrigeration industry and the fire protection industry got rid of their potent ozone-depleters in well under a decade. Indeed, some of these industries have gone through two rounds of transitions to safer chemicals in the last 20 years. And all of these industries have been able to produce better, more energy-efficient, and more profitable products.

But methyl bromide stands apart. The producer and the users of this chemical have dragged their feet on replacing this dangerous compound for two decades. Let's review:

The phase-out of methyl bromide was supposed to be completed by 2001 pursuant to the 1990 Clean Air Act Amendments. With a decade of lead-time, growers and other users should have invested in developing and field testing other agents and other agricultural practices, like every other industry did. Their effort was minimal. And their minimal effort was rewarded by pushing the deadline back to 2005, in conjunction with amendments to the Montreal Protocol to phase out methyl bromide world-

wide. An post-2005 exemption was allowed for so-called "critical uses," but all observers then thought this would be just a small percentage of historical ("baseline") methyl bromide use, just as the "essential use" exemptions for other ozone-destroying chemicals had been only a small fraction of their baselines.

Indeed, other countries with comparable agricultural conditions played by those rules, submitting critical use exemption requests, if any at all, that reflected small fractions of their historical methyl bromide use levels. Only the U.S. took a different tack. In 2003, U.S. growers and others sought exemptions totaling some 15,000 tons, more than 60 percent of country's baseline use in the early 1990s. The U.S. government requested more than 10,000 tons of exemptions, and nearly broke the back of the Montreal Protocol. For the first time in its history, the parties were unable to come to a consensus decision. For the first time, there was an impasse that could not be resolved without calling an extraordinary meeting of the parties.

For eight years running, the United States alone has requested more than 90 percent of all exemptions. Over this period, nearly every other developed nation has eliminated its need for methyl bromide. Specifically, every other strawberry- and tomato-growing country with Mediterranean-like growing conditions – including Italy, Spain, Greece, and Australia – has moved beyond use of methyl bromide. Even Mexico – the California strawberry growers' only competitor – is committed to end its use of methyl bromide this year.[1]

Throughout this period, and here again today, the California strawberry growers have led the pack in coming to Congress playing the hardship violin. In fact, however, California strawberry growers have done very well during the whole experience, according to a recent peer-reviewed economic study by Erin N. Mayfield and Catherine Shelley Norman, published in the *Journal of Environmental*

[1] "The Government of Mexico has committed to achieve the complete phase-out of MB by the end of 2012." United Nations Environment Programme, Executive Committee of the Multilateral Fund for the Implementation of the Montreal Protocol, Sixty-sixth Meeting, Montreal, 16-20 April 2012, "Project Proposal: Mexico, National methyl bromide phase-out plan (third tranche), ¶9, http://www.multilateralfund.org/66/English/1/6641.pdf.

Management.[2] They have expanded their strawberry acreage and increased their yields dramatically despite significant reductions in methyl bromide allocations: California strawberry acreage in 2010 had increased 83 percent over 1991 levels and 16 percent over 2004. Yields per acre in 2010 increased 29 percent over 1991 levels and 14 percent over 2004. California's share of U.S. production also increased during this period, from about 80 percent in 1991 to more than 90 percent in 2010. U.S. grower prices and total crop values adjusted for inflation also increased during the exemption years.

The expansion of the strawberry acreage treated with methyl bromide is extremely troubling because it breaks a commitment made by the U.S. government not to allow such expansion. For instance, the "National Management Strategy for Methyl Bromide, United States of America, December 2005" states: "An important way that the United States addresses the issue of avoiding increases in MeBr use is our policy to disallow any increases in acreage or throughput that CUE applicants might include in their CUE request."[3] This turns out to have been a hollow promise.

The growers' complaints often center on the claim of unfair competition from Mexico. Throughout this period, however, Mexican growers used less methyl bromide per acre than their California counterparts, and Mexico, as I mentioned, has committed to stop using methyl bromide this year. Mayfield and Norman note that although strawberry imports from Mexico increased as the overall U.S. strawberry market grew, Mexico's share of total U.S. consumption did not increase significantly, and U.S. growers' strawberry exports to Canada rose by almost as much as imports from Mexico.

Mayfield and Norman also note that the economic analysis supporting the critical use nomination for 2014 – an analysis prepared by the strawberry growers – indicates that a range of alternatives to methyl bromide are effective and available at comparable cost and without yield losses.

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[2] E. Mayfield & C. Norman, *Moving away from methyl bromide: Political economy of pesticide transition for California strawberries since 2004,* Journal of Environmental Management, Vol. 106, Pp. 93-101 (2012), available at http://www.sciencedirect.com/science/article/pii/S0301479712001909, and attached to this testimony.
[3] http://www.epa.gov/ozone/mbr/downloads/MeBrNatMgmtStrat.pdf, p. 4.

Notably, these results do not depend on methyl iodide, which was withdrawn from the market by its manufacturer earlier this year.

As it turns out, the industry is still sitting on a stockpile of methyl bromide made before 2005 and stored in railroad cars in various communities around the country. Believe me, tank cars of highly toxic methyl bromide baking in the sun on rail sidings are not something I'd want in my community, or rolling through my Congressional district, yet few people know if they enjoy that privilege. As of today, the stockpile still exceeds 1,200 tons – three time the U.S. critical use nomination for 2014.

Why is the stockpile important? Because the rules of the road under the treaty are that a country may request permission to manufacture new methyl bromide to serve critical use needs only if it has exhausted its stockpiles. The industry attempted to conceal that stockpile from both the public and the government, and this led to the U.S. government's initially misrepresenting to the other Montreal Protocol parties in 2003 that there would be no stockpile left in 2005. But the true stockpile, divulged only later in response to an NRDC lawsuit, was nearly 13,000 tons – more than the entire amount the U.S. claimed to need for 2005. The methyl bromide stockpile has been used – illegally, in our view – for crops that no longer qualify as critical uses, such as golf course turf grass, and to exceed the critical use limits on crops such as strawberries. Each year since 2004, the stockpile has been larger than the next year's total critical use request. That is true for 2013 and 2014. The deception over the stockpile, once revealed, almost caused the breakdown of the treaty process, and the existence of a continuing stockpile is still a major irritant between the parties today.

NRDC acknowledges that the amounts of U.S. critical use exemptions have been coming down, however belatedly. Many growers and other users have finally taken up alternative chemicals and alternative pest management practices, so that we have now come to the point where the only field use for which a critical use nomination is still being made in 2014 is California strawberries. Together with several structural and commodity uses, the total U.S. exemption request is down to slightly more than

400 tons, as compared to nearly 10,000 tons in 2005. This progress, though long delayed, is noteworthy and must continue. Further progress is possible even in the short run, through practices such as greater use of impermeable films (something other countries have already adopted) and by continued adoption of alternatives.

In short, the process is working. Now is not the time to tamper with the methyl bromide phase-out requirements under Montreal Protocol and the Clean Air Act. Mr. Chairman, the bill before you would pointlessly weaken curbs on this dangerous ozone-destroying chemical, threaten the recovery of the ozone layer, and further strain our relations with other countries that are already experienced with U.S. abuse of critical use exemptions. The bill does reckless damage in at least three major ways:

First, the bill would permanently define as "critical uses" all of the uses that were labeled critical in 2005, regardless of the fact that the vast majority of those crops and applications have successfully transitioned to alternatives and no longer even use methyl bromide. Absurdly, the bill would make golf course turf grass a "critical use," even though the Bush administration's agriculture department dropped it from the list in 2006. Why in the world does it make sense to revive and freeze into law an utterly out-dated list of "critical uses"?

Second, since growers and other applicants are seeking exemptions for a chemical that is otherwise already banned under both domestic and international law, and since they are in the best position to innovate and test alternatives, they quite properly now bear the burden of showing the need for methyl bromide and the absence of economically practical alternatives. But the bill would turn that burden around. It would allow applicants to submit their wish lists for exemptions without providing any data in support. Even though this chemical is already supposed to be banned, the bill would then require EPA to shoulder the burden of developing the data to support any reduction from the growers' or other applicants' requests. As the growers would be quick to point out, EPA does not run farms, and EPA does not run alternatives testing programs.

Absent the resources and access to data, EPA would have little choice but to forward the applicants' wish lists to the parties for consideration. Even from the growers' perspective, this would be a fool's errand. It is difficult enough for the U.S. to gain approval for its out-sized exemption requests when it can bring a reasonably robust case forward for technical scrutiny by the other parties. It actually helps the U.S. win approval for exemptions to have shown that the government has exercised some judgment and discipline in framing its requests, and that the U.S. is not asking for everything its domestic applicants may have wanted.

Third, the bill would blast an enormous new loophole into the Clean Air Act and our pesticide safety laws, by allowing any individual user to write his own ticket for up to 20 tons of methyl bromide simply by asserting the existence of an emergency. "Emergency" is conveniently defined to mean any situation where someone wants to use more methyl bromide than is available under a critical use exemption, and where he declares that there is no alternative. The bill would allow a hundred 20-ton emergency exemptions per year, up to a total of 2,000 tons per year (the amount of critical use exemptions in 2011). This would be a massive abuse of the emergency exemption provision under the Montreal Protocol, which has been invoked only twice so far (once by Australia and once by Canada) in genuine emergencies.

Imagine, Mr. Chairman, how cool it would be to be able to withdraw more cash from the bank than you have in your account, just by calling it an emergency. There's another name for that: bank robbery.

This is a bad bill, and an unneeded bill. It would harm public health, harm other farmers, and indeed even harm the farmers it is intended to help. The process is working. This Committee should let well enough alone.

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Moving away from methyl bromide: Political economy of pesticide transition for California strawberries since 2004

Erin N. Mayfield [a], Catherine Shelley Norman [a,b,*]

[a] Department of Geography and Environmental Engineering, The Johns Hopkins University, 3400 North Charles Street, Baltimore, MD 21218, USA
[b] Department of Economics, The Johns Hopkins University, 3400 North Charles Street, Baltimore, MD 21218, USA

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ABSTRACT

We examine the progress of the phaseout of the use of the pesticide methyl bromide in the production of California field strawberries. This phaseout is required under the Montreal Protocol and has been contentious in this sector, which receives exemptions from the schedule initially agreed under the treaty, and in international negotiations over the future of the Protocol. We examine the various ex ante predictions of the impacts on growers, consumers and trade patterns in light of several years of declining allocations under the Critical Use provisions of the Protocol and the 2010 approval of iodomethane for use in California and subsequent 2012 withdrawal of this alternative from the US market. We find that, contrary to ex ante industry claims, the years of declining methyl bromide use have been years of rising yields, acreage, exports, revenues and market share for California growers, even when faced with a global recession and increased imports from Mexican growers who retain the right to use the chemical under the Protocol. This has implications for the Protocol as a whole and for the remainder of the US phaseout of this chemical in particular.

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1. Introduction and background

US fruit and vegetable growers using the fumigant methyl bromide (MeBr), scheduled for phaseout under the Montreal Protocol on Substances that Deplete the Ozone Layer, faced uncertainty about the cost and effectiveness of alternative chemicals and practices, and many of them applied for exemptions allowing continued use after the planned elimination of MeBr. This process was controversial – so much so that the United States suggested that they might withdraw from the Montreal Protocol, up to that point considered a model of successful international environmental policy, if their nominations for exemptions were not granted (Gareau and DuPuis, 2009). In the exemption process, which allowed exceptions to the scheduled 2005 complete phaseout date, one of the most contested uses was for strawberry farming, especially in California where many alternatives are strictly regulated or disallowed. Growers argued that none of the alternatives met the 'economic and technical feasibility' conditions of the Critical Use Exemption (CUE) rules. DeCanio and Norman (2005) discuss possible interpretations of the feasibility criteria at length, emphasizing that it cannot mean that no changes in costs or agricultural practices are required of methyl bromide users, but there is not a consensus definition of precisely what standard must be met.

Currently, the majority of CUEs for methyl bromide are allocated to the United States.[1] The share of field (rather than nursery) strawberries in total exemption requests has also grown; the 2014 US field strawberries nomination was for over 93% of the total US allocation, and was exclusively for use in California, which produces 90% of US strawberries (ERS, 2011c). In 2007 the same share was only 13% and more geographically dispersed, including uses in the southeastern US as well as California (USDoS, 2010, 2005, ozone.unep.org). Substitutes have been slower to develop in California,

* Corresponding author. Department of Geography and Environmental Engineering, The Johns Hopkins University, 3400 North Charles Street, Baltimore, MD 21218, USA. Tel.: +1 410 516 5184; fax: +1 410 516 8996.
E-mail addresses: erin.noel.mayfield@gmail.com (E.N. Mayfield), norman@jhu.edu (C.S. Norman).

[1] For the last seven years reported, 2007 2013, approved US CUEs have been more than 75% of non-Article 5 exemptions approved globally, so US strawberry uses are a significant amount of remaining global use of MeBr. In the first year of the exemption process, US allowances were a bit over 40% of total non-Article 5 allocations. For 2013, the United States has received over 90% of approved CUE allowances. Article 5 parties, which are, roughly speaking, less developed countries, do not have to complete phaseout until 2015, but their total use peaked in 1998, and by 2010 total consumption in Article 5 and non-Article 5 countries were approximately equal (exclusive of quarantine and pre-shipment uses, which are regulated separately and excluded from the discussion throughout this paper) (ozone.unep.org).

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due to different farming practices and a relatively stringent regulatory climate that has slowed the approval of some MeBr alternatives. The California strawberry crop is worth more than $2 billion annually and is the 6th highest valued fruit crop in the state, so while the industry is small at the national level it is economically significant in the region.[2]

California growers and those negotiating the CUE process on their behalf were deeply concerned that the main source of US imports of fresh strawberries, Mexico, would not be required to eliminate the use of MeBr at the same time that California growers were scheduled to. The Montreal Protocol allows delays in the elimination of ozone depleting substances for less developed countries, and growers feared that lowered trade barriers under NAFTA would combine with a technological advantage to Mexican growers using the fumigant, leading to dramatically increased imports of fresh strawberries and reduced sales of and/or prices for domestic berries.

This work investigates how the process of phaseout has affected the California field strawberry industry and finds that management and regulatory decisions at the international, national, and state levels have allowed California growers to maintain and enhance their dominance in the domestic and North American market as the phaseout has progressed. The period between the beginning of the methyl bromide phaseout and the availability of iodomethane, the closest thing to a 'drop in' substitute yet developed, for use in the state has been characterized by slow elimination of MeBr, rising acreage, yields and consumption, improved balance of trade, increasing domestic market share, and rising or relatively stable prices. Iodomethane itself has recently been voluntarily withdrawn from the US market, and we consider how this might affect our assessment of the phaseout process to date.

2. Ex-ante analyses of economic effects and political factors influencing phaseout

Economic analyses earlier in the process did not reach a consensus regarding the likely impacts of phaseout. Norman (2005) relied heavily on data from nominations for CUEs and found that trends in demand growth for fresh strawberries[3] and significant pass through of cost increases to consumers were expected to outweigh the stated negative effects of production cost increases associated with use of alternative fumigants, even in the absence of direct government support, under fairly conservative assumptions, and that increased consumer costs per household would be minimal, even if they were substantial in aggregate.

Carpenter et al. (2000) simulated production, consumption, and crop prices for methyl bromide users (e.g., California) and direct competitors (e.g., Mexico) – prior to and after the 2005 MeBr ban using a spatial partial equilibrium model. To simulate post ban conditions, shifts in production technology and corresponding changes in production costs and monthly yields were assumed.[4] Model results suggested that following a ban, US consumers would pay higher prices for strawberries and consume fewer of them. The increased price of strawberries would outweigh increases in CA production costs for growers and, when coupled with increased acreage devoted to CA strawberry production, CA strawberry growers' gross and net revenues would increase and remain stable, respectively.

Goodhue et al. (2005) and Carter et al. (2005), on the other hand, suggested that MeBr phaseout could cause significant problems for US or California growers. The former included field trials to estimate weed control costs using MeBr and various available alternatives but were unable to estimate yield losses from the use of MeBr alternatives directly, and concluded that acreage and thus supply would have to decline significantly to raise market prices enough to eliminate the net losses to remaining growers. The latter note that a single annual demand elasticity parameterization obscures important variation in seasonal demand and supply functions and can bias estimates of losses downward, with the most significant losses accruing between mid May and early July. Their simulation results suggest full season losses of between 4 and 20% of revenue, with a point estimate of around 12%, excluding revenue realized from lower valued crops as acreage in strawberries decline. Neither study considered longer term trends in the fresh strawberry market.

The design of these studies reflected concerns that Mexico, which provided (and continues to provide) more than 99% of imported fresh strawberries to the US (ERS, 2010, Table 14), was an Article 5 country under the Montreal Protocol and thus not required to eliminate MeBr until 2015, at which point their MeBr use would also have to comply with CUE standards to be permitted. NAFTA rules would make it hard to shield US growers from Mexican competition. Rising costs to US producers forced to transition away from their preferred fumigant could make Mexican imports more competitive over more of the year, reducing market share and revenues to domestic growers. Carpenter, Gianessi, and Lynch (2000) projected that after the 2005 ban – exemptions notwithstanding – increased acreage in Mexico devoted to strawberry production would be observed, and in the absence of land and water constraints, Mexico would continue to increase acreage and displace acreage in California.

On the regulators side, there was concern that significant exemptions would slow the phaseout and increase lobbying efforts at the expense of efforts to develop and implement alternate fumigation strategies. Using even the lowest estimate of the cost burden of the elimination of MeBr for California strawberries growers from Norman (2005) of $51[5] ha/year suggests that diversion of funds to directly unproductive rent seeking around CUE rights could be significant; the 2011 industry survey indicates that 15,145 ha are planted in strawberries in California, and less than 5% of that land is devoted to organic production (CSC, 2011). This implies that delays in phaseout for conventionally grown berries could be worth more than $700,000 annually (15,145 × .95 × $51 $733,775), and any successful efforts to secure delays that cost less than this amount are profit maximizing for the industry as a whole.

The California Strawberry Commission (CSC), the most active industry group, doubled (nominal) federal lobbying expenditures from $40,000 in each of 2001–2007 to $80,000 in 2008, and expenditures have remained at that level through 2010 (Center for Responsive Politics, 2011). State nominal lobbying expenditures were about $30,000 for the 2001–2002 legislative session, as decisions about initial CUE applications were being made, and then dropped to around $3000 for the next session, rising for each subsequent legislature to a level of about $20,000 in 2009–2010 (CalAccess, 2011). It is likely, of course, that only some of these

[2] http://www.californiastrawberries.com.

[3] We focus on fresh berries throughout; in the US, frozen berries are largely a residual crop (ERS, 2011c), and as they are not perishable this market operates quite differently. Large increases in the share of production going for frozen or otherwise processed berries might suggest quality issues associated with various changes to fumigation processes, but we do not observe this in the data.

[4] The model assumes that the best alternative technology which is assumed to be the technology resulting in the highest yield per acre for the lowest cost per acre is selected. Given that the study was completed in 2000, the best technologies projected at the time do not entirely correspond to the alternatives actually employed during the phaseout.

[5] All figures converted to 2010 dollars using the CPI unless otherwise noted.

efforts were focused on preserving MeBr phaseout exemptions for growers. We were not able to find evidence of significant lobbying expenditures for strawberry growers in other regions. While lobbying expenditures are one indicator of lobbying efforts, the rapidity of regulatory movement – in this case, the reduction timeline – may also be suggestive. The reduction timeline in California has been much less aggressive than in other US regions, which no longer use MeBr for field strawberries, and more broadly, the reduction timeline in the US has been much less aggressive than other non Article 5 parties. Taken together, the lobbying expenditures and reduction timeline suggest that if lobbying has slowed the phaseout of methyl bromide for strawberries in CA, it has been a rational investment for the industry, even if the costs of using alternative pesticides are a relatively small fraction of revenues and profits.

The Critical Use Exemption process involves stakeholders who use the regulated chemical, national nominations, and recommendations or analysis by the Technology and Economic Assessment Panel (TEAP) of the Montreal Protocol, leading to final amounts which must be approved by the Parties to the Protocol at their annual meeting. In the US, the Environmental Protection Agency (EPA) solicits yearly applications with supporting information on use patterns and economic impacts from growers, and then the Department of State submits these as Critical Use Nominations (CUNs). For the last year for which data are available – the nominations and final decisions for 2012 exemptions – the CSC requested permits to treat 4454 ha, which were passed on to the Parties to the Montreal Protocol, who approved 4421 of those hectares, albeit at a lower application rate than was originally requested.[6] If this smaller amount receives the low estimate of value from continued use of MeBr, CA growers have gained about $225,000 in 2012 by securing the 2012 exemptions, as well as slowing further phaseout and broader price impacts until their chief competitor in the North American fresh strawberry industry completes their phaseout. At this point Mexican growers presumably lose any price advantage gained by ongoing MeBr use, and alternative pest control practices will be more established in California.

Interestingly, this approved MeBr fumigation allowance for about 30% of California acreage annually could mean use over the majority of the growing region on an intermittent basis. The CSC notes that "[m]ethyl bromide is often being used in rotation with alternative fumigants. Many growers will use alternative fumigants for 2–3 years then rotate back to methyl bromide to clean up emerging weed and disease problems" (California Strawberry Commission, 2008. *Request for a critical use exemption for methyl bromide on strawberries for the 2011 use season.* Cited in 2013 US Field Strawberries CUN). While a move towards using MeBr every 2–3 years rather than annually is certainly a substantial reduction in MeBr applications, it is not a reduction in the geographic area reliant on MeBr as part of strawberry production, and thus reflects less progress towards achieving a permanent phaseout than the reported reductions in acreage needing treatment would suggest. Unobserved cooperation within the industry to produce this outcome would undermine the intent of the Parties to the Protocol, particularly as it could allow the use of MeBr on fields put into production after the beginning of phaseout. In California, 2009 acreage represented an increase of 89%, or 7600 ha, over the 1991 'baseline' year established for MeBr under the Protocol (ERS, 2010, Table 4). It is not possible to determine if new acreage is using MeBr on the basis of allocations currently in use, as these are not broken out by sector or sub state geographic regions by the US EPA once exemptions are granted (Federal Register, 2011). While the United States did articulate a policy of not allowing growth in CUNs due to new acreage (UNEP, 2005), they did not specify that new acreage reliant on MeBr was not allowed even if it did not drive increasing total amounts of requested MeBr, and so the continued decline in CUNs for this sector seems to satisfy this domestic policy.

While lobbying efforts are ongoing, the CSC and other industry groups also work closely with farmers and researchers developing and testing MeBr free growing methods. CSC reports research expenditures of over ten million dollars to date toward this end, presumably beginning in the early to mid 1990s, which suggests that research expenditures are a substantial part of the CSC budget (calstrawberry.com). Additionally, within regional nomination applications, research expenditures and funding resources have historically been reported and used to substantiate nominations.[7] Sufficient data to elicit trends in those expenditures is not available. Overall, it seems reasonable to deduce that investment in new technology hedged by investment in lobbying for continued exemptions represents an effective risk management strategy for growers and has been an influential driver of industry and regulator decision making.

The political economic and sociological issues around agricultural exemptions to the MeBr phaseout have been studied extensively. Clark (2001) offers an early analysis of the relationship between growers, the state of California, and the Federal EPA. Badulescu and Baylis (2006) consider the harmonization of pesticide rules under NAFTA and the possibility that that process has favored US strawberry producers. Kent Monning (2007) raises concerns about the environmental justice implications of the use of the CUE process in California.

More recently, DuPuis and Gareau (2008); Gareau (2008, 2010, 2012) and Gareau and DuPuis (2009) argue in a series of papers that increasing pressure to provide market solutions rather than command and control ones – as evinced partly by the economic justification for exemptions to agreed phaseout schedules, which was not allowed for the previously established 'Essential Use Exemptions' granted for other ozone depleting substances in earlier stages of the Protocol – undermined the later stages of the Montreal Protocol. They further suggest that an emphasis on the credibility of estimates of private costs over estimates of public benefits will drive decision making about exemptions in the future, while in the past a precautionary principle approach to the human and environmental risks associated with ozone depleting substances was more important. Stakeholder processes have been 'captured' to a significant degree by industry groups rather than involving a broader group more focused on the welfare of civil society as a whole. That this mode of discourse is so dominant in US policymaking is thus offered as an explanation for the ongoing use of significant amounts of MeBr in the US when other countries granted early exemptions have completed phaseout.

[6] The 2013 nominations proved very contentious in 2011; additional bilateral (including with the CSC as well as with representatives of affected nations) and TEAP meetings were added to the schedule and multiple submissions were revised and new research offered during the process (UNEP, 2011a). The decision in the advance draft report of the 23rd Meeting of the Parties reflects the MBTOC (the Methyl Bromide Technical Options Committee, part of the TEAP) recommendation (a 2013 exemption of 461.186 metric tons for field strawberries) but not that of the minority report offered by several members of the MBTOC (UNEP, 2011a,b), which recommended granting the full nomination amount (531.737 metric tons). Application rates used to calculate CUNs and CUEs and the availability of alternative pesticides in specific California growing regions were disputed within the TEAP and among governmental and nongovernmental stakeholders.

[7] Publically reported research expenditure information is incomplete CSC has reported research expenditures as Confidential Business Information, and detailed expenditure data are not typically reported in regional nominations.

3. Progress and barriers in eliminating MeBr under the Montreal Protocol

For the first year of CUNs, 2005, 28 countries nominated critical uses. This number has declined steadily and most recently, four nominating parties (the US, Japan, Australia, and Canada) requested CUEs for 2013 (UNEP, 2011). Global CUEs for non Article 5 countries have decreased by 94% since 2005. Use in Article 5 countries has also declined, falling below total non Article 5 use for the first time in 2007. This decline is partly due to the support of phaseout programs paid for by the Protocol's Multilateral Fund, which is not available to non Article 5 countries. 2010 MeBr use in Article 5 countries was 5.2% of the 1991 baseline.

Nominations by the US and requests for nominations from the California Strawberry Commission between 2005 and 2014 are shown in Fig. 1. The US, which has had the slowest average annual rate of decrease in MeBr usage of non Article 5 countries using the CUE process, had nonetheless reduced CUN amounts by 78% from 2003 to 2013. Although the US has been accelerating the MeBr phaseout in recent years, with a large drop in the 2014 nomination, a complete phaseout has not been planned and it remains unclear when complete phaseout will be achieved.

Within the US, California is now the only state still requesting critical use exemptions for field strawberries. Porter et al. (2006) conducted a global meta analysis of strawberry yields based on hundreds of studies and found that many alternatives produce "statistically equivalent yields" to MeBr, and thus worked to undermine arguments for exemptions related to technical feasibility. The resistance to phaseout of MeBr in California has centered on technical issues but also on economic feasibility and uncertainties associated with the availability of alternative fumigants – namely iodomethane. Approval of iodomethane for use in California was predicted for 2003, and then 2005 (Carter et al., 2005), but it was not actually available for use until December 2010. The failure of California to permit the use of iodomethane was a key rationale for the ongoing exemption request in that state (UNEP, 2011); this is consistent with the US not decreasing its CUN request between the nominating years 2010 and 2011. Since the registration of iodomethane in the 2011 growing season, however, only one California strawberry grower has used it, and that usage was small in scale (Wozniacka et al., 2012).

The registration of iodomethane by the US Environmental Protection Agency and the California Department of Pesticide Regulation was controversial due to potential public and occupational health hazards resulting from its use in pre plant soil applications. After first denying registration of iodomethane in April 2006, the US EPA granted a one year registration in October 2007 and, by 2008, licensed iodomethane for sale and use in the US with some restrictions on its application. Most states – with California the most notable exception – quickly followed suit by registering the fumigant. California eventually did approve the sale and use of iodomethane, but with restrictions more stringent than those imposed by the US EPA and other states. Legal challenges to the approval of this fumigant are ongoing, and an ongoing dialogue with respect to concerns about the registration of iodomethane persists between the general public, the US EPA, the California state legislature, and the risk assessment community, including government scientists involved in assessing the risk of iodomethane, a neurotoxin and possible carcinogen (Urevich, 2011). In early 2012, while no legal ruling against the use of iodomethane was made, the manufacturer announced that, based on an internal review of the fumigant and its economic viability in the U.S. marketplace, they would no longer sell this alternative fumigant in the United States and withdrew its registration in California (Chawkins and Marcum, 2012; ALC, 2012).

4. California strawberries today

US strawberries had record production levels in 2009; production, real value per unit and the total real value of the fresh strawberry crop have risen every year since 2004 according to the USDA (ERS, 2010, Table 1). Real US cash receipts have risen in every year from 2005 to 2010, the last year reported (ERS, 2011a, Table A 8). As noted above, acreage in California has also increased according to each of several data series (California Agricultural Resource Directory, 2010 2011, CSC, 2011; ERS, 2010), contrary to the predictions of declining acreage in the Carter et al. (2005) work and consistent with Carpenter et al. (2000). The ERS data go back the farthest and show that harvested acres of California strawberries have increased steadily since 1970. An OLS linear regression of acreage on time for 2001–2009 data fits well and yields an estimated increase of 650 ha/year; regressions including the earlier decades also show positive and significant trends but do not fit the data as well, suggesting that the time trend alone is not as explanatory over longer periods. These data show acreage increases in every year since 1997, with the exception of 2007, when they declined by less than 1%. Additionally, the ERS data show that the share of California acres in US strawberry acreage has grown steadily over time, from less than a third of the total in the early eighties, to more than half by the mid 90s and rising over two thirds in 2006, where it remains.

Productivity of planted acres has also risen during this time period. ERS data on California yields from 1970 to 2009 show steadily increasing output per acre (ERS, 2010 Table 4). This trend continues for years subsequent to the onset of efforts to eliminate MeBr, though yields are, predictably, subject to weather and other conditions and thus more volatile than acreage. The share of California production in total domestic production has also grown over the time period covered, and has hovered around record highs of 88–89% since 2003. More recently, the Fruit and Tree Nuts report notes of 2010 that "last year, the increase in average yields per acre

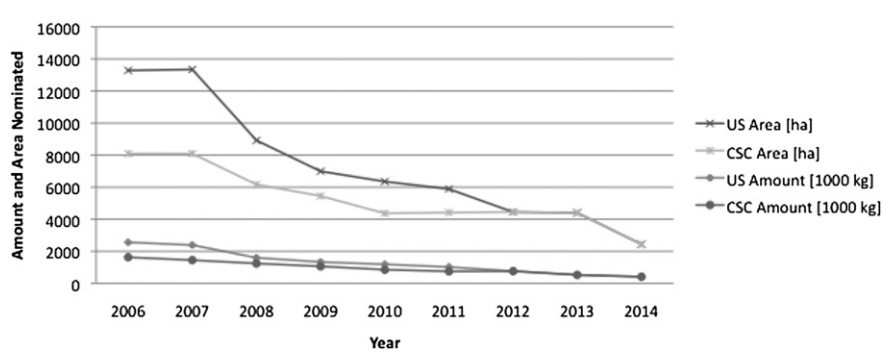

Fig. 1. US and California Critical Use Nominations, with MeBr requests and acreage.

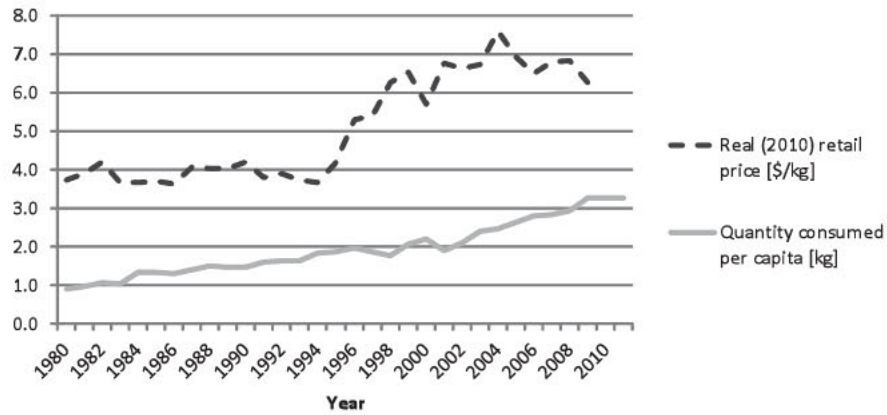

Fig. 2. US fresh strawberry prices and consumption.

in California (up 7 percent from 2009) more than made up for the decline in harvested acres (down 3 percent), resulting in a larger crop" (ERS, 2011c).

On the consumption side, we see that per capita consumption and total consumption of fresh and frozen strawberries continues to rise. In fact, per capita annual consumption of fresh strawberries has broken record levels in each year from 2003 to 2009 (ERS, 2011c; ERS, 2010, Table 12) even as real retail prices have stayed relatively stable or declined slightly. The most recent figures suggest an increase of 48% in per capita consumption of fresh berries since 2002, the last year covered in Norman (2005); with population growth that has amounted to a 67% increase in total US consumption over the same period. The continuing increase in per capita consumption as well as trends in real retail prices can be seen in Fig. 2.

We examine seasonal patterns in retail prices to evaluate hypotheses about patterns of trade raised in some of the ex ante studies discussed above. Real retail prices in June, the period identified by Carter et al. (2005) as most vulnerable to losses in a MeBr phaseout, rose in 5 of the 10 most recent years for which data are available (2000–2009). The average of real June retail prices from 2005 to 2009 was 1% higher than for 2000–2004, suggesting no significant change in the trend over time as a driver of this observation. Looking more closely, however, and in contrast with all but 3 of the preceding 24 years of available data, we note that for 2004–2008 May retail prices were higher than April prices, reversing again in 2009. Grower prices confirm this trend; for 2005–2011, May prices to growers for fresh berries were higher than April prices in 5 years and lower in two years (http://quickstats.nass.usda.gov).

While farming is subject to significant variability from year to year, both in the various growing regions domestically and abroad, this is suggestive of an increasingly competitive market in North America. Norman (2005) predicted that the pre 2005 gap between higher April prices and lower May prices was likely to decrease in size in the absence of methyl bromide. Ex post, we see that the gap has not just diminished but has reversed, while significant MeBr use continues. In the past, imports from Mexico peaked in April and domestic deliveries peaked in May or June. The historic drop in prices as domestic berries hit the markets in bulk suggested that exporting costs were high enough for Mexican growers that expanding exports during this period was relatively unattractive. In recent years, we have not observed a significant shift in strawberry acreage away from northern California growing areas, which deliver strawberries later in the season, and towards southern regions, where strawberries come in earlier (CSC, 2011), which might offer a domestic explanation for this shift in the pattern of relative prices throughout the year, so the currently observed pattern of relatively lower April prices is consistent with the US market becoming more attractive for Mexican growers wishing to export for more of the season or US growers facing rising costs in their peak production periods. It could also be that unobserved changes in crop timing associated with the use of MeBr alternatives have shifted the timing of peak deliveries in some parts of the state.

Investigating trends in imports and exports of fresh strawberries in more detail, however, does not provide strong supporting evidence for the hypothesis that increased Mexican imports are driving intra year changes in relative prices. Imports of fresh strawberries to the United States, almost exclusively from Mexico, have indeed grown substantially, continuing a trend observed well before MeBr restrictions began. They have more than doubled since 2004 (ERS, 2011b and Table G 1, ERS, 2011a). The share of Mexican imports in domestic consumption has changed less, however, trending slowly upward since the mid 1980s and now around 8%.[8] This may reflect increasing retail availability and consumption in the off seasons for domestic strawberries as well as increased April exports from Mexico.

United States exports also grew during this time, rising more than 50% from 2004 to 2010 (Table G 2, ERS, 2011a). The bulk of these exports go to Canada, which consumes considerably more strawberries than are produced there. The increase in tonnage of exports to Canada is very similar to the increase in imports from Mexico, suggesting that changing price patterns over time cannot be cleanly ascribed to trade advantages for Mexican growers selling in the United States. Domestic exports could well increase the scarcity of domestic berries at peak periods, driving domestic prices up. Strawberry exports do peak in May (ERS, 2011a, Tables G6–G8). Unfortunately, import and export data by month are only available for a few years, making it difficult to discern trends over time with confidence.

Also affecting trade patterns in North America may be the promulgation of Country of Origin Labeling (COOL) regulations in the United States (http://www.ams.usda.gov/AMSv1.0/COOL). For the 2009 and subsequent seasons all fresh strawberries sold in the United States were required to carry labels indicating where they were grown and packed. One expectation of supporters of this policy was that consumers would prefer domestic products over imports, and this may have reduced the vulnerability of California growers to cheaper imports from Mexico in particular. Carter and Zwane (2003) argue that this was in essence a (costly) protectionist policy. Van Ittersum et al. (2007) note that consumers may prefer domestic or local region products both because they believe them to be better or safer, or because they have a preference for

[8] Calculations based on ERS (2011b) yield slightly different shares than those given in ERS (October 2010, Table F-14).

supporting growers in geographic regions that they identify with. Either of these would help California growers and hurt Mexican exporters in the domestic market. While we cannot isolate any impact of this over the short period since the rules have been established, it remains clear that the majority of the US market continues to be served by domestic growers.

The MeBr alternative iodomethane has been approved for use in Mexico and a commercial launch there is planned for 2012 (ALC, 2010). As an Article 5 country, Mexico has until 2015 to phaseout MeBr under the Montreal Protocol; however, the government of Mexico has committed to completely phaseout methyl bromide by 2012 (UNEP, 2010),[9] by which point it seems likely that growers there will be able to use iodomethane and California growers will use continuing allocations of MeBr and any of several alternatives which show little to no yield changes in current research (summarized in USDoS, 2012). Costs for various production inputs and growing conditions will of course vary and be drivers of comparative advantage in international trade as with any commodity. It is unlikely that changes in land use in California or Mexico have been driven by an expectation of continued MeBr use in Mexico after it is curtailed in the United States.

Additionally, increases in imports may reflect changing trade advantages unrelated to MeBr phaseout in the United States. From 2002 to 2009, imports of Mexican lemons increased from negligible to a major trade commodity, increasing to 54 times initial levels. Avocados increased eleven fold, raspberries increased eight fold, pineapples were up 250%, and pecans and cocoanut meat also increased more rapidly than fresh strawberries. Tangerine, lime, and mango imports grew more slowly than strawberries but still rose significantly (ERS, 2011a, Table G 1). Trade changes driven by NAFTA or other drivers of increased globalization should not be ascribed to the ongoing MeBr phaseout without more substantial evidence than we are able to find.

5. California strawberry production cost estimates

Looking at the various sample budgets available from Cooperative Extension in California (UC Cooperative Extension, 2001a–c, 2004a–d, 2006, 2010, 2011a–b), we do not observe clear links between decreasing availability of MeBr and costs or profits. 2010 and earlier reports note that alternatives to MeBr are available and in use, but the sample budgets assume fumigation with MeBr and chloropicrin (or 'Pic'); Pic allows for significantly lower rates of MeBr application in areas where MeBr had previously been used alone. Of the two 2011 reports one notes that methyl bromide availability is limited and does not specify a fumigant in the line item budgets and the other uses Pic alone.

In the geographically central of the three largest growing regions, fumigation costs as a share of total costs were 2.4% in the 2001 sample budget, 3.7% in 2004, 3.5% in 2006 and 2.9% in 2011. For the same 3 years estimated net returns were 1.6, 14.2, 7.6, and 3.2% of total costs. In the main growing region to the south we have budgets for 2001, 2004, and 2011 which show a decline in fumigation costs as a share of the total, from 6.0 to 5.7 to 3.1%, while net returns increased from 9.5 to 13.4% and then dropped to 2.2%. In the northernmost growing region, budgets for 2001, 2004 and 2010 show increasing fumigation costs (5.2, 5.4 and 6.9% of total costs, respectively) and fluctuating net returns (6.6, 9.4 and 4.0%). These numbers offer some insights into input and production costs, in particular suggesting weakly declining fumigation costs and yielding some evidence of declining net revenues in the most recent years, but we note that the sample budgets are designed to offer a general understanding of costs and revenues using current methods rather than to support rigorous economic analysis.

Critical Use Nominations themselves are another source of data on trends in production costs and revenues. The nominations through 2013 give a baseline yield rate for fumigation with 100% methyl bromide and discount it by some fraction for each alternative pest control regime. While detailed budgets are not provided, annual CUNs for CUEs also include estimates of the economic impacts of MeBr as compared to alternatives.[10] These estimates are developed to support the case that additional exemptions to use MeBr in California are needed to avoid 'significant market disruption,' which is a key part of the standard established in Decision IX/6 of the Montreal Protocol to define a use as critical. Alternatives are shown with associated yield estimates and implied costs to producers facing changed yields and other practices. For 2006–2013 CUNs, the baseline MeBr yield estimates fluctuate a bit, dropping by around 15% from 2006 to 2008 levels in 2009–2010 and then rising again for 2011–2013 nominations. Reported yields per hectare are well below those reported in the sample budgets referenced above, typically around 40–50,000 kg/ha in recent CUNs, with some alternatives in the 30–40,000 range in earlier nominations, while first year strawberry yields in the sample budgets are around 60–80,000 kg/ha and the most recent second year yield reported is over 50,000 kg/ha (UC Cooperative Extension, 2011c). The yield loss associated with moving from MeBr to a mixture of 1,3 dichloropropene (1,3 D) and chloropicrin is steady at 14% throughout, suggesting that the loss rate estimate was not revised over time but simply applied to the MeBr number for a given year. This alternative is the only one included in every nomination[11]; metam sodium (MS) and a mixture of Pic and MS were excluded from 2010 to 2009, respectively, and a mixture of Pic and MeBr was not added until the 2010 nomination. Iodomethane is included for the first time in the 2013 nomination.

Projected strawberry prices drop by about 30% from 2010 to the 2011 nomination estimates, and they remain at this low level through the 2013 nomination. This price, $1.37/kilogram,[12] is well below current and recent reported grower receipts (ERS, 2010); it is not clear why recent nominations have used such a low baseline price. This price drop helps explain why the estimated value of MeBr use as opposed to 1,3 D+Pic can be relatively stable, ranging between $43–68 per kilogram for 2006–2013 nominations, while the figure for "percentage loss in net revenues" swings up to 1269% in 2011 and subsequent years, after previously being estimated at 55 and 87%. While the loss to net revenue is appealing as a proxy for disruption suffered by growers, the nominations note that the

[9] In 2008, Mexico's MeBr consumption was below consumption allowed under the Montreal Protocol. As of 2010, those implementing the National Methyl Bromide Phase-Out Plan for Mexico (the United Nations Industrial Development Organization (UNIDO) along with the governments of Italy, Spain, and Canada) intended to eliminate the remaining MeBr (approximately 900 ODP tonnes) by 2012, provided requested monies from the Multilateral Fund were received. The plan initially proposed that the strawberry sector convert near the end of the phaseout because "strawberry growers were reluctant to reduce MB consumption" (UNEP, 2010, p. 5). However, Mexico's strawberry growers have since requested immediate assistance in order to accelerate completion of the phaseout.

[10] These figures are all reported in nominal dollars, as the requests are filed a few years in advance of the proposed use, and do not specify nominal or real figures. Additionally, many of the numbers do not change from year to year, suggesting that the precision of the estimates is not such that deflating them should drive conclusions.

[11] It is worth noting that the 1,3-D mix is not available to all growers, as many California townships restrict 1,3-D use (Carpenter et al., 2001) and some counties restrict Pic application. This may be why the extension service budgets above exclude it, and this may also make it difficult to draw statewide conclusions on the basis of variation in yield estimates between 1,3-D alone and in combination and MeBr.

[12] The CUN itself reports 'units'; we believe these to be kilograms based on matching with previous California nominations.

required gross revenues less operating costs are "difficult to measure and verify" (USDoS, 2004–2011). Net revenues are sensitive to the implied change in gross revenues of much lower strawberry prices even in the absence of significant cost shifts, and smaller net revenues produce bigger percentage changes for a given nominal cost increase or yield decrease.

As this article was being finalized for publication, the 2014 Critical Use Nomination for field strawberries in California was made public. It requests 415 metric tonnes of MeBr for field strawberries, a bit over a 20% decline from the request for 2013. The drop in requested acreage to be treated is about 50%, suggesting decreasing use of MeBr in combination with other chemicals and thus at higher rates, while the baseline fumigant in the economic impact table is now a mixture of MeBr and Pic rather than MeBr alone. The economic impact analysis shows no yield losses for any alternative, a substantially higher output price for growers of $2.51 per unit, a roughly 60% increase in reported yields to nearly 80,000 kg/ha, and greatly reduced or even negative loss measures. The estimated loss or gain as a percentage of net revenue ranges from 9% (for an alternative using iodomethane) to 5% across all reported alternatives (USDoS, 2012). Chloropicrin alone yields an increase in net revenue of 2% relative to the baseline. Thus the key driver of the request is now the limited access in some specific areas to use of some of the alternative fumigants, or the requirement for buffer zones around schools and residential areas. However, the township caps that limit 1,3 D are being reached in regions where strawberry acreage has grown substantially since the US agreement to phaseout methyl bromide. It is difficult to argue that a sub state regulatory decision that limits the amount of acreage in all crops that can be treated with certain pesticides represents a substantial disruption of the California strawberry market due to the elimination of methyl bromide.

It is interesting to note that with the exception of the 2006–2008 nominations the economic impact estimates in the CUNs assume no price gap per unit produced using MeBr and using alternatives. Wolverton (2012) indicates that in 2006–2008 the change in prices was used to reflect anticipated planting delays and subsequent later deliveries of crops to market for growers using alternative fumigation practices rather than broader market impacts. Constant output prices across alternatives with significantly differing yields suggest that these economic impact estimates assume no market price responses to significant supply swings (including projected yield losses of up to 30% for California growers, which would certainly affect the domestic and North American markets), and thus do not account for the significant amount of any cost increase that will be passed along to consumers as the market reaches a new equilibrium price (see Norman, 2005 for detailed discussion of the impact of relatively inelastic consumer demand for fresh strawberries on market prices and the distribution of the burden of rising production costs). If all acres not receiving exemptions were using alternatives with substantially lower yields and similar or increased costs, we would expect market prices to rise and moderate reductions in profits.

While we do not observe profits directly in the way that we do acreage and revenues, it is difficult to reconcile the history of CUN figures for California yields and costs using alternatives with the increasing use of alternatives and the increasing yields per acre and increases in total acreage noted above. The continued expansion in acres noted above is not consistent with an industry facing large losses as the phaseout continues; basic economics tells us that rising profits attract entry into an industry and falling profits drive exit, as more remunerative investments are sought for the land and capital previously employed in the failing sector. It seems likely that modifications of farming practices in concert with the use of non iodomethane MeBr alternatives have been increasingly successful at preserving yields in those areas that are doing without MeBr either altogether or at least in some years. Input substitution as the price of fumigation relative to other inputs into the strawberry growing process rises – altered weeding practices or schedules, perhaps, or alternate cultivars or crop rotations – would be expected to lower the costs of compliance with the phaseout process. We have found no evidence suggesting zero input substitution characterizes this industry, and any substitutability across inputs will reduce cost burdens on growers. Learning by doing should also lower costs and gaps in yields across different pest control strategies over time, as growers and fumigation contractors become accustomed to using alternatives. Further and perhaps most significantly, it seems that the calculations used to support the granting of CUEs in this sector do not allow for the ability of growers to share cost increases with consumers, who may by their numbers and relatively inelastic demand bear the majority of any remaining burden without individually experiencing price increases as economically disruptive.

6. Additional drivers of change and trends

While per capita consumption of fresh berries by Americans has continued to rise since 2004, it is not obvious that this is driven by rising per capita incomes as earlier data suggested to Norman (2005). Mean and median household and per capita income trends were disrupted by the global recession, with US median household income falling in 2008, 2009 and 2010, mean household income falling in 2007, 2008, 2009 and 2010, and per capita income falling in 2009 and 2010 (Historical income tables, www.census.gov). With a relatively short data period to contend with and a lack of detailed information about changes in income distribution

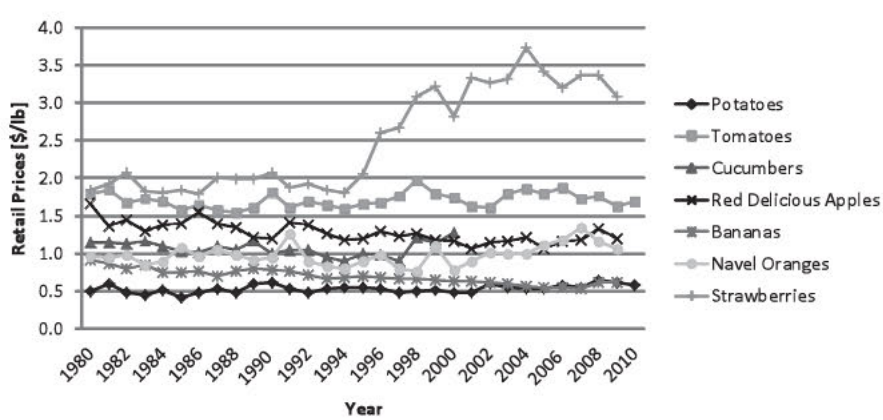

Fig. 3. US fruit and vegetable real retail prices.

and the relationship between income and strawberry consumption, disentangling trends in prices, consumption, and income to estimate relationships is imprecise.

One thing we do note in this market is that while prices of many fresh fruits and vegetables, including strawberries, have trended slightly downwards since 2008 (ERS, 2010 Table 12 and October 2011 Table A 7), over a longer time horizon, we observe a marked difference in fresh strawberry prices, which have increased by 85% from 1994 to 2008, compared to the prices of some other fruits and vegetables, which have largely been stable or increased to a much lesser extent (Fig. 3). Per capita consumption of fruits overall remained constant from 1994 to 2008, while per capita vegetable consumption initially increased from the mid 90s to 2000 but declined subsequently. This suggests that significantly increased strawberry consumption in the face of rising or stable prices in recent years is not likely to be driven by a decline in the price of strawberries relative to substitute fruits and vegetables. Changes in income, tastes, and preferences as well as the increased availability of strawberries at all times of the year are combining to support increased per capita and total strawberry consumption.

7. Conclusion

We offer an ex post analysis of the impact of the mandated phaseout process for methyl bromide on California strawberry growers to date. Ex ante estimates of the economic impact of the elimination of MeBr were required by and influential in the CUN and CUE processes, in contrast with either a benefit cost approach including public health and environmental protection gains, as required by many of the domestic environmental policies of Parties to the Montreal Protocol, or with the Essential Use Exemption process used for other ozone depleting substances eliminated earlier in the ozone protection regime. While this is not an ex post analysis of the originally expected complete phaseout, and thus cannot be directly compared with ex ante predictions based on the complete elimination of MeBr use, it does offer insight into the gap between predictions and outcomes of a strawberry industry moving away from this ozone depleting pesticide while facing import competition from a major trading partner with a more lenient phaseout schedule.

Contrary to many ex ante predictions and concerns expressed by stakeholders, California strawberry growers have thrived in recent years relative to both domestic and foreign competitors. They have successfully worked to ensure that MeBr has been available for significant fractions of their significantly expanded acreage, increased exports, and continued to enjoy rising yields and revenues as well as increased demand from consumers. The interim years between the planned elimination of MeBr and the increasing success of alternatives as detailed in the 2014 CUN and other reports have been years of expansion in the face of global recession and increased imports from Mexico, and successful navigation of technical and regulatory changes. Industry data suggests that the real burdens associated with changing agricultural practices have not kept this sector from profitability and growth in a challenging economic environment, though we cannot know how much faster growth might have been if MeBr use had continued unabated.

Alarming numbers in the CUNs sent to the Parties to the Montreal Protocol are not consistent with the success of California strawberry growers in aggregate as use of MeBr has been reduced. Nor are they consistent with basic economics. The 'economic disruption' standard of the CUE process was not intended to require the Parties to permit application of MeBr on new acreage to allow limitless expansion of a given industry using MeBr, and it is difficult to justify ongoing exemptions to support expansion rather than protect existing growers and growing regions. If all the new acres in production since 2005 are being managed profitably without MeBr, and existing acres are using less MeBr less often while overall and per acre yields and revenues rise steadily, it seems we have reached a point where alternatives are demonstrating successes for field strawberries in California.

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Points of Testimony

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3. Asthma, COPD and Acute Bronchitis can occur in the middle of the night, on weekends, during hikes, picnics, excursions, or camps far from cities. Severe Asthma flare-ups and COPD/ Bronchitis flare-ups can cause critical, sometimes progressive shortness of breath that can lead to death and very severe distress if untreated. Asthma especially is allergy and exercise triggered. Picnicking near a hay field, visiting relatives with cats, cleaning a moldy basement or dusty carpet can trigger severe life-threatening asthma flare-ups. Exercise also triggers flares. These generally require immediate treatment, usually with 2-4 puffs of a rescue bronchodilator given within minutes of the onset of airway obstruction. Death from asthma can occur within as little as 20 minutes (due to hypoxia, or starving for air) if asthma and bronchospasm are not rapidly treated.
4. Every patient with Asthma and COPD should carry with them a rescue bronchodilator (such as albuterol HFA inhaler or epinephrine CFC inhaler) per Guidelines of U.S. and Global Asthma and COPD organizations.
5. Since Acute Asthma, Acute COPD and Acute Bronchitis are potential medical emergencies requiring immediate treatment, *over-the-counter therapies can play a key life-saving role* when patients have a flare-up.
6. Another similar emergency condition is acute bee sting anaphylaxis, or food, shrimp or peanut anaphylaxis, or acute allergy to penicillin or another drug. In all these cases there are readily available over-the-counter medicines, Benadryl (dephenhydramine), other antihistamines, (cetirizine, loratidine, fexofenadine), decongestants like Sudafed (pseudoephedrine available OTC in some states), and other rescue-relief medicines that patients can give themselves within minutes in an emergency.

7. This is a key point. Patients have a fundamental right to self-treatment, to try to heal or treat themselves in whatever ways they can, before they resort to the expense and inconvenience of seeing a doctor. This is a fundamental part of American values and American self-reliance, what we might call the Pioneer American Spirit; Americans have a right to treat themselves first and foremost with whatever remedies are available. We would never have settled the Midwestern, Southern, or Western U.S. without this spirit. Many Americans today in Montana, Colorado, California, Idaho, Arizona, Michigan, Wisconsin, Alabama, Georgia, Oregon, etc., live on rural ranches and farms miles from any doctor or hospital. Americans have a fundamental right to treat ourselves, at least with initial emergency first aid treatments. This is who we are.
8. Historically 60-100 years ago asthma was fortunately rare, and was notoriously difficult to treat. Patients smoked asthma cigarettes with anti-cholinergic medicines. They downed theophylline pills and teas, breathed in steam and struggled to take showers, trying to ease their breathing. These were truly the "dark ages" of asthma care. And many Americans died if their severe asthma did not resolve.
9. For 49 years, through four generations, over-the-counter rescue breathing medicines have been readily available OTC to Americans with Asthma or COPD or Bronchitis flare-ups. Primatene Mist (CFC) was released in about 1963. Other brands of inhalers and pills containing epinephrine have also been available over-the-counter to any person without a doctor's appointment for nearly 50 years.
10. Only now as of December 31, 2011, has the U.S. EPA and FDA banned pharmacies in the U.S. from selling Primatene Mist (CFC) or any other inhaled epinephrine products.

11. Let me make this clear. As of January 1, 2012, there are no OTC rescue asthma medicines in U.S. pharmacies whatsoever. There are none.
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14. You can think of an OTC rescue inhaler like epinephrine inhaler (Primatene Mist) as *a life preserver* for patients with severe flare-ups of asthma, COPD or acute bronchitis.
15. Just as on the *Titanic* or the *Costa Concordia*, people don't think about life preservers until they are drowning. Is it really right to lock up all the life preservers and give the only keys to a ship's doctor or a ship's Captain? As my teenage son says, good luck with that.

16. Rescue inhalers like Epinephrine (inhaled CFC or eventually HFA) should continue to be available over-the-counter to Americans without a requirement for a doctor's visit or a prescription or an ER visit. This is basically a "First Aid" medicine, like a band-aid for a cut, or Benadryl for a bee sting, or a Heimlich maneuver for a choking person. There need to continue to be over-the-counter, fast acting rescue bronchodilators available to Americans in need. They have had these continuously available since 1963. Only in January 2012 did the EPA and FDA prematurely withdraw CFC Primatene Mist inhaler without ensuring that there were alternative OTC rescue inhalers for patients with acute Asthma, COPD and Bronchitis.
17. The EPA and FDA have raided your "First Aid Kit," and removed a key rescue inhaler therapy. An extension on the withdrawal of Primatene Mist (CFC) for two years or 18 months is needed to allow an alternative HFA Epinephrine inhaler to be developed and to be approved for over-the-counter use by all Americans.

Thank you for your attention.

Edward M. Kerwin, MD

Summary

Testimony of Edward Kerwin, MD
Senior Medical Director, Allergy & Asthma Center of Southern Oregon, PC

- Asthma, COPD and Acute Bronchitis effect more than 30 million Americans. They cause episodic severe breathlessness requiring the use of rescue bronchodilator inhalers.
- For 49 years Americans have had an over-the-counter (OTC) rescue inhaler alternative, called Primatene Mist (epinephrine) with a chlorofluorocarbon (CFC) propellant. CFC Primatene Mist has been available for four generations of Americans, since 1963.
- The first principal of medicine is that patients have a right to treat themselves, to render first aid, to try to heal their own health before they go to any doctor or ER. This is a fundamentally American value, and how our rural frontiers were settled. Americans have a right to treat themselves through first aid in emergencies.
- OTC Inhaled Epinephrine (CFC) is a lifesaving rescue medicine for acute asthma, COPD, albuterol. This is similar to the role Benadryl plays for bee sting, peanut, or penicillin anaphylactic reactions. Such rescue medicines need to be available over-the-counter. There should be no "locking up" of these life preserving medicines in pharmacies and doctors' offices. They are needed promptly within minutes, in the middle of the night, in rural areas, in inner cities, by the poor and infirm, by Americans who may have no rapid medical access to a doctor or hospital.
- An 18 month to two year extension of the licensing of OTC Primatene Mist (CFC) inhaler in the U.S. will allow time for a suitable HFA (hydrofluoroalkane) replacement to be developed as an OTC rescue inhaler for Asthma, COPD, and bronchitis patients, available to all Americans.

Points of Testimony

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4. Every patient with Asthma and COPD should carry with them a rescue bronchodilator (such as albuterol HFA inhaler or epinephrine CFC inhaler) per Guidelines of U.S. and Global Asthma and COPD organizations.
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16. Rescue inhalers like Epinephrine (inhaled CFC or eventually HFA) should continue to be available over-the-counter to Americans without a requirement for a doctor's visit or a prescription or an ER visit. This is basically a "First Aid" medicine, like a band-aid for a cut, or Benadryl for a bee sting, or a Heimlich maneuver for a choking person. There need to continue to be over-the-counter, fast acting rescue bronchodilators available to Americans in need. They have had these continuously available since 1963. Only in January 2012 did the EPA and FDA prematurely withdraw CFC Primatene Mist inhaler without ensuring that there were alternative OTC rescue inhalers for patients with acute Asthma, COPD and Bronchitis.
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Edward M. Kerwin, MD

Summary

Testimony of Edward Kerwin, MD
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- Asthma, COPD and Acute Bronchitis effect more than 30 million Americans. They cause episodic severe breathlessness requiring the use of rescue bronchodilator inhalers.
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- OTC Inhaled Epinephrine (CFC) is a lifesaving rescue medicine for acute asthma, COPD, albuterol. This is similar to the role Benadryl plays for bee sting, peanut, or penicillin anaphylactic reactions. Such rescue medicines need to be available over-the-counter. There should be no "locking up" of these life preserving medicines in pharmacies and doctors' offices. They are needed promptly within minutes, in the middle of the night, in rural areas, in inner cities, by the poor and infirm, by Americans who may have no rapid medical access to a doctor or hospital.
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6. Another similar emergency condition is acute bee sting anaphylaxis, or food, shrimp or peanut anaphylaxis, or acute allergy to penicillin or another drug. In all these cases there are readily available over-the-counter medicines, Benadryl (dephenhydramine), other antihistamines, (cetirizine, loratidine, fexofenadine), decongestants like Sudafed (pseudoephedrine available OTC in some states), and other rescue-relief medicines that patients can give themselves within minutes in an emergency.

7. This is a key point. Patients have a fundamental right to self-treatment, to try to heal or treat themselves in whatever ways they can, before they resort to the expense and inconvenience of seeing a doctor. This is a fundamental part of American values and American self-reliance, what we might call the Pioneer American Spirit; Americans have a right to treat themselves first and foremost with whatever remedies are available. We would never have settled the Midwestern, Southern, or Western U.S. without this spirit. Many Americans today in Montana, Colorado, California, Idaho, Arizona, Michigan, Wisconsin, Alabama, Georgia, Oregon, etc., live on rural ranches and farms miles from any doctor or hospital. Americans have a fundamental right to treat ourselves, at least with initial emergency first aid treatments. This is who we are.
8. Historically 60-100 years ago asthma was fortunately rare, and was notoriously difficult to treat. Patients smoked asthma cigarettes with anti-cholinergic medicines. They downed theophylline pills and teas, breathed in steam and struggled to take showers, trying to ease their breathing. These were truly the "dark ages" of asthma care. And many Americans died if their severe asthma did not resolve.
9. For 49 years, through four generations, over-the-counter rescue breathing medicines have been readily available OTC to Americans with Asthma or COPD or Bronchitis flare-ups. Primatene Mist (CFC) was released in about 1963. Other brands of inhalers and pills containing epinephrine have also been available over-the-counter to any person without a doctor's appointment for nearly 50 years.
10. Only now as of December 31, 2011, has the U.S. EPA and FDA banned pharmacies in the U.S. from selling Primatene Mist (CFC) or any other inhaled epinephrine products.

11. Let me make this clear. As of January 1, 2012, there are no OTC rescue asthma medicines in U.S. pharmacies whatsoever. There are none.
12. So if you have an acute bee sting allergy in the forest, or at night, or in the inner city, or as an elderly person in your home, you can still get Benadryl, Zyrtec, Claritin or Allegra at any local 7-11 store or gas station.
13. But if you get an acute asthma flare-up on a hike in rural America, in the inner city, at night or on a weekend, you are out of luck. Maybe you can get an immediate doctor's appointment within 20 minutes…. As my teenage son would say, good luck with that. Maybe you are super organized and already have a prescription asthma/COPD rescue medicine like prescription albuterol HFA with you. But we all know that up to half of Americans are not so organized with their healthcare. Maybe you can treat yourself with "dark ages" treatments (see item 8 above). But even though for 50 years rescue epinephrine has been available OTC to every American, now there is no rescue inhaler that you can get in rural America, in the West, South, Midwest, or Northeast, in inner cities, or for poor or elderly patients with poor mobility.
14. You can think of an OTC rescue inhaler like epinephrine inhaler (Primatene Mist) as *a life preserver* for patients with severe flare-ups of asthma, COPD or acute bronchitis.
15. Just as on the *Titanic* or the *Costa Concordia*, people don't think about life preservers until they are drowning. Is it really right to lock up all the life preservers and give the only keys to a ship's doctor or a ship's Captain? As my teenage son says, good luck with that.

16. Rescue inhalers like Epinephrine (inhaled CFC or eventually HFA) should continue to be available over-the-counter to Americans without a requirement for a doctor's visit or a prescription or an ER visit. This is basically a "First Aid" medicine, like a band-aid for a cut, or Benadryl for a bee sting, or a Heimlich maneuver for a choking person. There need to continue to be over-the-counter, fast acting rescue bronchodilators available to Americans in need. They have had these continuously available since 1963. Only in January 2012 did the EPA and FDA prematurely withdraw CFC Primatene Mist inhaler without ensuring that there were alternative OTC rescue inhalers for patients with acute Asthma, COPD and Bronchitis.
17. The EPA and FDA have raided your "First Aid Kit," and removed a key rescue inhaler therapy. An extension on the withdrawal of Primatene Mist (CFC) for two years or 18 months is needed to allow an alternative HFA Epinephrine inhaler to be developed and to be approved for over-the-counter use by all Americans.

Thank you for your attention.

Edward M. Kerwin, MD

Summary

Testimony of Edward Kerwin, MD
Senior Medical Director, Allergy & Asthma Center of Southern Oregon, PC

- Asthma, COPD and Acute Bronchitis effect more than 30 million Americans. They cause episodic severe breathlessness requiring the use of rescue bronchodilator inhalers.
- For 49 years Americans have had an over-the-counter (OTC) rescue inhaler alternative, called Primatene Mist (epinephrine) with a chlorofluorocarbon (CFC) propellant. CFC Primatene Mist has been available for four generations of Americans, since 1963.
- The first principal of medicine is that patients have a right to treat themselves, to render first aid, to try to heal their own health before they go to any doctor or ER. This is a fundamentally American value, and how our rural frontiers were settled. Americans have a right to treat themselves through first aid in emergencies.
- OTC Inhaled Epinephrine (CFC) is a lifesaving rescue medicine for acute asthma, COPD, albuterol. This is similar to the role Benadryl plays for bee sting, peanut, or penicillin anaphylactic reactions. Such rescue medicines need to be available over-the-counter. There should be no "locking up" of these life preserving medicines in pharmacies and doctors' offices. They are needed promptly within minutes, in the middle of the night, in rural areas, in inner cities, by the poor and infirm, by Americans who may have no rapid medical access to a doctor or hospital.
- An 18 month to two year extension of the licensing of OTC Primatene Mist (CFC) inhaler in the U.S. will allow time for a suitable HFA (hydrofluoroalkane) replacement to be developed as an OTC rescue inhaler for Asthma, COPD, and bronchitis patients, available to all Americans.

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Washington Office
1150 18th Street, N.W.
Suite 300
Washington, D.C. 20036-3816
P. (202) 296 - 9770
F. (202) 296 - 9776
www.thoracic.org

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25 Broadway, 18th Floor
New York, NY 10004
P. (212) 315 - 8600
F. (212) 315 - 6498

Testimony of the American Thoracic Society before the Energy and Power Subcommittee of the House Energy and Commerce Committee

Presented by Monica Kraft, MD
President of the American Thoracic Society
Wednesday, July 18, 2012.

I am Monica Kraft MD, and I am a professor of Medicine at Duke University and current president of the American Thoracic Society. As both a researcher and a clinician, I have spent most of my professional life dedicated to the diagnosis and management of patients with asthma and I direct the Duke Asthma, Allergy and Airway Center at Duke. It is with this professional and scientific background that I offer to present testimony of the American Thoracic Society on legislation to restore epinephrine inhalers back on the U.S. market place. It is my strongly held view and the view of the American Thoracic Society, that returning epinephrine inhalers to the U.S. market, even for a limited time, would be ill advised.

This view is shared by several other physician organizations including, the American Academy of Allergy Asthma and Immunology, the American College of Asthma Allergy and Immunology, the American Association of Respiratory Care and the National Association for the Medical Direction of Respiratory Care.

Asthma

As background, asthma is common and potentially life threatening medical condition where the airways of lung are inflamed, severely restricting air flow to the lung. For many people with asthma, it can feel like breathing through a straw.

Asthma effects between 5 and 10% of the population, so most everyone knows someone who has asthma. Therefore, over 24.6 million Americans have physician diagnosed asthma, including 7.1 million children. While the majority of asthma patients can and will successfully manage their asthma, every year, people die as a result of asthma attacks.

In the lung, the airways are inflamed, which means they are red and swollen which can cause them to narrow then and restrict airflow. The focus of asthma treatment is with anti-inflammatory medications, such as inhaled corticosteroids. In addition, medications that cause the airways to widen (bronchodilate) are also used. In more severe asthma, , physicians try a combination of other drugs to treat asthma which may include medications to more directly treat allergic symptoms, or in the most severe cases, oral corticosteroids such as prednisone,.

Health care professionals play an important role in educating patients about their asthma, including asthma triggers like tobacco smoke, air pollution, and allergens such as pet dander, cockroaches and dust mites, to find the right combination of medications, along with proper drug administration techniques to help people with asthma live full, active lives.

The take away message is that in the majority of cases, asthma can be successfully treated by working with health care professionals to find the right combination of safe and effective medications.

Epinephrine is NOT one of the medications that is considered safe for the treatment of asthma.

Epinephrine

Epinephrine is non-selective bronchodilator. This means that it has effects not only in the lung to bronchodilate but its non-selective nature means it has effects upon other organs such as the heart. Therefore, epinephrine or Primatene® can cause a significantly increased heart rate. This unwanted side effect can lead to cardiac stress and heart attacks in older patients or patients with heart disease.

For years the medical community has recognized the dangerous side effects of epinephrine for the treatment of asthma and has recommended against it use for asthma. In 1999 the American Medical Association 1) urged that warning labels on over the counter epinephrine

inhalers be strengthened to warn patients about the dangers of epinephrine use, 2) encouraged FDA to consider removing inhaled epinephrine from the market and 3) requested studies to determine whether the availability of inhaled epinephrine is a risk factor in asthma morbidity and mortality. The American Medical Association again reaffirmed this position in 2009.

Several expert panels have produced recommendations on the treatment of patients with asthma. None of the expert guidelines recommend the use of inhaled epinephrine --like Primatene Mist--to treat asthma. The National Asthma Education and Prevention Program (NAEPP), an expert panel convened by the National Institutes of Health, has issued treatment guidelines for management of asthma. NAEPP recommends against the use of epinephrine for treating asthma exacerbations stating:

> "Drugs of choice for acute bronchospasm: Inhaled route has faster onset, fewer adverse effects, and is more effective than systemic routes. The less beta2-selective agents (isoproterenol, metaproterenol, isoetharine, and **epinephrine***)* are not recommended due to their potential for excessive cardiac stimulation, especially in high doses. (*emphasis added)*(2)

The American Thoracic Society strongly encourages any patient who is using over the counter medications--like Primatene Mist CFC--to treat their asthma to see a healthcare provider who can help the patient develop an asthma management plan and recommend more effective and safer medications to manage the asthma. Asthma action plans are dynamic plans that help guide a patient on how to manage their asthma on good days, bad days and those days in between. I have attached a sample asthma action plan with my testimony.

Pending Legislation

One of the goals of today's hearing is to discuss the pros and cons of enacting legislation to either permanently or temporarily restore inhaled epinephrine for the treatment of asthma to the U.S. market. If the intent of the legislation is to restore a safe and effective asthma drug to the market place, then this legislative effort is mis-informed. Inhaled epinephrine is not a safe drug for the treatment of asthma. The adverse side effects of epinephrine are serious and well documented. No current clinical practice guideline for the diagnosis and treatment of asthma recommends the use of epinephrine. In fact, asthma guidelines specifically recommend against inhaled epinephrine for treating asthma.

If the legislative intent is to provide access to an inexpensive drug for the treatment of asthma, then the legislative effort is laudable, but mis-directed. Inhaled epinephrine's risks outweigh its benefits.

I am also concerned about sending a very confusing message to patients. Physicians, drug makers and retailers have spent a lot of time and effort educating patients about the Primatene Mist transition and treatment alternatives patients have now that Primatene Mist is no longer available. Putting Primatene Mist back on the market – for an indefinite period of time – will send a very confusing message to patients.

Congress should be considering ways to increase patient access to health care professionals who can work with patients to find an effective combination of drugs to control asthma. We should not be abandoning patients with a serious medical condition like asthma to self diagnosis and self medication with less effective drugs that have well known serious side effects.

I hope the committee will keep the view of the American Thoracic Society in mind as it considers legislation on inhale epinephrine for the treatment of asthma. I would be happy to answer any questions you may have.

1) AMA House of Delegates policy H-115.972 (CSA Rep.2 A-99, reaffirmed CSPH Rep. 1 A-09)

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U.S. HOUSE OF REPRESENTATIVES

Testimony Before the Sub Committee on Energy and Commerce

Hearing on U.S. Agricultural Sector Relief Act of 2012 & The Asthma Inhalers Relief Act of 2012

Mark Murai, President
California Strawberry Commission

7/18/2012
Washington, D.C.

PREPARED TESTIMONY OF MARK MURAI

At Congressional Hearing:

Sub Committee on Energy and Commerce

July 18, 2012 in Washington, D.C.

Good morning Mr. Chairman and Ranking Member.

My name is Mark Murai. I am a third-generation strawberry farmer and president of the California Strawberry Commission. I represent all of California's strawberry farmers, shippers, and processors.

Thank you for holding a hearing on the topic of the Montreal Protocol. It is critical that all of us achieve economic and environmental progress together.

Farmers Lead the World to Find Alternatives

The United States has eliminated over 90% of ozone depleting products and the ozone layer is healing faster than predicted[1]. I am proud to say that strawberry farmers have taken this seriously. We have innovated new farming techniques (such as drip fumigation) and employed new technologies (such as emission reduction measures) to reduce our methyl bromide imprint.

California strawberry farmers are also leaders in organic production methods. These farmers grow more organic strawberries than all other 49 states combined. In fact, nearly one out of five California strawberry farmers also farm with organic methods.

[1] *Scientific Assessment of Ozone Depletion: 2010*. National Oceanic and Atmospheric Administration, National Aeronautics and Space Administration, United Nations Environment Programme, World Meteorological Organization, European Commission

Largely due to our commitment, the U.S. Environmental Protection Agency (EPA) awarded California strawberry farmers with the 2008 Stratospheric Ozone Protection Award for transitioning more strawberry acres to alternatives, faster than any other place in the world.

We are not resting on this success. We continue to innovate and seek alternatives. Most recently, we expanded our partnership with California's EPA in a joint research project aimed at finding fumigant alternatives. As these efforts move forward, it is essential that EPA adopt a more balanced approach that recognizes our accomplishments as well as the realities of farming.

Farmers Need Clean Soil

Specifically, strawberry farmers require clean soil, free of harmful bacteria, fungus, and pathogens. To fully grasp the seriousness of soil disease, one only needs to remember the Irish potato famine, where an entire nation and crop was decimated by germ-infested soil.

The same is true of our crop: in the past century, strawberries have been repeatedly wiped out by disease. Notwithstanding its damage to the ozone, methyl bromide revolutionized farming because it cleaned the soil, protecting our plants and livelihoods.

When EPA told us to replace methyl bromide with other fumigants we did so. At first, we switched to drip applied alternatives. However, after multiple years of repeated use of the alternatives, we learned that they did not work on all of the soilborne diseases. In 2008, we saw the emergence of new diseases that resulted in widespread crop failure[2]. The following images show the impacts.

[2] Dr. Tom Gordon, *Professor and Chair, Department of Plant Pathology, University of California, Davis,* letter to Dr. Dan Legard. July 25, 2008.

2008, California Strawberry fields in a state of collapse after being treated with non-methyl bromide alternatives that were not effective against soil borne disease.

The CUE Process Needs to be Improved

In response to this new data, we submitted a request to EPA for a Critical Use Exemption (CUE) that would allow us to clean the soil of these diseases. We proposed that we could reduce methyl bromide use by using the alternatives for several years and then cleaning the soil with methyl bromide once every three or four years. In other words, we proposed a system to rotate different treatments that would achieve both reduced use of methyl bromide as well as clean soil.

Unfortunately, the EPA responded by telling farmers to use methyl iodide instead. More specifically, EPA stated, "Our 2013 critical use nomination assumes an aggressive transition rate to methyl iodide of 7% per year between now and 2013, resulting in a reduction of 21%..."[3] …However, methyl iodide registration has been canceled in California and the registrant has withdrawn the product.

[3] *EPA Communique to the Montreal Protocol,* via the U.S. Department of State. August 25, 2010,

We requested that EPA restore the amount of methyl bromide immediately, but they have not yet taken any action to help the farmers.

New Science Report on Methyl Bromide C.U.E.'s

The newest scientific information by 312 international scientists sponsored by NOAA, NASA, UNEP, WMO, and the E.U. report that:

- The ozone layer is improving faster than predicted.
- It will require about 39 years to fully restore the ozone layer to 1980 levels.
- Methyl bromide C.U.E.'s will have virtually no effect on the 39 year schedule.

More specifically, the report stated,

> *"…the Scientific Assessment of Ozone Depletion: 2010 is the product of 312 scientists from 39 countries of the developed and developing world who contributed to its preparation and review (191 scientists prepared the report and 196 scientists participated in the peer review process)."*
>
> ***"Methyl bromide:*** *Continuing critical-use exemptions at the approved 2011 level indefinitely would delay the return of EESC to 1980 levels by 0.2 year."*

In other words, indefinite use of methyl bromide at 2011 C.U.E. levels would delay the repair of the ozone layer by 73 days.

What is the benefit of allowing continue use of methyl bromide?

The California Department of Food and Agriculture commissioned an economic study by the University of California Davis. This report states that if there is no methyl bromide and no methyl iodide, California communities will lose over $1.5 billion annually and more than 23,000 jobs annually[4].

[4] *Costs of Methyl Iodide Non-Registration: Economic Analysis.* Goodhue, Rachel, Howard, Peter, Howitt, Richard. California Department of Food and Agriculture. May 2010.

If all of the scientists and economists are accurate, the environmental impact of continued methyl bromide C.U.E.'s would add less than 73 days to a 39 year schedule, while the economic benefit will be $58 billion and 897,000 jobs, over those same 39 years.

Please help to bring some common sense to this issue and restore our C.U.E.

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TELEPHONE: (530) 752-0300
FAX: (530) 752-5674

ONE SHIELDS AVENUE
DAVIS, CALIFORNIA 95616-8680

25 July 2008

Dan Legard, Ph.D.
Director of Research
California Strawberry Commission

Dear Dan:

As per your request, I am providing you with a brief summary of observations and laboratory results related to recent problems affecting strawberry fruit production fields in the Oxnard/Camarillo area. In June of this year, dead and dying plants were sampled in four fields that received pre-plant bed fumigation with something other than methyl bromide. Plants from three of these fields were similar in that a species of *Fusarium* grew directly from the water conducting tissue (xylem) in the crown. In some cases, the same fungus was also recovered from petioles. It is very unusual to recover fungi from within the vascular tissue unless they are pathogenic. Thus, although not all tests have yet been completed, it highly likely that the fungus recovered from diseased strawberry plants is a vascular pathogen. Such a pathogen, a specialized strain of *Fusarium oxysporum*, is known from Japan and may have been introduced into California. Most likely prior use of effective fumigants prevented the pathogen from becoming established. In the absence of such treatments, there is a great risk that this pathogen will become more widespread and have a significant negative impact on strawberry production throughout California.

In the fourth field, although symptoms appeared superficially similar to those in the other three fields, *Fusarium* was not recovered from any of the sampled plants. Instead, *Macrophomina* grew luxuriantly from the crown tissue of all plants. Thus, it appears that at least two different fungal pathogens may be responsible for the increasingly common collapse problems observed in Southern California. As with *Fusarium* it seems likely that problems caused by *Macrophomina* will become more common in the absence of recourse to effective fumigants, such as methyl bromide.

Please let me know if I can provide any further information on this.

Sincerely,

Thomas R. Gordon
Professor and Chair
Department of Plant Pathology

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Jason Shandell

VP and General Counsel

Amphastar Pharmaceuticals, Inc.

US House of Representatives

Energy and Commerce Committee

Energy and Power Subcommittee

July 18, 2012

I am Jason Shandell, Vice President and General Counsel, for Amphastar Pharmaceuticals, Inc., the parent company of Armstrong Pharmaceuticals, Inc.

Amphastar believes in placing people before profits and therefore we are grateful to the Members and staff of the Energy and Commerce Committee for their assistance in helping us to distribute the remaining units of Primatene® Mist. We strongly believe that allowing patients to have access to Primatene® Mist is better than leaving it to expire in a warehouse in California.

History:

Primatene® Mist, an epinephrine inhaler with CFC as propellant, was developed by Wyeth Labs in 1967. Amphastar purchased the rights to market the Primatene®® Mist brand from Wyeth in July 2008.

Primatene® Mist is approved "for temporary relief of occasional symptoms of mild asthma". There are at least 2-3 million loyal Primatene® Mist users.

This drug was manufactured by Armstrong Pharmaceuticals Inc. since 1984 until August of 2011. Once our allocated CFC to produce Primatene® Mist was exhausted, we stopped manufacturing the product on August 12, 2011 and shut down Armstrong's manufacturing facility plant in West Roxbury, Massachusetts.

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Energy and Commerce Committee

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Statement of Chris Ward

To the House Energy and Commerce Committee, Subcommittee on Energy and Power

July 18, 2012

I am Chris Ward, I live in Washington, DC, and I am a past Chairman of the volunteer Board of Directors of the Asthma and Allergy Foundation of America. I have had asthma all of my life. When I was a child, there were few choices for treating my asthma. I have been fortunate that more and better asthma treatments have come into use. I have also been fortunate to be under the care of an allergist since childhood when I was diagnosed. Now, there are a variety of safe, effective medications from which to choose to treat my asthma, and I am a grateful beneficiary.

Making epinephrine bronchodilators like Primatene Mist available over-the-counter may give patients a false sense of security if patients use this medication to achieve short term control when long term control is indicated. Asthma is a chronic disease and short term symptom relief may lull patients into a false sense of security and think they have no need to follow up with their physician.

Asthma patients need professionals who can recognize levels of asthma control and recommend the most appropriate, effective medication to achieve control. Left on their own with medication like epinephrine bronchodilators to rely on, patients can get into trouble.

Sound public policy should provide patients with opportunities to get appropriate treatment directed by skilled professionals. Having access to Primatene Mist over-the-counter can put

patients at risk if they delay getting an appropriate diagnosis and effective treatment to keep their asthma in control.

Some argue that in case of an asthma attack, patients need to be able to go to a retail drug store or supermarket to buy Primatene Mist over-the-counter. Should we recommend that someone having an asthma emergency go to a store to buy a device over calling 911 and going to an emergency room or hospital? If patients need unplanned refills, or replacement devices, they can contact their prescriber or get appropriate medications from the emergency room.

Another false assumption is that low income people need these medications because they are low cost. While the price of Primatene Mist may be lower than the total cost of or co-pay for more effective bronchodilators, the relief from these epinephrine devices does not last as long. Thus, the long term cost is actually higher.

Allowing over-the-counter access to this product may seem to erase the cost of visiting a prescriber. However, over-the-counter bronchodilators can promote self-diagnoses, which is particularly unsafe for the symptoms of asthma. With proper diagnoses and treatment, people can control their asthma symptoms, avoiding high-cost interventions like emergency department visits and hospitalizations. Cutting out care by qualified medical practitioners could be dangerous for the patient and costly to the healthcare system.

The decision to withdraw Primatene Mist from the US market was made years ago. Lifting the ban now will lead to confusion. There will be little opportunity to inform patients about the

nature of this change and to urge them to seek care from a professional if they think they have asthma.

I know that asthma is a serious chronic condition, and I know what a difference effective treatment can make. I urge you, for all current and future asthma patients, to reject any attempt to re-release Primatene Mist to the US market as an over-the-counter product.

END

THE ASTHMA AND ALLERGY FOUNDATION OF AMERICA

The Asthma and Allergy Foundation of America (AAFA), founded in 1953 by the two leading professional medical organizations in the United States devoted to the allergy/immunology specialty, is the oldest asthma and allergy patient group in the world. AAFA is an independent not-for-profit association dedicated to improving the quality of life for people with these chronic conditions through education, advocacy and research. To achieve its mission, AAFA conducts national campaigns, disseminates education programs and tools, articulates policy positions and works with state and regional AAFA chapters, Educational Support Groups, governments, coalitions, corporate sponsors, health professional groups and volunteers.

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I am Chris Ward, I live in Washington, DC, and I am a past Chairman of the volunteer Board of Directors of the Asthma and Allergy Foundation of America. I have had asthma all of my life. When I was a child, there were few choices for treating my asthma. I have been fortunate that more and better asthma treatments have come into use. I have also been fortunate to be under the care of an allergist since childhood when I was diagnosed. Now, there are a variety of safe, effective medications from which to choose to treat my asthma, and I am a grateful beneficiary.

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Asthma patients need professionals who can recognize levels of asthma control and recommend the most appropriate, effective medication to achieve control. Left on their own with medication like epinephrine bronchodilators to rely on, patients can get into trouble.

Sound public policy should provide patients with opportunities to get appropriate treatment directed by skilled professionals. Having access to Primatene Mist over-the-counter can put

patients at risk if they delay getting an appropriate diagnosis and effective treatment to keep their asthma in control.

Some argue that in case of an asthma attack, patients need to be able to go to a retail drug store or supermarket to buy Primatene Mist over-the-counter. Should we recommend that someone having an asthma emergency go to a store to buy a device over calling 911 and going to an emergency room or hospital? If patients need unplanned refills, or replacement devices, they can contact their prescriber or get appropriate medications from the emergency room.

Another false assumption is that low income people need these medications because they are low cost. While the price of Primatene Mist may be lower than the total cost of or co-pay for more effective bronchodilators, the relief from these epinephrine devices does not last as long. Thus, the long term cost is actually higher.

Allowing over-the-counter access to this product may seem to erase the cost of visiting a prescriber. However, over-the-counter bronchodilators can promote self-diagnoses, which is particularly unsafe for the symptoms of asthma. With proper diagnoses and treatment, people can control their asthma symptoms, avoiding high-cost interventions like emergency department visits and hospitalizations. Cutting out care by qualified medical practitioners could be dangerous for the patient and costly to the healthcare system.

The decision to withdraw Primatene Mist from the US market was made years ago. Lifting the ban now will lead to confusion. There will be little opportunity to inform patients about the

nature of this change and to urge them to seek care from a professional if they think they have asthma.

I know that asthma is a serious chronic condition, and I know what a difference effective treatment can make. I urge you, for all current and future asthma patients, to reject any attempt to re-release Primatene Mist to the US market as an over-the-counter product.

END

THE ASTHMA AND ALLERGY FOUNDATION OF AMERICA

The Asthma and Allergy Foundation of America (AAFA), founded in 1953 by the two leading professional medical organizations in the United States devoted to the allergy/immunology specialty, is the oldest asthma and allergy patient group in the world. AAFA is an independent not-for-profit association dedicated to improving the quality of life for people with these chronic conditions through education, advocacy and research. To achieve its mission, AAFA conducts national campaigns, disseminates education programs and tools, articulates policy positions and works with state and regional AAFA chapters, Educational Support Groups, governments, coalitions, corporate sponsors, health professional groups and volunteers.

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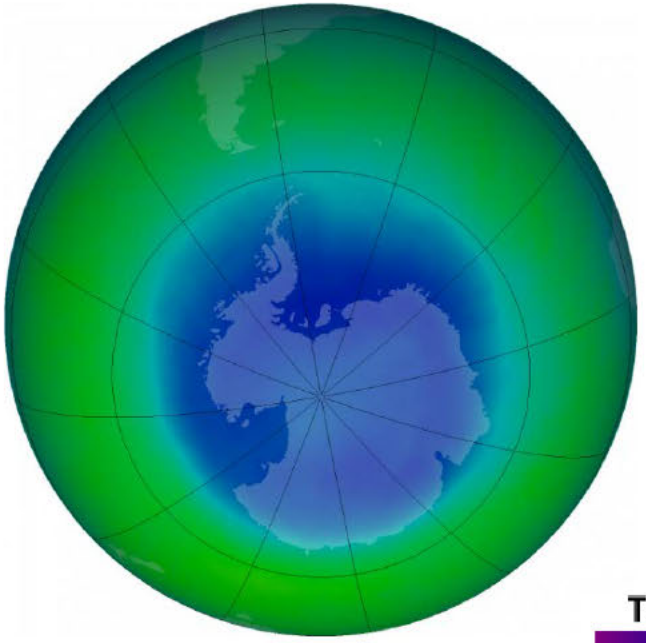

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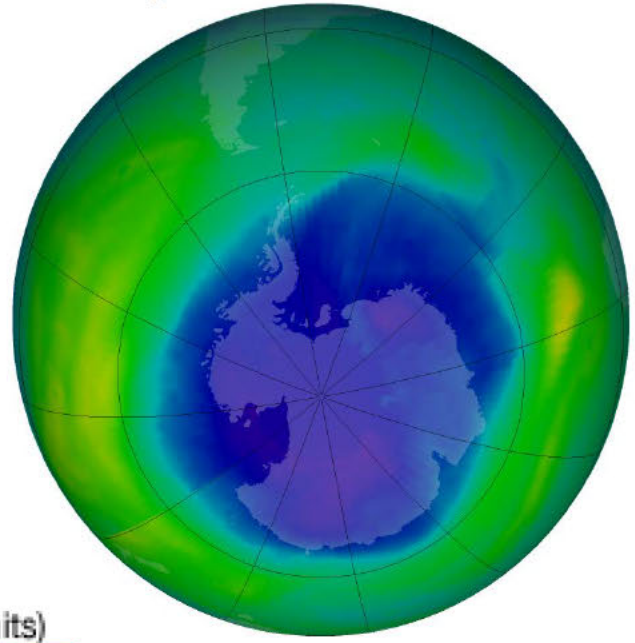

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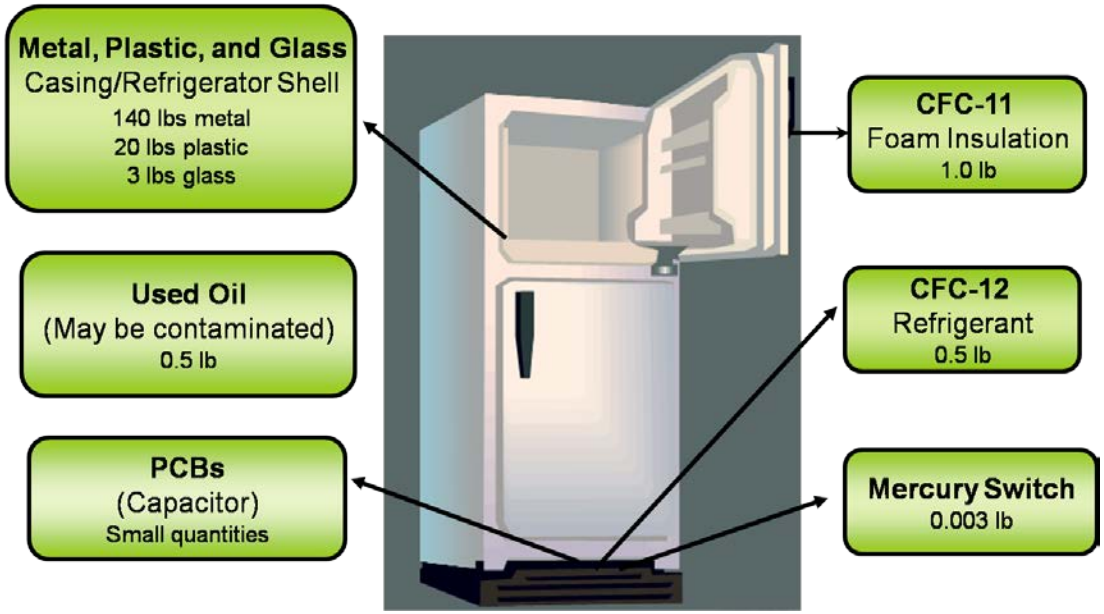

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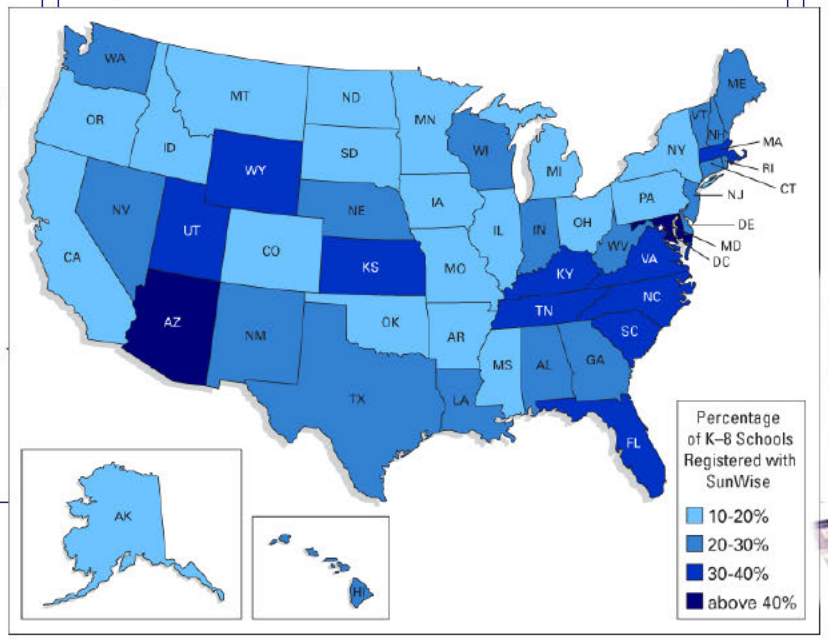

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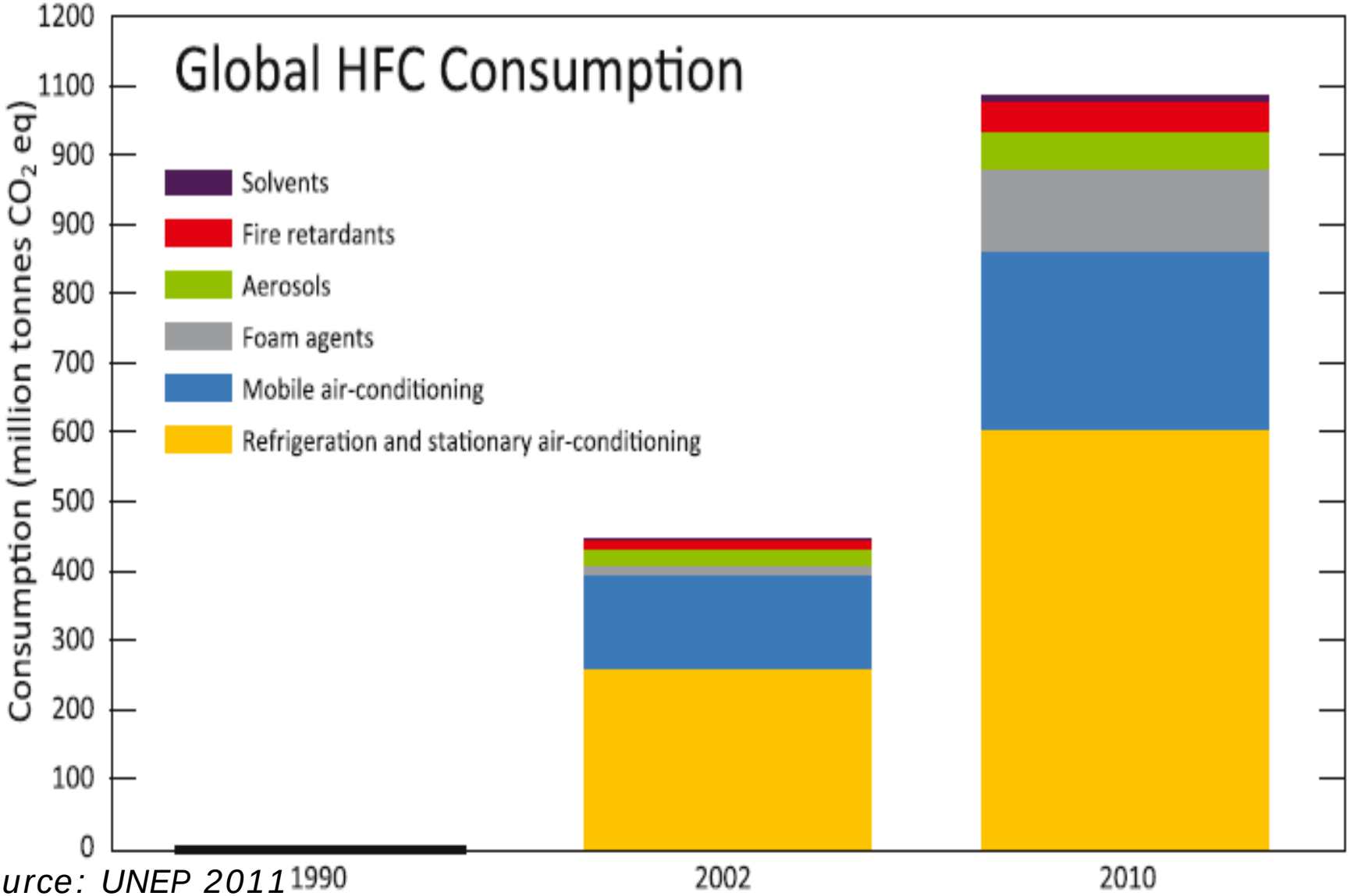

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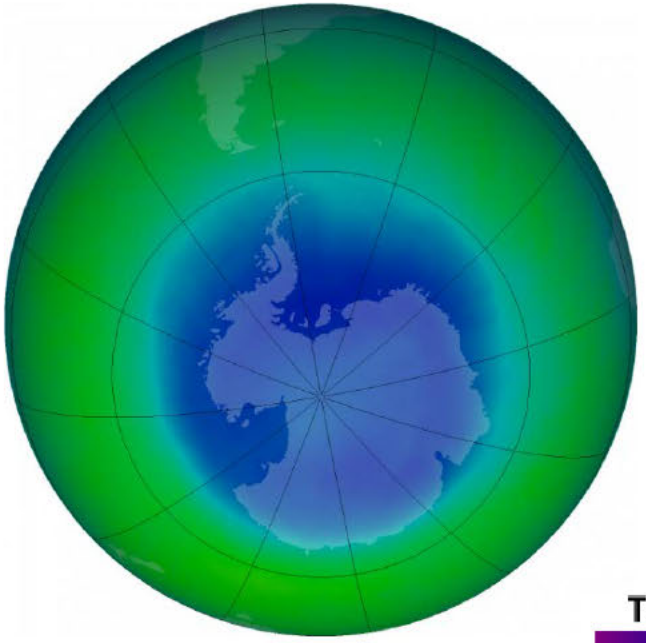

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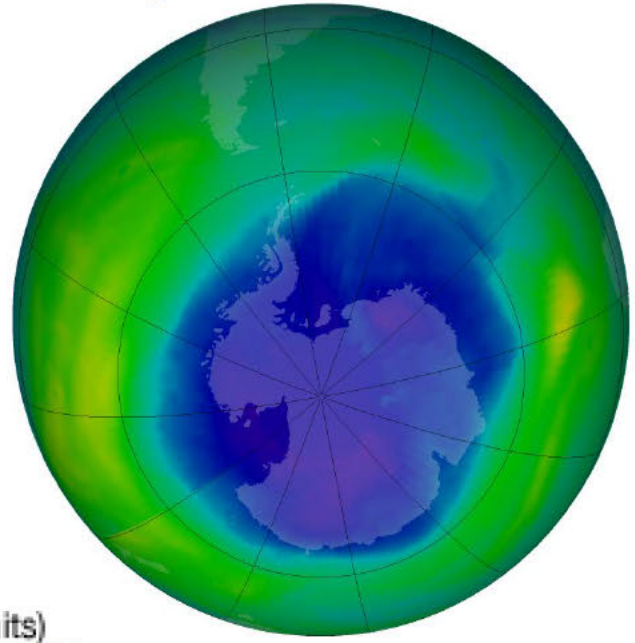

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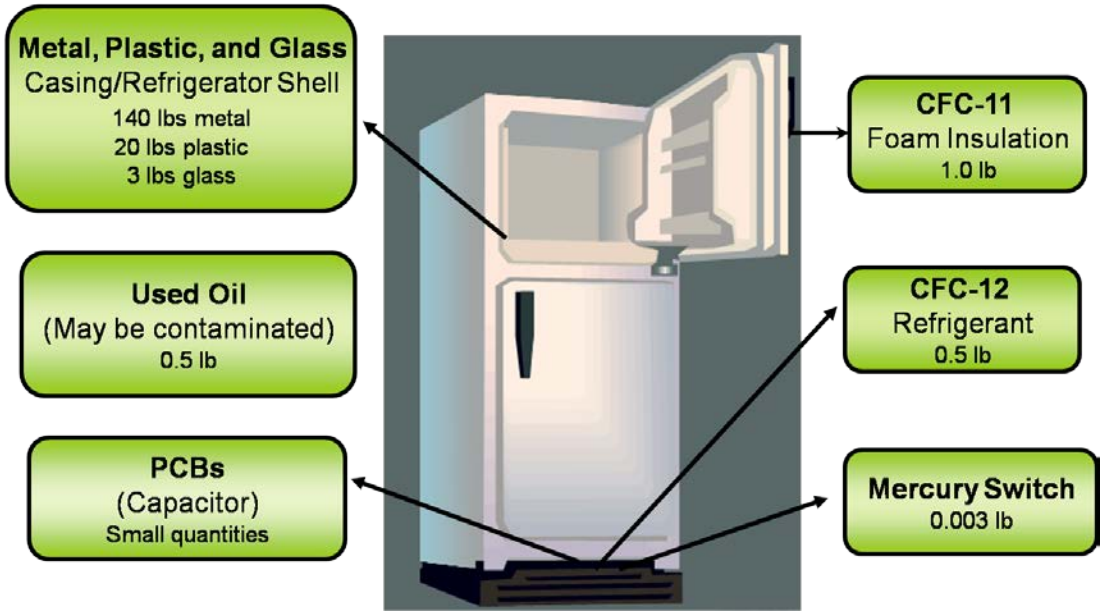

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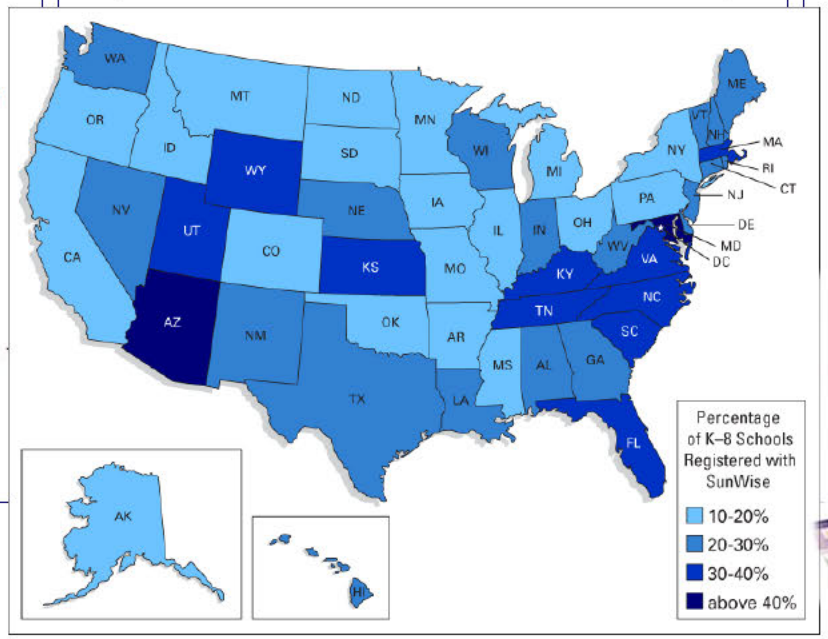

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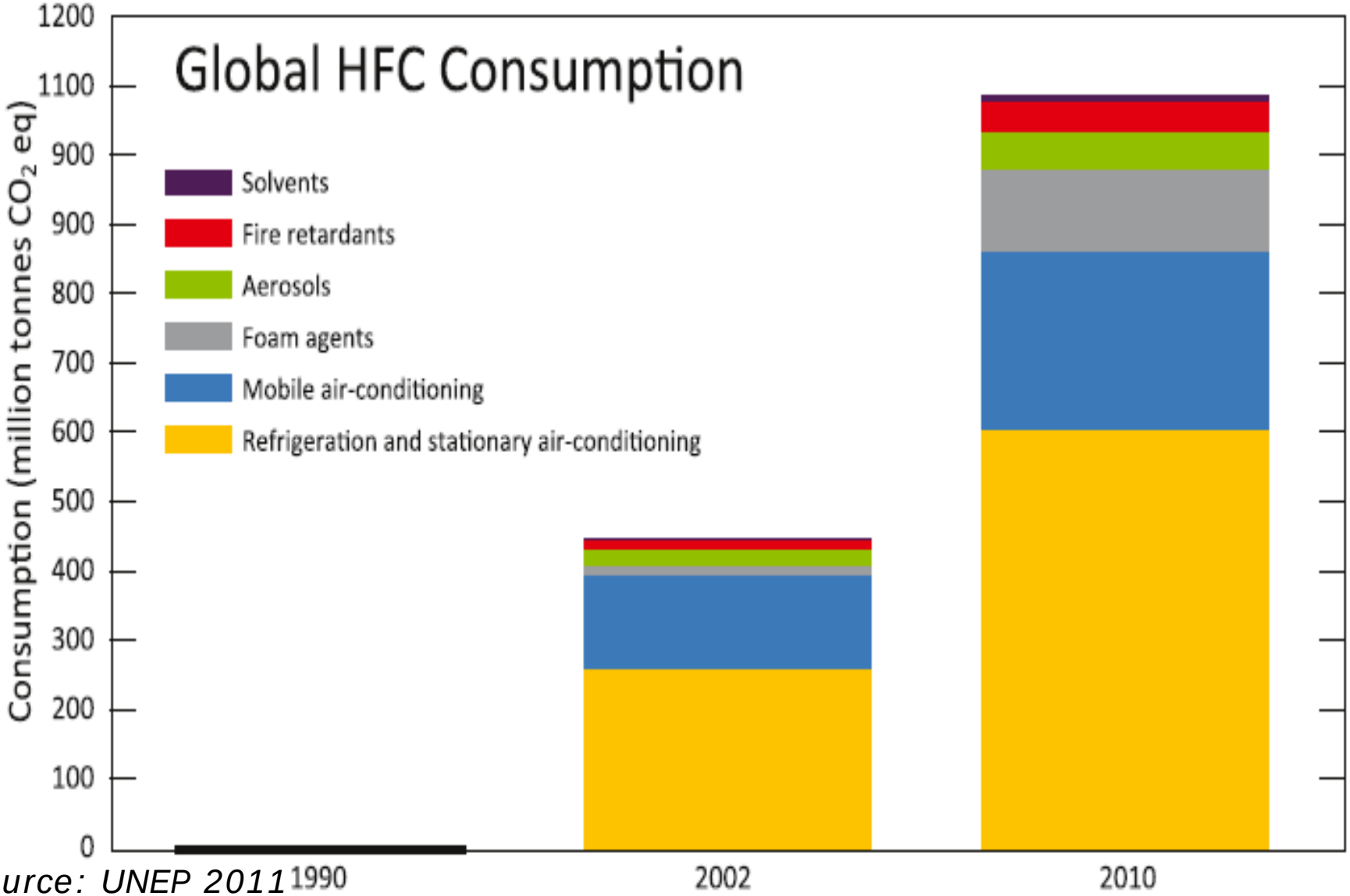

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WORLD RESOURCES INSTITUTE

WRI REPORT

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Using Existing Federal Laws and State Action to Reduce Greenhouse Gas Emissions

NICHOLAS M. BIANCO
FRANZ T. LITZ
KRISTIN IGUSKY MEEK
REBECCA GASPER

About the Authors

Nicholas Bianco leads WRI's efforts with U.S. states and U.S. federal agencies as they work together and in parallel to develop programs to reduce greenhouse gas emissions. His areas of research include the role of states in future federal climate programs; the regulation of greenhouse gas emissions via existing regulatory authorities; market-based pollution control programs; and stacking of payments for ecosystem services (e.g., greenhouse gas offsets). Nicholas previously worked with the Massachusetts Department of Environmental Protection on climate change and air quality programs. While there, he worked on several market-based air quality and climate change programs, including the Regional Greenhouse Gas Initiative (RGGI), a regional carbon dioxide cap-and-trade program for the power sector. Contact: nbianco@wri.org.

Kristin Meek is an Associate in the Climate and Energy Program at the World Resources Institute. She supports WRI's efforts with U.S. states and U.S. federal agencies as they work together and in parallel to develop programs to reduce greenhouse gas emissions. Prior to joining WRI, Kristin worked with SAIC's climate change services team, where she focused on a wide range of GHG management projects for federal government agencies, local governments, and private sector entities. Projects included supporting the U.S. Energy Information Administration's national inventory of greenhouse gases, EPA's Greenhouse Gas Reporting Program and Climate Leaders Program, researching issues related to new and existing carbon offset project types, and developing community-level GHG inventories for cities and counties across the country. Contact: kmeek@wri.org.

Rebecca Gasper is a Research Assistant in WRI's Climate and Energy Program. She supports WRI's efforts with U.S. states and U.S. federal agencies as they work together and in parallel to develop programs to reduce greenhouse gas emissions. Before joining WRI, Rebecca worked at the Center for Integrative Research (CIER) at the University of Maryland. She worked primarily on climate change mitigation and adaptation at the regional and international levels. She also has experience supporting state efforts to develop water quality markets. Contact: rgasper@wri.org.

Franz Litz is the Executive Director of the Pace Energy & Climate Center, a legal and policy think tank, and Professor of Energy and Climate Change Law in Pace Law School's top-ranked environmental law program. Franz leads his Center's work at the state, regional, national, and international levels on climate change, energy efficiency, renewable energy, transportation, and community energy. Franz is an expert on the federal Clean Air Act, state-level climate and energy policies, and emissions trading. Franz actively convenes officials from U.S. states and Canadian provinces cooperating on energy and climate change policy issues. He also frequently brings stakeholders from diverse viewpoints together to engage policy makers on difficult energy and climate policy issues. Before assuming his leadership role at the Pace Energy & Climate Center in 2011, Franz was a senior fellow at the World Resources Institute in Washington, DC. He led WRI's state and regional climate change initiatives, as well as WRI's engagement with the U.S. EPA. Contact: flitz@law.pace.edu.

Pace Energy and Climate Center
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Summary for Policymakers

I. Introduction

CLIMATE CHANGE IMPACTS IN THE UNITED States are increasingly evident and come with steep economic and social costs. The frequency and intensity of extreme weather events has increased in recent years, bringing record-breaking heat, heavy precipitation, coastal flooding, severe droughts, and damaging wildfires.[1] According to the National Oceanic and Atmospheric Administration (NOAA), weather-related damages in the United States were $60 billion in 2011, and are expected to be significantly greater in 2012.[2]

The mounting costs convey an unmistakable urgency to address climate change by reducing greenhouse gas emissions (GHGs). This report examines pathways for GHG reductions in the United States through actions taken at the federal and state levels without the need for new legislation from the U.S. Congress.

This report answers a number of key questions:

- What are current U.S. GHG emissions? Without further action to reduce emissions, what are they projected to be in 2020 and 2035?
- What legal and policy tools exist under current federal law to achieve emissions reductions? What additional actions can states pursue to contribute to emissions reductions?
- Which legal and policy tools at the state and federal levels offer the greatest potential for achieving emissions reductions in the near- and mid-term?
- Can the U.S. meet its international commitment to reduce emissions 17 percent below 2005 levels by 2020 without new federal legislation?
- Can the U.S. put itself on a trajectory to meet or exceed its long-term commitment of reducing emissions by more than 80 percent below 2005 levels by 2050, without new legislation from Congress?

The answers to these questions are set out in detail in the body of this report. Two significant findings stand out. First, it is clear the U.S. is not currently on track to meet its 2020 reduction pledge, however, this target is achievable through implementation of strong new federal measures to reduce emissions using existing legal authorities. Second, the mid-century goal of reducing emissions by 80 percent or more appears unattainable using existing authorities. New legislation will eventually be needed.

BOX 1 Key Conclusions and Recommendations

1. Without new action by the U.S. Administration, greenhouse gas (GHG) emissions will increase over time. The U.S. will fail to make the deep emissions reductions needed in coming decades, and will not meet its international commitment to reduce GHG emissions by 17 percent below 2005 levels by 2020.
2. The U.S. EPA should immediately pursue "go-getter" emissions reductions from power plants and natural gas systems using its authority under the Clean Air Act. These two sectors represent two of the top opportunities for substantial GHG reductions between now and 2035.
3. The U.S. Administration should pursue hydrofluorocarbon (HFC) reductions through both the Montreal Protocol process and under its independent Clean Air Act authority. Eliminating HFCs represents the biggest opportunity for GHG emissions reductions behind power plants.
4. U.S. states should complement federal actions to reduce emissions through state energy efficiency, renewables, transportation, and other actions. States can augment federal reductions.
5. New federal legislation will eventually be needed, because even go-getter action by federal and state governments will probably fail to achieve the more than 80 percent GHG emissions reductions necessary to fend off the most deleterious impacts of climate change.

Potential reductions in the United Stated were assessed in a 2010 WRI Report entitled *Reducing Greenhouse Gas Emissions in the United States Using Existing Federal Authorities and State Action.*[3] This updated report revisits these questions, taking into account the latest GHG emissions information and recent actions taken at the federal and state levels. Since the publication of the last report, notable factors influencing U.S. GHG emissions include:

- Reduced global economic growth, including slower growth of economic output in the United States;
- Increased fuel switching from coal to natural gas in the generation of electricity; and
- Reduced demand for transportation fuel, partly as a result of higher petroleum prices, lower miles traveled, and more efficient vehicles.

These factors and others, including the issuance of new motor vehicle emissions and fuel efficiency standards for cars and trucks, will reduce greenhouse gas emissions. However, even with these factors, we project that total U.S. emissions will experience relatively modest growth over the coming decades.

At the 2009 Conference of the Parties of the United Nations Framework Convention on Climate Change in Copenhagen, Denmark, President Obama made a commitment to reduce U.S. greenhouse gas emissions in the range of 17 percent below 2005 levels by 2020. Despite the inability of Congress to pass comprehensive climate change legislation, the Administration has re-committed to the Copenhagen pledge and taken some steps to reduce emissions using authority under existing laws.[4] While the Administration has reaffirmed its commitment to this target, it has not yet matched that commitment with adequate action. Though significant progress has been made in some areas since our 2010 analysis, most notably with the vehicle rules, key opportunities, such as reductions from power plants, remain untapped. The fact that the U.S. remains far from the "go-getter" emissions trajectory laid out in our 2010 report reinforces the urgency for taking strong action now.

Although the U.S. emissions reduction commitment for 2020 represents an important step toward reducing GHG emissions, much greater reductions are necessary. According to the Intergovernmental Panel on Climate Change, industrialized countries need to collectively reduce emissions between 25 and 40 percent below 1990 levels by 2020 and 80 to 95 percent below 1990 levels by 2050 in order to keep global average temperatures from increasing more than 2 degrees Celsius above preindustrial levels. This report evaluates the potential for meeting the 17 percent commitment and the deeper longer-term reduction pathway necessary to avoid the worst impacts of climate change.

BOX 2 Ambition Matters

Within the bounds of what is legally and technically possible, the single most important factor influencing emissions reductions is political and policy ambition. This analysis considers three levels of ambition:

- **Lackluster.** This is low ambition and represents the results of actions of lowest cost or least optimistic technical achievement.
- **Middle-of-the-Road.** This is mid-level ambition and represents the results of actions of moderate cost and moderately optimistic technical achievement.
- **Go-Getter.** This is the highest ambition achievable without new congressional action. It represents the results of actions of higher cost or most optimistic technical achievement.

The term "go-getter" is not meant to suggest the actions are adequate to achieve U.S. reduction targets or reductions the science suggests are necessary to ward off the worst effects of climate change.

1. *America's Climate Choices: Panel on Advancing the Science of Climate Change.* National Research Council, 2010.ISBN 978-0-309-14588-6. Accessible at: <http://www.nap.edu/catalog.php?record_id=12782>.
2. *Preliminary Info on 2012 U.S. Billion-Dollar Extreme Weather/ Climate Events.* National Oceanic and Atmospheric Administration. Accessible at: <http://www.ncdc.noaa.gov/news/preliminary-info-2012-us-billion-dollar-extreme-weatherclimate-events>. (Last accessed January 15, 2013)
3. Accessible at: <http://www.wri.org/publication/reducing-ghg-emissions-using-existing-federal-authorities-and-state-action>.
4. Most recently, the U.S. delegation to the Conference of the Parties of the UN Framework Convention on Climate Change in Doha, Qatar, made it clear that the 17 percent pledge is not contingent on new legislation from Congress.

Attaining even the 17 percent reduction goal will require new and ambitious action from the U.S. Administration—ambitious action that must survive court challenges. Real progress depends on numerous actions not yet taken by the U.S. Administration—especially for stationary emissions sources like power plants, natural gas systems, and industry. U.S. states may also need to take action to fill any emissions gaps left by the federal government. Achieving the necessary mid-century reductions will almost certainly require the U.S. Congress to act to achieve the needed reductions.

Section II summarizes the report's key findings, including the range of reductions that are possible and a brief description of the analytical approach. An examination of current emissions in the United States and projected emissions without new actions follows in Section III. Section IV summarizes the sector-by-sector actions the federal government might take under existing laws. Section V summarizes potential state actions. Section VI sets out summary conclusions. Two detailed appendixes set out the assumptions and methodologies for the federal and state analyses. The picture revealed is one of significant potential greenhouse gas emissions reductions, provided there is sufficient political will to take strong action.

II. Charting a Path Forward in the U.S.: Summary of Key Findings

This report identifies significant potential for GHG emissions reductions by the U.S. Administration under current laws and through state-level actions, as well as the limitations of current tools. The reductions actually achieved will depend on the level of ambition brought to the effort by the U.S. Administration, including executive agencies such as the U.S. Environmental Protection Agency. At the state level, outcomes will depend on the number of states that choose to support renewable energy, energy efficiency, and transportation measures, and to pursue policies that the federal government opts not to pursue or that go beyond the minimum stringency set by the federal government. Key findings are set out below for federal and state actions.[5]

A. FEDERAL GHG REDUCTIONS POSSIBLE WITHOUT NEW LEGISLATION

- Only with "go-getter" ambition by the U.S. Administration can the United States achieve emissions reductions using current law that meet or exceed the Copenhagen commitment to reduce global warming pollution by at least 17 percent below 2005 levels by 2020.[6] With middle-of-the-road ambition, the United States will fall well short of its 17 percent commitment, unless supplemented by go-getter actions by the states.

- Even with go-getter ambition, long-term emissions reductions fall short of the level of reductions necessary to put the United States on pace to reach its long-term reduction goal of reducing emissions 83 percent below 2005 levels by 2050. New congressional legislation is therefore necessary to achieve reductions in line with what the international scientific community agrees is necessary by mid-century in order to stabilize global average temperatures and avert the worst impacts of climate change.

- After taking action to significantly improve motor vehicle fuel efficiency, the U.S. Administration should now apply similar ambition to reducing emissions from a wider range of sources, such as existing power plants, if it is to achieve the needed reductions.

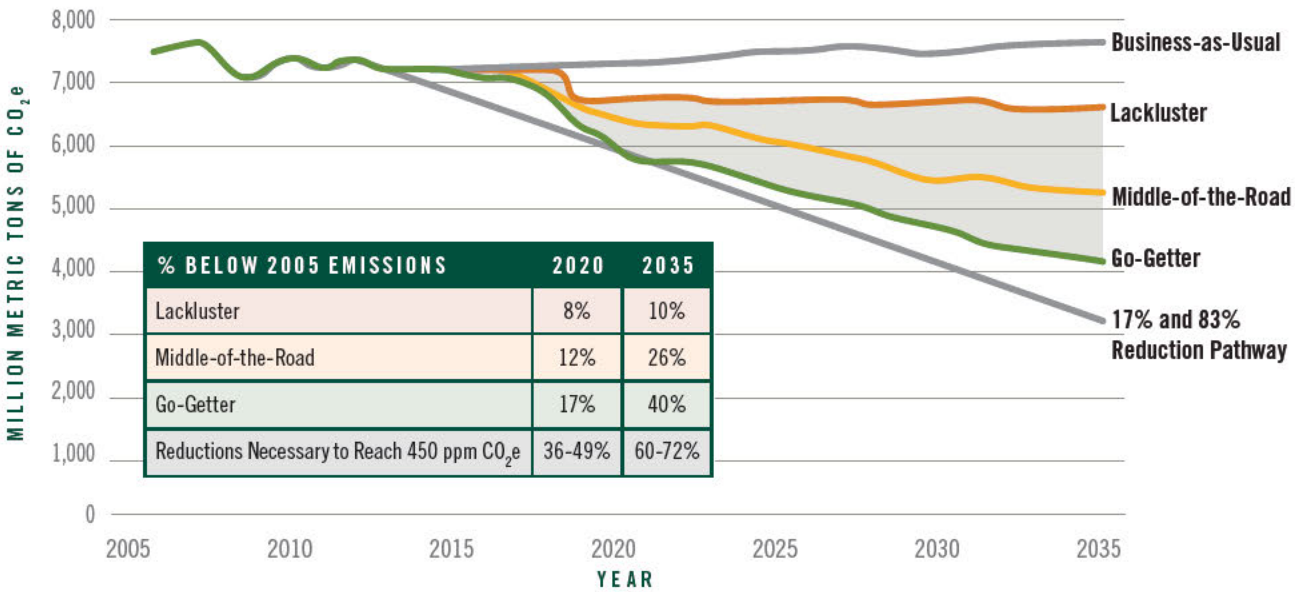
- The greatest projected emissions reduction opportunities by 2020 and beyond come from four federal policy measures. The Administration will need to pursue these opportunities if the United States is to achieve the 17 percent reduction target. Those policies are:

  - standards to reduce carbon pollution from existing power plants (48 percent of total emissions gap between business-as-usual (BAU) and 2020 target);

5. For data sources and an explanation of how expected emissions trends were compiled, please consult the appendixes. For the sake of clarity and brevity, sources are not provided in this summary.

6. The U.S. commitment in Copenhagen calls for reductions in 2020 "in the range of 17 percent [below 2005 levels], in conformity with anticipated U.S. energy and climate legislation." The U.S. submission notes that the ultimate goal of legislation pending at the time was to reduce emissions by 83 percent below 2005 levels in 2050.

FIGURE 1 Projected U.S. Emissions under Different Federal Regulatory Scenarios



% BELOW 2005 EMISSIONS	2020	2035
Lackluster	8%	10%
Middle-of-the-Road	12%	26%
Go-Getter	17%	40%
Reductions Necessary to Reach 450 ppm CO_2e	36-49%	60-72%

Note: The Intergovernmental Panel on Climate Change's (IPCC's) *Fourth Assessment Report* (2007) indicates that industrialized countries need to collectively reduce emissions between 25 and 40 percent below 1990 levels by 2020 and 80 to 95 percent below 1990 levels by 2050 to keep atmospheric concentrations of greenhouse gases from exceeding 450 parts per million of CO_2e and to keep global average temperatures from increasing more than 2 degrees Celsius above pre-industrial levels. This target does not necessarily represent any particular country's share. Due to modeling limitations, this figure depicts HFC consumption, which is generally thought to be equivalent to life-cycle emissions. For this and all other figures, we use the global warming potentials provided in IPCC's *Fourth Assessment Report*. There are some limited exceptions. See Appendix I for more details.

- requirements to phase out the use of certain hydrofluorocarbons (HFCs) (23 percent of total emissions gap between BAU and 2020 target);
- standards to reduce methane emissions from natural gas systems (11 percent of total emissions gap between BAU and 2020 target);[7] and
- actions to improve energy efficiency in the residential, commercial, and industrial sectors (8 percent of total emissions gap between BAU and 2020 target).

B. STATE ACTION COULD HELP THE U.S. MEET NEAR-TERM PLEDGE

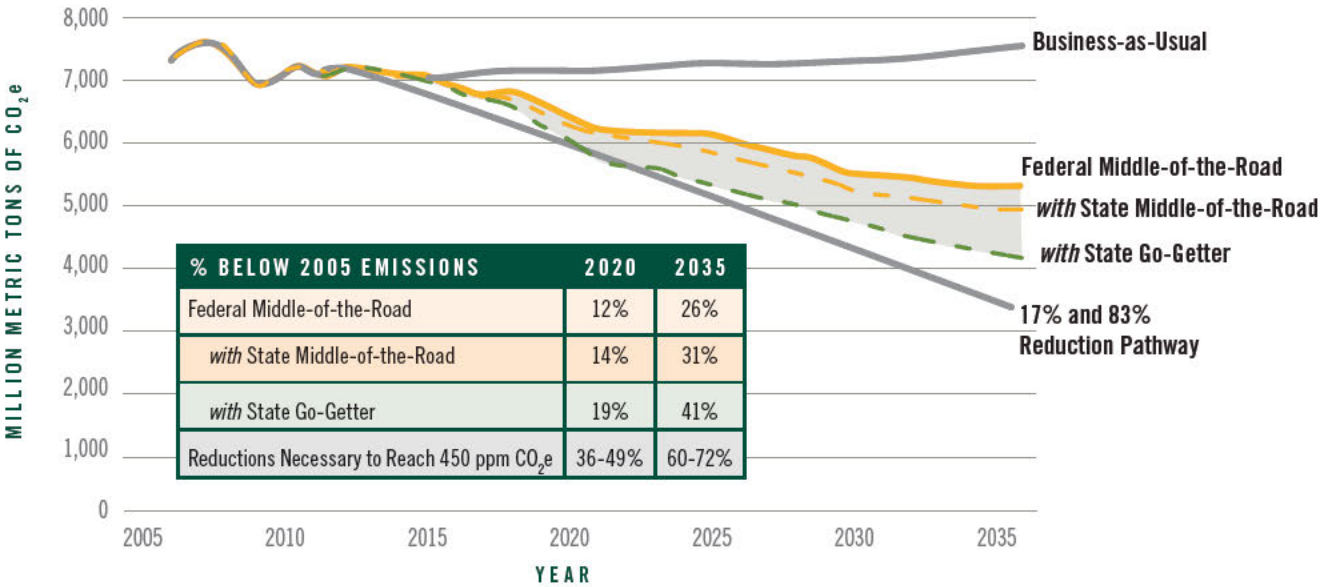
- States can be important contributors to efforts to reduce GHG emissions. If the U.S. Administration were to pursue policies with middle-of-the-road ambition, for example, states could pick up the slack and help the United States reach its goal of reducing emissions 17 percent below 2005 levels by 2020.
- If the federal government pursues a lackluster effort, even a go-getter effort by states is unlikely to achieve the U.S. Administration's 2020 reduction goal.
- Beyond 2020, go-getter state action combined with middle-of-the-road federal action falls short of putting the United States on track to make the mid-century reduction target. This suggests that strong new federal legislative action will be needed.

C. THE STUDY IN BRIEF

This updated report represents the authors' projections of the range of greenhouse gas emissions reductions possible if federal agencies and certain states implement measures to reduce GHG emissions. The report projects the range of reductions possible under current federal law based on a review of published analyses of technical feasibility. The report characterizes three emissions scenarios based on different levels of effort by federal and state actors: "lackluster," "middle-of-the-road," and "go-getter."

7. There is considerable uncertainty with regard to emissions for natural gas systems. The absolute magnitude of abatement opportunities is thus also uncertain. Nevertheless, our analysis suggests that there are important opportunities to reduce emissions from this sector. Those reductions are some of the lowest cost opportunities identified in this analysis.

FIGURE 2 Projected U.S Emissions with State Action Coupled with Middle-of-the-Road Federal Action



% BELOW 2005 EMISSIONS	2020	2035
Federal Middle-of-the-Road	12%	26%
with State Middle-of-the-Road	14%	31%
with State Go-Getter	19%	41%
Reductions Necessary to Reach 450 ppm CO_2e	36-49%	60-72%

Note: Due to modeling limitations, this figure depicts HFC consumption, which is generally thought to be equivalent to life-cycle emissions.

1. Analysis of Federal Actions

The analysis of federal actions is based on a legal assessment of the measures the U.S. Administration, including key federal agencies like EPA, may take under existing federal laws. The federal analysis assumes no new legislation is adopted. Technical studies were used to identify the range of reductions possible within a given sector or subsector. The legally and technically feasible range of reductions was then evaluated based on the level of ambition necessary to achieve a particular point in the range. Where available, we relied more heavily on studies that provided a consideration of the costs needed to achieve a particular outcome to provide a sense of the federal regulatory resolve necessary to achieve those reductions.

Where only a low level of ambition is necessary to achieve a particular technically and legally feasible outcome within a specific sector or subsector, the outcome was judged to be "lackluster." If a high level of ambition is necessary to achieve a particular reduction outcome deemed technically and legally possible, the effort necessary was deemed "go-getter" in our scenarios. "Middle-of-the-road" outcomes were those judged possible with moderate ambition and usually at the middle of the range deemed technically and legally possible.

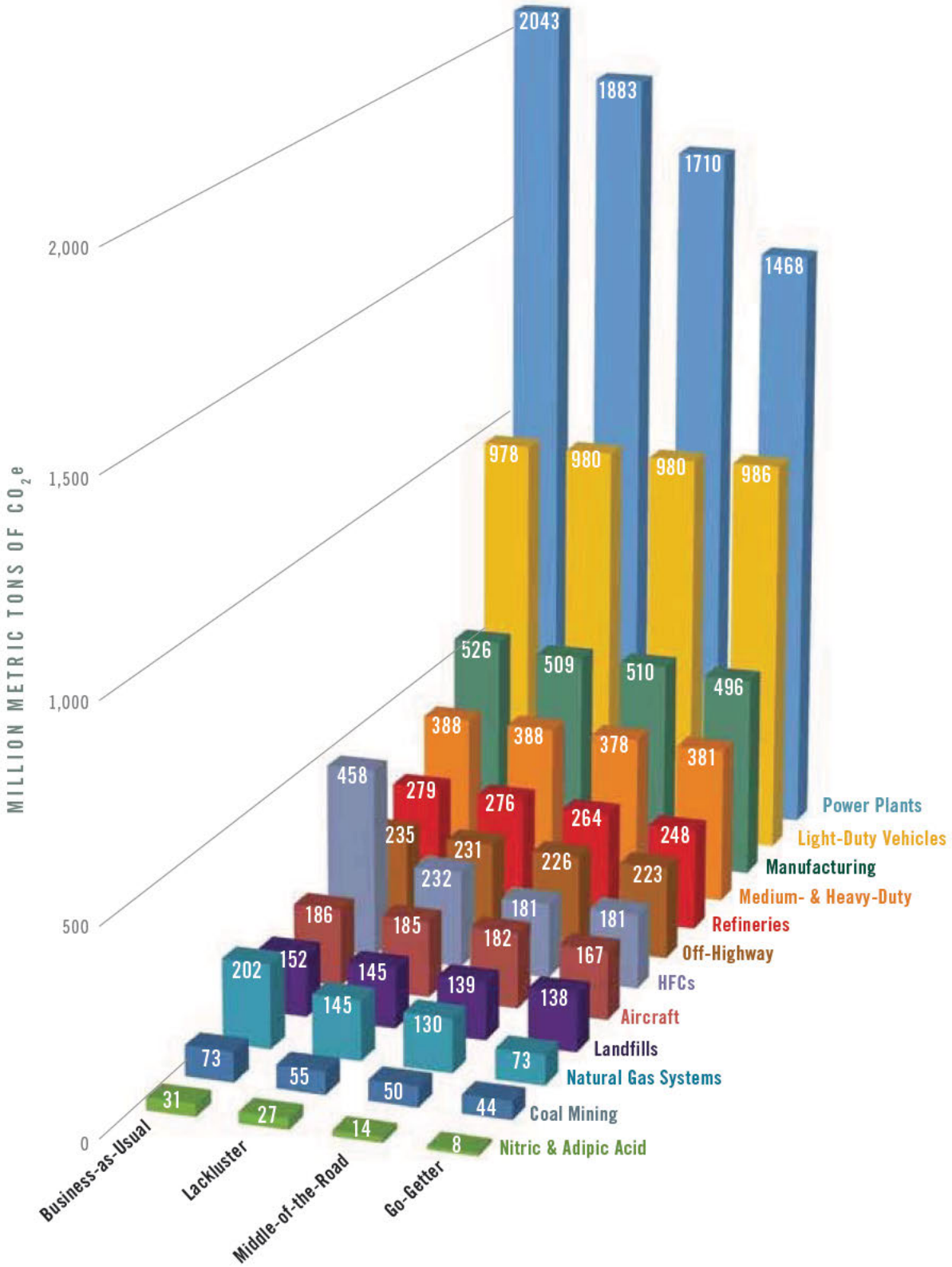
Lackluster emissions reductions from all sectors and subsectors analyzed were aggregated to determine the lackluster emissions pathway through 2035. The same approach was taken for middle-of-the-road and go-getter reductions.

2. Analysis of State Actions

The state analysis has two components: the first considers the impact of states taking action in the absence of federal action; the second considers the impact of states taking action in the presence of varying levels of federal action. In both components we examine the implication of states implementing the same types of policies modeled for the federal government, as well as complementary state-level actions in the transportation, energy efficiency, and renewables areas.

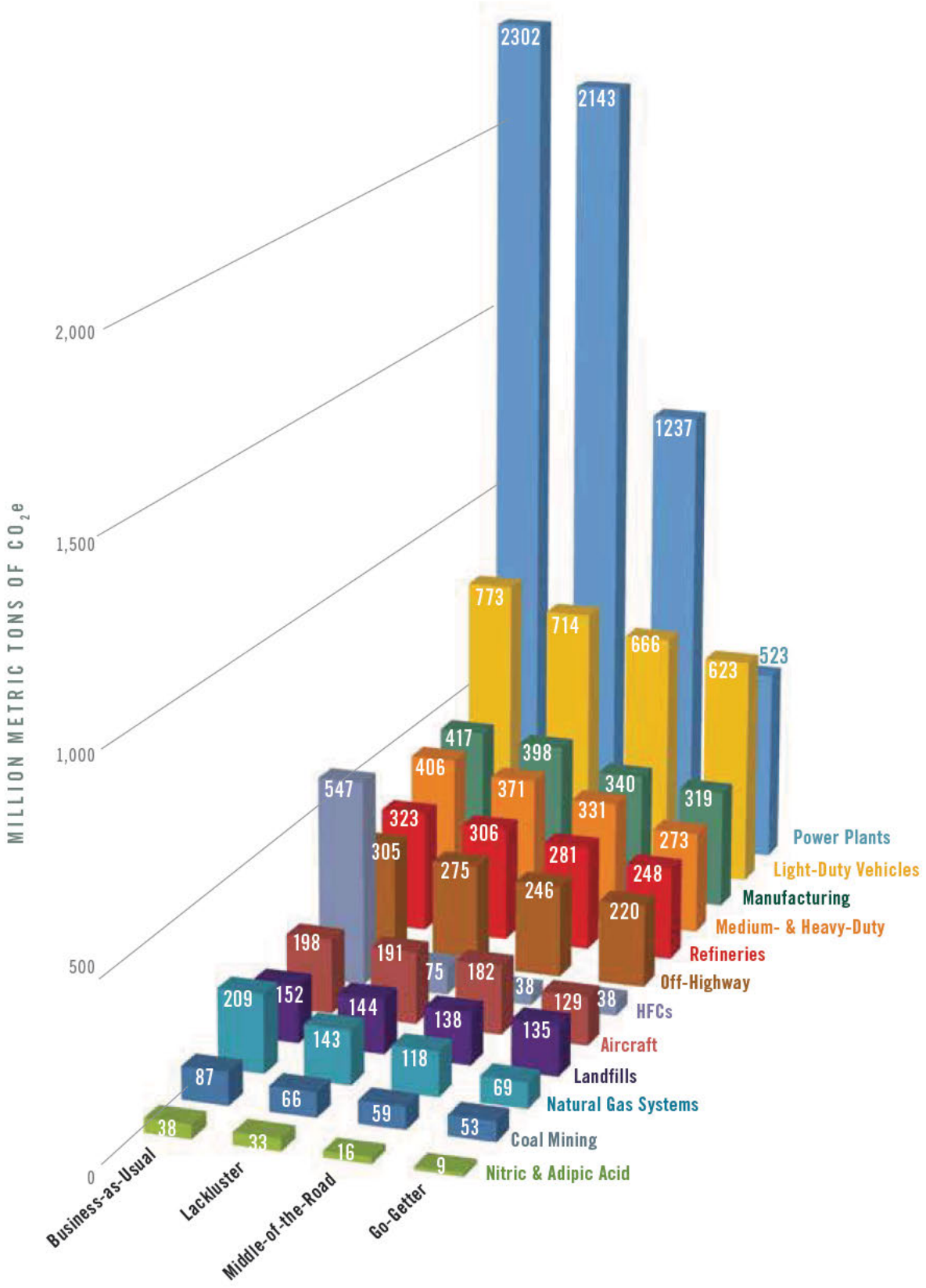
For transportation, the state scenarios consider measures to encourage low carbon fuels and reduce vehicle miles traveled. In the energy efficiency area, measures examined include increased electric end-use energy efficiency, improved building performance, and increased deployment of combined heat and power. For renewables, the analysis adds new and additional renewable energy policies across a certain number of states.

FIGURE 3 Projected U.S. Emissions in 2020 by Sector under Different Federal Regulatory Scenarios



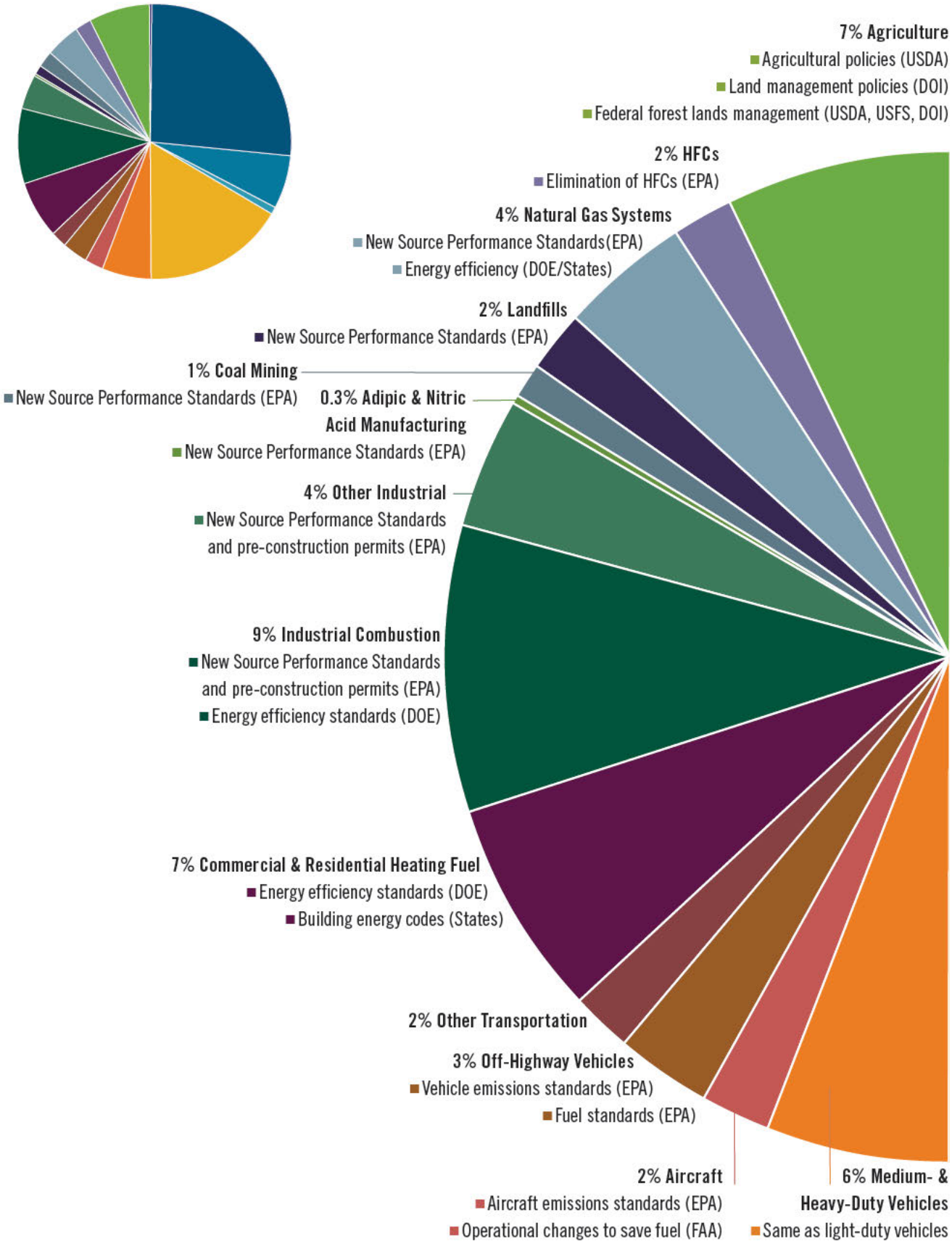
Note: Figure 3 depicts the emissions under the three federal regulatory scenarios by sector or category of sources in 2020. The bars on the left represent business-as-usual emissions. Emissions under the lackluster, middle-of-the-road, and go-getter scenarios are then shown moving from left to right of the business-as-usual emissions. Light-duty vehicle emissions initially increase in our scenarios due to assumptions about vehicle electrification and crediting rates. As shown in Figure 4, these trends reverse in later years. See Appendix I for more information. Due to modeling limitations, this figure depicts HFC consumption, which is generally thought to be equivalent to life-cycle emissions.

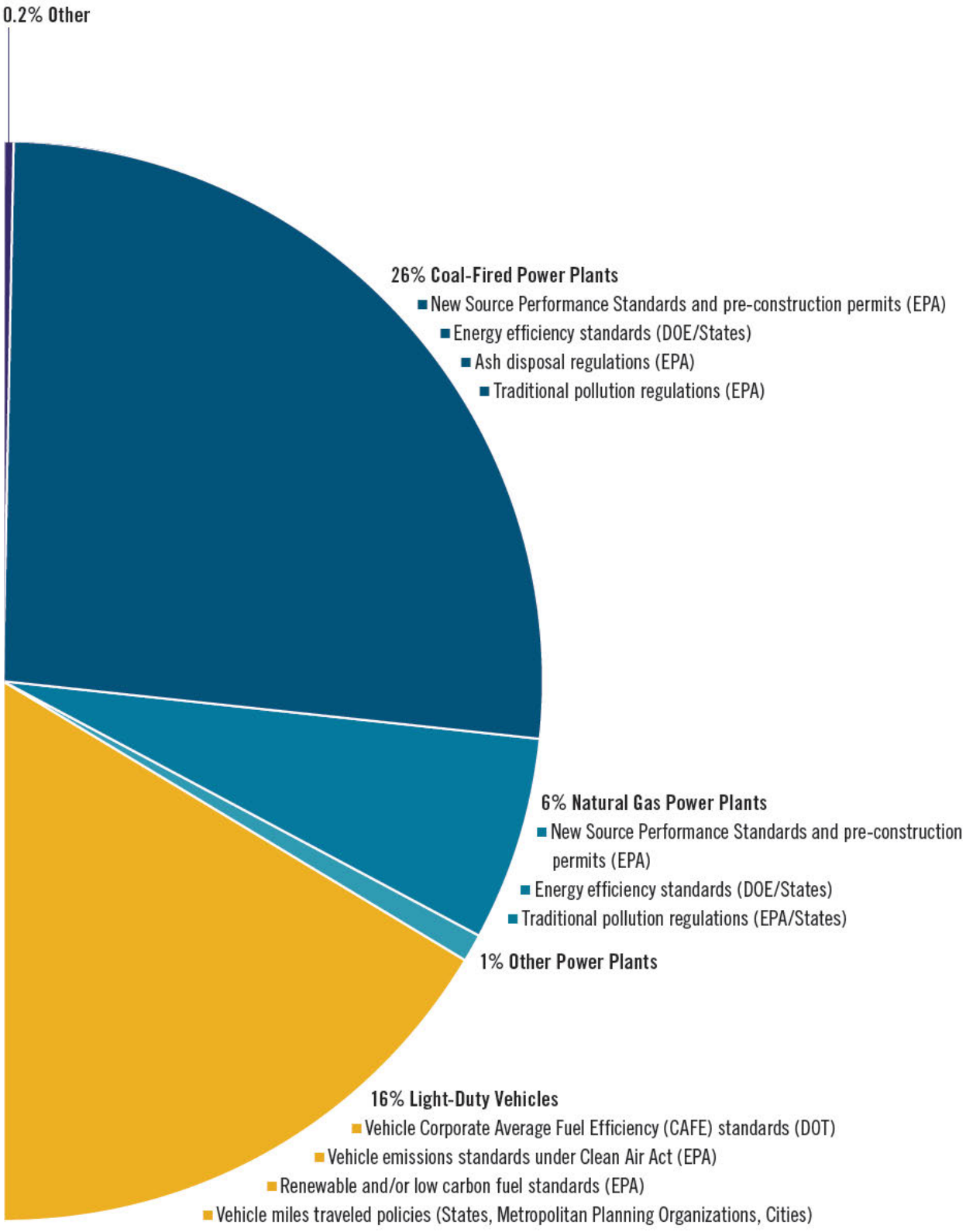
FIGURE 4 Projected U.S. Emissions in 2035 by Sector under Different Federal Regulatory Scenarios



Note: Figure 4 depicts the emissions under the three federal regulatory scenarios by sector or category of sources in 2035. The bars on the left represent the business-as-usual emissions. Emissions under the lackluster, middle-of-the-road, and go-getter scenarios are then shown moving from left to right of the business-as-usual emissions. Due to modeling limitations, this figure depicts HFC consumption, which is generally thought to be equivalent to life-cycle emissions.

FIGURE 5 U.S. Greenhouse Gas Emissions by Sector and Corresponding Federal Authorities, 2010





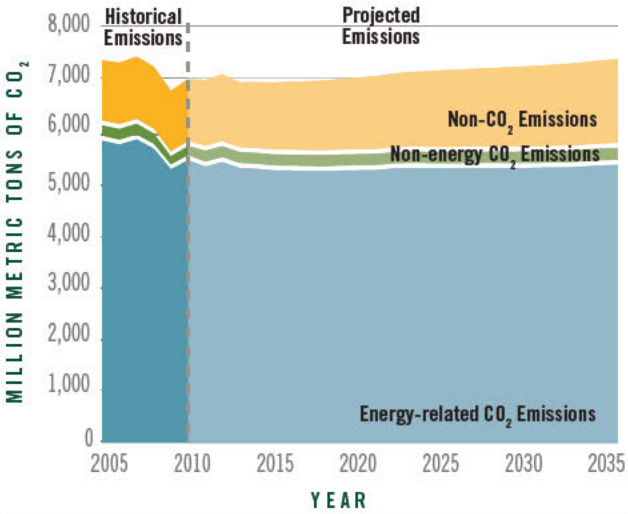
Source: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010*. U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>; *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas*. James Bradbury, Michael Obelter, Laura Draucker, Wen Wang, and Amanda Stevens. World Resources Institute, Working Paper, forthcoming.

Unlike the federal analysis, many of the state measures modeled would require new legislation at the state level. Also unlike the federal scenario, whether state action is "lackluster", "middle-of-the-road" or "go-getter" is a function of how many states adopt the measures modeled, and in some cases the ambition of the policies pursued.

3. Analysis of Federal and State Actions Together

Given that it is unlikely that federal action will occur without state action or that state action will occur without federal action, we analyzed emissions scenarios with both federal and state action. States can be expected to continue to be active in areas of traditional state purview such as energy resource planning and energy efficiency, while also compensating for weak federal action. To capture this dynamic, we modeled varying levels of action for federal and state action.

FIGURE 6 Projected U.S. Greenhouse Gas Emissions if no New State or Federal Action is Taken



Source: See sources listed under Figures 7 and 8 below.

III. The Road the U.S. is on Now: Business as Usual

The reduction pathways presented in this report are best considered in light of current U.S. emissions, along with recent and future emissions trends. A snapshot of U.S. emissions using the most recent data available is presented below, together with a summary of U.S. emissions by key sectors and recent actions to reduce them by federal agencies.

A. CURRENT U.S. EMISSIONS

In 2010 the United States emitted almost 7 billion metric tons of carbon dioxide equivalents (CO_2e), which represents a decrease of about 6 percent below 2005 levels and a 10 percent increase over 1990 levels. Fossil-fuel combustion was responsible for nearly 80 percent of U.S. emissions, with power plants accounting for about 40 percent of combustion emissions, or one-third of the total U.S. GHG inventory, according to EPA. The second largest contributor to total GHG emissions is the transportation sector, with approximately 30 percent of U.S. emissions. Non-CO_2 emissions and CO_2 emissions that result from industrial processes (as opposed to combustion) represented approximately 22 percent of U.S. total GHG emissions.

Figure 5 shows the 2010 U.S. emissions inventory by sector and subsector, together with the corresponding federal regulatory tools available to achieve reductions in the sector.

B. WHAT HAPPENS WITH NO NEW POLICIES? UNDERSTANDING CURRENT U.S. EMISSIONS TRENDS

Before discussing the reduction pathways projected for this report, it is important to describe the major emissions trends that are part of the business-as-usual projections. Business-as-usual emissions trends have shifted downward since the 2010 version of this report. While energy-related CO_2 emissions are projected to rise slowly but remain below 2010 levels through 2035, non-CO_2 emissions are projected to steadily increase over the same time period. The primary trends are noted here:

- **Current Energy-related Carbon Dioxide Emissions Down from 2005 Levels.** In 2011 carbon dioxide emissions from energy sources, which account for nearly 80 percent of U.S. GHG emissions, were 8.7 percent below 2005 levels. Nearly half of those reductions (48 percent) came from the power sector. The rest of the reductions came from transportation (28 percent), industry (18 percent), and buildings (6 percent).[8]

- **Future Energy-CO_2 Emissions Expected to be Relatively Flat.** Our projections suggest that if no future policy actions are taken, then energy-CO_2 emissions will remain approximately 10 percent

8. *Closer than You Think: Latest U.S. CO_2 Pollution Data and Forecasts Show Target Within Reach.* NRDC Issue Brief. Dan Lashof. July 2012.

below 2005 levels in 2020, and will increase slightly through 2035 to levels that are about 8 percent below 2005 levels (Figure 7).

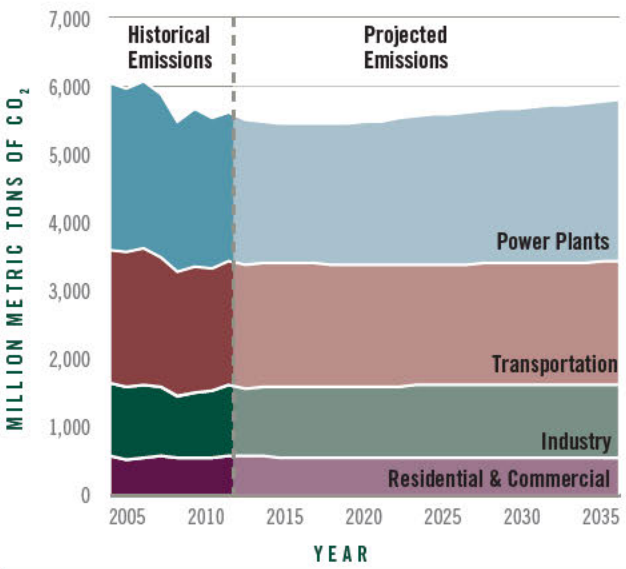
- Those trends are driven by a number of factors, including:

  - **Falling Energy Demand.** The economic slowdown experienced by the United States and other parts of the world over the period from 2008 to 2012 has led to decreased demand for goods and services and reduced energy consumption.[9] Over time, this trend is expected to reverse as economic growth picks up. In addition, the industrial sector was affected significantly by the recent economic turndown and saw a decrease in both production and emissions. This decline is projected to be temporary. Manufacturing output is expected to accelerate from 2010 through 2020, and emissions are projected to increase by 4 percent over this time.[10]

  - **Rise of Natural Gas and Renewables.** The power sector is shifting from coal-fired generation toward natural gas-fired and renewable generation. This trend is driven in part by increases in natural gas extraction, low natural gas prices, increasing coal prices, and new (non-GHG) regulations for the power sector. Increases in renewable generation are driven by state renewable standards, voluntary purchases of "green" energy, and decreasing renewable energy costs. However, gas prices are expected to slowly rise from current levels and demand for electricity is expected to rise 18 percent by 2035 from 2010 levels.[11]

  - **New Vehicle Rules.** The transportation sector is expected to become less carbon-intensive, due in large part to high petroleum prices and new federal GHG emissions and fuel efficiency standards covering light-, medium- and heavy-duty vehicles. These gains will be partially offset by continued increases in vehicle miles traveled.[12] Transportation emissions are projected to increase 1 percent below 2011 levels by 2035.

FIGURE 7 Projected U.S. Energy-Related Carbon Dioxide Emissions if no New State or Federal Action is Taken



Source: U.S. Energy Information Administration, Annual Energy Review (Years 2005-2011); U.S. Energy Information Administration, Annual Energy Outlook (Years 2012-2035)

- **Non-Energy Emissions on the Rise.** Trends for non-energy and non-CO_2 emissions, such as natural gas systems, refrigerants, and landfills, show a likely rise. In 2010, non-energy and non-CO_2 sources accounted for about 22 percent of total U.S. emissions. We project that these emissions will increase roughly 18 percent above 2005 levels by 2020 and 36 percent above 2005 levels by 2035, even after accounting for 2012 regulations that affect portions of natural gas systems and HFCs from vehicles. Those trends are driven by several factors, including:

  - **CFCs Phased Out, HFCs Phased In.** HFC emissions are increasing due to the phaseout of chlorofluorocarbons (CFCs) and other ozone-depleting substances under the Montreal Protocol, which is intended to

9. *Annual Energy Review 2012.* Figure 1.1, Primary Energy Overview (Consumption). EIA, September 2012. Accessible at: <http://www.eia.gov/totalenergy/data/annual/pdf/aer.pdf>.
10. *Annual Energy Outlook 2012 with Projections to 2035. EIA, June 2012.* Accessible at: <http://www.eia.gov/forecasts/aeo/pdf/0383(2012).pdf>.
11. *Annual Energy Outlook 2012 with Projections to 2035.* EIA, June 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/pdf/0383(2012).pdf>.
12. *Annual Energy Outlook 2012 with Projections to 2035.* EIA, June 2012.

BOX 3 Recent Federal Action 2010–12

Since the 2010 report, federal agencies have taken a number of actions that are reducing GHG emissions. The most significant actions from a GHG reduction perspective are summarized below. These are all incorporated into our new business-as-usual projections.

- **Passenger cars and light-duty trucks.** In August 2012 EPA and the National Highway Traffic Safety Administration (NHTSA) finalized new fuel economy and GHG standards for passenger cars and light-duty trucks for model years 2017–2025. These standards equate to a fleet-wide average of 54.5 mpg (101 g CO_2e/km) if they are met solely through fuel economy improvements (as opposed to reductions in HFC emissions from air conditioners). This is approximately double the fuel economy of vehicles sold in 2010. EPA estimates that the rule will save nearly 2 billion tons of CO_2e over the life of the program. This is in addition to the estimated 960 million tons of CO_2e over the life of the prior regulations for model years 2012–2016.

- **Heavy-duty vehicles.** In August 2011 EPA and NHTSA finalized the first-ever fuel efficiency and GHG emission standards for model year 2014 through 2018 medium- and heavy-duty vehicles. EPA estimates that this rule will reduce CO_2 emissions by approximately 270 million metric tons over the life of vehicles sold during the 2014–2018 model years.

- **Natural gas systems.** In April 2012 EPA finalized four regulations that will reduce emissions of volatile organic compounds, sulfur dioxide (SO_2), and air toxics from oil and natural gas systems. EPA estimates that the new standards will have the co-benefit of reducing annual methane emissions by an estimated 19–33 million metric tons of CO_2e.

- **Energy efficiency standards for new appliances.** Between 2009 and 2011, the Department of Energy established 17 new standards. According to analysis by the Appliance Standards Awareness Project and the American Council for an Energy-Efficiency Economy, these standards are expected to save 126.2 TWh in 2025 and 146.8 TWh in 2035.

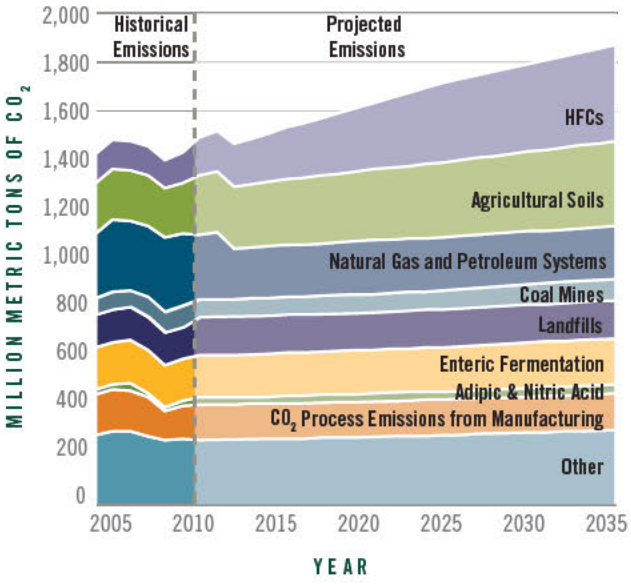
- **Non-GHG regulations for power plants.** EPA has also finalized several other non-GHG-related environmental regulations for power plants, most notably those for mercury and other air toxics. Some modeling has suggested that these rules could lead to the retirement of old, inefficient, coal-fired power plants.

protect and restore the ozone layer in the upper atmosphere, and the Clean Air Act. This trend is expected to continue as the interim substitutes, HCFCs, are also phased out as they are currently being replaced with gases that have a high global warming potential.

- **With the Natural Gas Boon, More Methane Leaks.** Extraction of natural gas in the United States has increased by over 25 percent over the period of 2005 to 2011 due to rapid development of shale gas resources.[13] Increases in natural gas extraction lead to larger fugitive methane emissions from natural gas systems. Fugitive methane emissions are expected to fall significantly, however, due to 2012 EPA regulations that reduce emissions of volatile organic

13. *Monthly Energy Review.* Table 1.2, Primary Energy Production by Source. EIA, December 2012. Accessible at: <http://www.eia.gov/totalenergy/data/monthly/pdf/sec1_5.pdf>.

FIGURE 8 Projected U.S. Non-CO_2 and Non-Energy Emissions if no New State or Federal Action is Taken



Source: U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010 (Years 2005-2010)*; U.S. Environmental Protection Agency, *Draft Global Non-CO_2 Emissions Projections Report 1990-2030 (Non-CO_2 Years 2011-2035)*; RTI, *Applied Dynamic Analysis of the Global Economy Model (Non-energy CO_2 Years 2011-2035)*; *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas.* World Resources Institute. Working Paper. James Bradbury, Michael Obelter, Laura Draucker, Wen Wang, and Amanda Stevens.

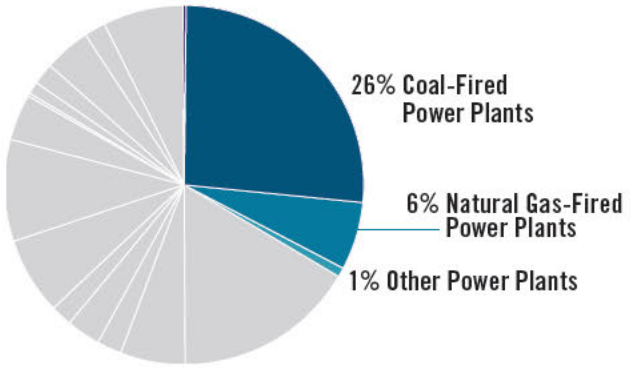
compounds, sulfur dioxide, and air toxics from natural gas systems. Actions to reduce those emissions will also reduce methane emissions (see Box 3 for more details).

IV. Understanding the Federal Reduction Pathways

A. ABOUT THE SECTOR-BY-SECTOR APPROACH

This analysis is a bottom-up assessment of the policies and regulatory tools available to the U.S. Administration, through the federal executive agencies tasked with implementing such regulations—to reduce GHG emissions. The analysis began with an examination of the makeup of U.S. emissions in 2010, followed by research and analysis into existing laws on authority to reduce emissions. We reviewed available literature to determine the range of emissions reductions technically feasible for each sector or subsector. Lastly, we considered legal authority, technical feasibility, cost and political will in constructing lackluster, middle-of-the-road, and go-getter scenarios for each sector or subsector. We briefly describe the scenarios for each sector or subsector below, beginning with the sectors that our analysis indicates offer the greatest potential for reductions. A more detailed discussion of our federal methods is provided in Appendix I.

FIGURE 9 Power Plant Emissions



As a Share of U.S. Emissions in 2010

B. ELECTRIC POWER

The electric sector is the largest single source of GHG emissions in the United States. In 2010 it made up 33 percent of total U.S. GHG emissions, and about 40 percent of all carbon pollution from the combustion of fossil fuels. This sector also represents the single biggest opportunity for emissions reductions using existing legal and regulatory tools.

1. Power plants

Carbon pollution from power plants can be reduced through the following federal regulatory authorities:

TABLE 1 Projecting New Source Performance Standards for Power Plants

	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Existing plants	Emissions reductions consistent with a 5 percent improvement in efficiency starting in 2018.	Aggregate emissions reductions across all electric generators equal to an 18 percent reduction in emissions in 2021 compared to 2012 emission levels, and a 33 percent reduction in 2035.	Aggregate emissions reduction across all electric generators equal to a 38 percent reduction in emissions in 2021 compared to 2012 emission levels, and a 74 percent reduction in 2035.
New plants	Standards initially consistent with EPA's proposal (1,000 pounds of CO_2 per megawatt-hour of output). Beginning in 2020, new unit performance improves to 570 pounds of CO_2 per megawatt-hour by 2030.	Standards initially consistent with the lackluster scenario. Beginning in 2028, new units achieve emissions rates equivalent to carbon capture and storage (CCS) with a 90 percent capture rate.	Standards initially consistent with the lackluster scenario. Beginning in 2020, new units achieve emissions rates equivalent to CCS with a 90 percent capture rate.

TABLE 2 Appliance and Equipment Efficiency Standards (Electric)

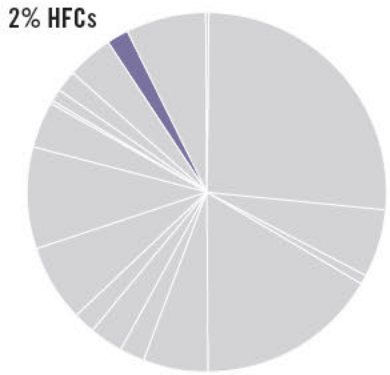
LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
192 TWh savings in 2025 from the residential and commercial sectors, plus additional savings from the industrial sector. Annual savings remain constant through 2035.	212 TWh savings in 2025 and 306 TWh savings in 2035 from the residential and commercial sectors, plus additional savings from the industrial sector.	364 TWh savings in 2025 and 525 TWh savings in 2035 from the residential and commercial sectors, plus additional savings from the industrial sector.

a. **Performance standards for new and existing sources under section 111 of the federal Clean Air Act**
Under section 111 of the Clean Air Act, EPA may prescribe emissions limitations based on the "best system of emission reduction" for new and modified existing sources within source categories EPA determines cause or contribute significantly to air pollution that may reasonably be anticipated to endanger human health or welfare.[14] To determine the "best system of emission reduction," EPA considers technological feasibility, cost, lead time, and energy and non-air environmental impacts.[15] In the spring of 2012 EPA proposed new source performance standards (NSPS) for new power plants.

In addition, for any source category EPA regulates on the federal level, EPA must also promulgate guidelines to states to use in developing requirements for existing sources under section 111(d). In regulating existing sources, states must determine the "best system of emission reduction" for existing sources while taking into account the same factors EPA uses to set limitations for new sources, and also the remaining useful life of existing sources.[16] The form of regulations imposed on existing sources is not tightly prescribed in the statute, and EPA has previously taken the position that states could implement flexible, market-based approaches in setting standards from existing sources. Table I specifies our three scenarios for new and existing power plants under section 111.

b. **Appliance and equipment efficiency standards under Department of Energy authority**
The Department of Energy (DOE) may promulgate efficiency standards for consumer appliances and non-consumer equipment under authority already granted DOE in current law. Based on available studies, the three scenarios analyzed assume progressively greater reductions through appliance and equipment standards, ranging up to 364 TWh of annual savings from residential and commercial consumers in 2025 and 525 TWh annual savings in 2035, with additional savings from industrial consumers.

FIGURE 10 HFC Emissions



As a Share of U.S. Emissions in 2010

C. HYDROFLUOROCARBONS

Hydrofluorocarbons (HFCs), used primarily for refrigeration and air conditioning, represented only 2 percent of all U.S. global warming pollution in 2010. Despite their relatively small share of the U.S. emissions picture today, our analysis finds HFCs can provide some of the greatest reductions by 2020 and through 2035. EPA has existing authority to regulate HFC consumption under Title VI of the Clean Air Act. EPA can phase down the use of HFCs under

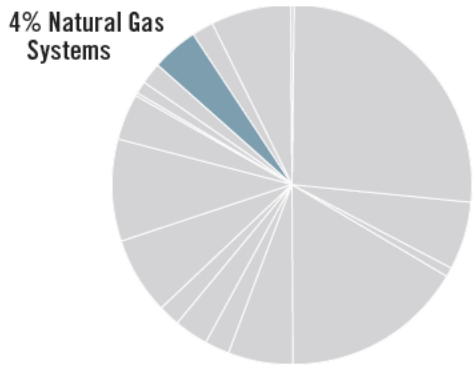
14. 42 U.S.C. §§ 7411(a)(1) & 7411(b)(1)(A).). U.S. Environmental Protection Agency. "Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act." Accessible at: <http://www.gpo.gov/fdsys/pkg/FR-2009-12-15/pdf/E9-29537.pdf>.
15. 42 U.S.C. §§ 7411(a)(1).
16. 42 U.S.C. §§ 7411(d)(1)(B).

TABLE 3 Emissions Reduction Schedule for Hydrofluorocarbons

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Consumption ramp-down occurs three years later than the schedule detailed in the joint North American Proposal.	Consumption is ramped-down in a manner consistent with the joint North American Proposal, which calls for an 85 percent reduction below 2005–2008 levels by 2033.	Consumption is ramped-down more rapidly than in the joint North American Proposal, achieving the 85 percent reduction target in 2028, five years earlier than detailed in the joint North American Proposal.

its Significant New Alternatives Program (SNAP), implementing section 612 of the Clean Air Act. The U.S. Administration has proposed an international ramp-down schedule to achieve reductions worldwide under the Montreal Protocol. Our middle-of-the-road scenarios for HFCs assume this proposed ramp-down schedule is met in the United States. The lackluster scenario assumes that the same ramp-down schedule is implemented, but on a delayed timeline, commencing in 2019 instead of 2016. Meanwhile, the go-getter scenario assumes a more ambitious reduction schedule.[17]

FIGURE 11 Emissions from Natural Gas Systems



As a Share of U.S. Emissions in 2010

D. NATURAL GAS SYSTEMS

Global warming pollution from natural gas systems accounts for approximately 4 percent of U.S. emissions. Yet like HFCs, our analysis suggests that natural gas systems may be among the top emissions reduction opportunities in the near term. Similar to power plants, EPA can regulate natural gas systems by implementing emissions performance standards for methane under section 111 of the Clean Air Act for new and existing natural gas systems. They may also be able to achieve additional GHG emissions reductions

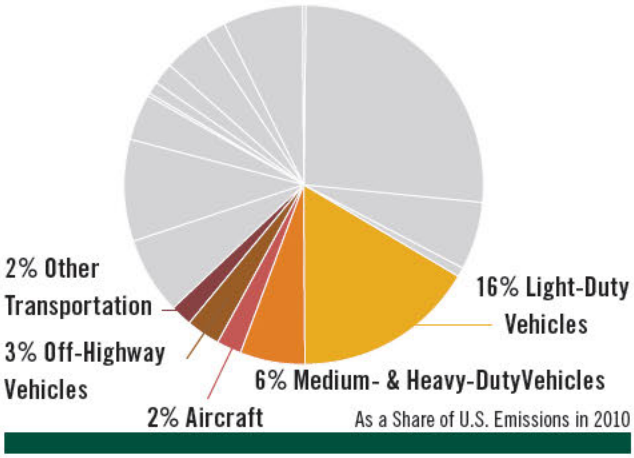
17. Due to modeling limitations, our analysis examines changes in HFC consumption. In the United States, HFC consumption is roughly equivalent to life-cycle emissions due to low rates of capture and destruction. See Appendix I for a more detailed discussion.

TABLE 4 Performance Standards to Reduce Emissions from Natural Gas Systems

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Emissions reductions of 26 percent from business-as-usual starting in 2019. Assumes implementation of plunger lift systems to reduce emissions from liquids unloading at new and existing wells, and leak monitoring and repair to reduce fugitive emissions from production, processing, and compressor stations.	Emissions reductions of 37 percent from business-as-usual starting in 2019. Assumes implementation of measures in lackluster scenario and conversion of existing high-bleed pneumatic controllers to low-bleed or no-bleed controllers to reduce emissions from production, processing, and transmission.	Emissions reductions of 67 percent from business-as-usual starting in 2019. Assumes implementation of measures in middle-of-the-road scenario, as well as desiccant dehydrators to reduce emissions during dehydration of wet gas; improved compressor maintenance to reduce emissions during processing; hot taps in maintenance of pipelines during transmission; and vapor recovery units to reduce emissions during storage.

by tightening standards for other air pollutants, such as volatile organic compounds and air toxics, as they recently did with respect to new equipment in the U.S. oil and gas sector. Through one or more of these regulatory paths, EPA could require equipment changes, upgrades, changes to operational practices, and inspection and leak prevention. Table 4 details the three scenarios analyzed. However, there is a great deal of uncertainty with regard to emissions for natural gas systems. This means that the absolute magnitude of abatement opportunities is uncertain. Nevertheless, our analysis identifies important opportunities to reduce emissions from this sector. Those reductions are some of the lowest cost opportunities identified in this analysis. See the appendix for a more detailed discussion of uncertainties and opportunities.

FIGURE 12 Transportation Emissions



E. TRANSPORT VEHICLES

Transportation is one of the largest sources of global warming pollution in the United States, accounting for 30 percent of the 2010 inventory. Improving the efficiency of motor vehicles has been a priority for the Obama Administration, which promulgated new standards to reduce emissions and raise the fuel efficiency of light-, medium- and heavy-duty vehicles. Our analysis finds that it is possible to achieve additional reductions from light-, medium-, and heavy-duty vehicles. In addition, there are opportunities to reduce emissions of global warming pollution from aircraft and off-highway vehicles.

1. Passenger vehicles

Under Title II of the Clean Air Act, EPA has the authority to regulate greenhouse gas emissions from new light-duty cars and trucks, and has done so already in two consecutive rulemakings covering vehicles sold through model year 2025. In conjunction with EPA's rulemaking, the Department of Transportation's National Highway Traffic Safety Administration (NHTSA) may promulgate corporate average fuel economy (CAFE) standards regulating the average fuel efficiency of new vehicles. Because standards have already been issued covering light-duty vehicles through model year 2025, our analysis focuses on the time period after 2025. Table 5 outlines the three scenarios, with the lackluster scenario projecting improvements at half the rate of the previous standards, middle-of-the-road projecting continuation of the same rate of improvement, and go-getter increasing the rate of improvement significantly.

2. Medium- and heavy-duty vehicles

For medium- and heavy-duty vehicles, EPA has established emissions standards and NHTSA has established fuel economy standards for model years 2014 through 2018. These standards are included in our business-as-usual emissions trajectory. Our emissions reduction scenarios pick up in model year 2020 using the same legal authority, but making different assumptions about the stringency of the next set of standards. As shown in Table 5, our lackluster scenario assumes a rate of improvement that is just half that of the current standards through 2035, middle-of-the-road projects a continuation of the current standards through 2035, and the go-getter scenario considerably increases new standards to meet the maximum level of efficiency currently thought to be technically achievable in that time frame.

3. Off-Highway engines

EPA may also regulate off-highway sources of global warming pollution under Title II of the Clean Air Act. For the lackluster, middle-of-the-road, and go-getter scenarios, respectively, the analysis assumes new standards can achieve 0.9 percent, 1.8 percent, and 2.4 percent annual improvement in the emissions rate for new equipment and engines from 2018 to 2035.

4. Aviation and aircraft

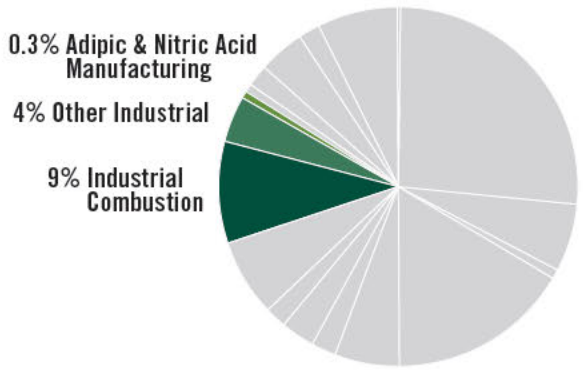
The Federal Aviation Administration (FAA) may make operational improvements in the air traffic control system that could achieve significant carbon pollution reductions over time. We draw our assumptions about operational improvements from an EPA analysis of the reductions possible and the FAA's comments on that analysis. Our scenarios, shown in Table 5, bound the range of reductions estimated by EPA and FAA.

TABLE 5 Vehicle Emissions Standards, Efficiency Standards, and Operational Improvements

	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Light-duty vehicles	Vehicle standards continue to improve from 2026–2035 at roughly half the rate of the 2017–2025 standards (2 percent per year). This results in a 131 grams per mile emissions standard and a 61 mpg CAFE standard in 2035.	Vehicle standards continue to improve from 2026–2035 at roughly the same rate as the 2017–2025 standards (4 percent per year). This results in a 104 gram per mile emissions standard and a 75 mpg CAFE standard in 2035.	Vehicle standards continue to improve from 2026–2035 at 6 percent annually. This results in a 81 grams per mile and a 92 mpg CAFE standard in 2035.
Medium- & heavy-duty vehicles	Standards continue to improve through 2035 at half the rate of the 2013–2018 standards by vehicle category—about a 1.3 percent annual improvement.	Standards continue to improve through 2035 at the same rate as the 2013–2018 standards by vehicle category—about a 2.6 percent annual improvement.	By 2020–2022, the medium- and heavy-duty fleet reduces its emissions rate by an average 26 percent and by 42 percent in 2023–2025 compared to 2010. Standards continue to improve annually by 1 percent through 2035.
Off-highway	From 2018 to 2035, a 0.9 percent annual improvement in the emissions rate for new equipment and engines.	From 2018 to 2035, a 1.8 percent annual improvement in the emissions rate for new equipment and engines.	From 2018 to 2035, a 2.4 percent annual improvement in the emissions rate for new equipment and engines.
Aviation	Through 2035, a 0.17 percent annual emissions reduction from operational improvements via FAA's NextGen Program.	Through 2035, a 0.4 percent annual emissions reduction from operational improvements via FAA's NextGen Program.	Through 2035, a 1.4 percent annual emissions reduction from operational improvements via FAA's NextGen Program, plus a 2.3 percent annual improvement in the performance of new aircraft and engines.

EPA has statutory authority under Title II of the Clean Air Act to promulgate standards to reduce emissions from new and existing aircraft engines. To date, EPA has never exercised that authority to require aircraft engine manufacturers to meet standards that the industry association has not previously adopted voluntarily. Nevertheless, our go-getter scenario, shown in Table 5, projects the emissions reductions that could be achieved if EPA were to pursue this regulatory course of action.

FIGURE 13 Industrial Emissions



As a Share of U.S. Emissions in 2010

F. INDUSTRY

Emissions from industrial facilities comprised 13 percent of U.S. global warming pollution in 2010. Fossil fuel combustion at industrial facilities accounts for 9 percent of U.S. emissions, while non-combustion industrial processes account for 4 percent of emissions. When accounting for upstream, indirect CO_2 emissions from power plants, the industrial sector is responsible for 23 percent of total U.S. GHG emissions.

EPA may regulate industrial stationary sources of emissions through performance standards under section 111 of the Clean Air Act. As with power

TABLE 6 Performance Standards to Reduce Industry Emissions

	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Fossil-fuel combustion in manufacturing and cement kilns	Emissions reductions consistent with a 10 percent improvement in combustion efficiency by boilers.	Emissions reductions consistent with harnessing all cost-effective energy efficiency across all processes and energy uses at manufacturing facilities. Emissions standards also drive reductions in process emissions from cement kilns.	Emissions reductions consistent with harnessing all cost-effective energy efficiency across the entire manufacturing facility. All new units must meet emissions rate equivalent to natural gas combustion. Emissions standards also drive reductions in process emissions from cement kilns.
Refineries	Emissions reductions consistent with a 1 percent improvement in efficiency beyond business-as-usual projections.	Emissions reductions consistent with a 5 percent improvement in efficiency beyond business-as-usual projections.	Emissions reductions consistent with a 10 percent improvement in efficiency beyond business-as-usual projections.
Nitric and adipic acid manufacturing	A 13 percent reduction in emissions.	A 56 percent reduction in emissions.	A 75 percent reduction in emissions.

plants, this is accomplished through EPA's setting of standards for new sources and issuing regulations that provide states with guidelines for covering existing sources. New source requirements typically take the form of a simple emissions rate, while regulation of existing sources can be more flexible.

1. Fossil fuel combustion in manufacturing and cement kilns

As with fossil-fuel burning power plants, reducing the GHG emissions profile of the industrial sector can be accomplished through improvements to the efficiency of boilers, fuel switching, and use of renewable energy such as biomass or geothermal, among other methods. Additional reductions are possible if regulations require a manufacturing facility to capture all cost-effective process efficiencies across an entire operation, beyond the boiler. Table 6 details the three scenarios analyzed for projecting possible reductions from the industrial sector. In addition, for the middle-of-the-road and go-getter scenarios for cement kilns, we assume emissions standards are used to drive reductions in process emissions through greater use of blended cements, and potentially carbon capture and storage, achieving reductions in process emissions of 2 percent in 2020 and 13 percent in 2035.

2. Petroleum refineries

EPA's advanced notice of proposed rulemaking, *Regulating Greenhouse Gas Emissions Under the Clean Air Act,* indicated that efficiency improvements in refineries are possible in the range of 10 to 20 percent. Some efficiency improvements are included in our business-as-usual projections, however. Therefore, in order to generate conservative estimates of emissions reductions, starting in 2018 we model lackluster, middle-of-the-road, and go-getter scenarios with reductions in annual GHG emissions of 1, 5, and 10 percent reductions beyond business-as-usual projections, respectively.

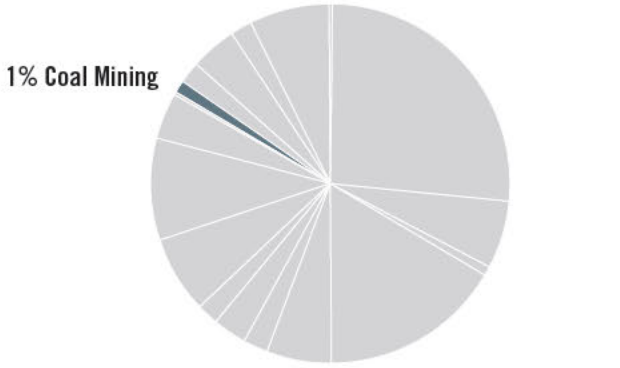
3. Nitric and adipic acid manufacturing

Nitric acid is primarily used as a feedstock for synthetic fertilizer, and also used to produce adipic acid and explosives. Adipic acid is used in the production of nylon and is a flavor enhancer in foods. The production of both compounds leads to emissions of nitrous oxide, a potent greenhouse gas. Though nitric and adipic acid manufacturing makes up less than 0.5 percent of total U.S. global warming pollution, there are opportunities to achieve dramatic reductions at low cost, making it a good target for policy.

To reduce emissions from acid manufacturing, EPA can use its authority under section 111 of the Clean Air Act to set standards for new manufacturing plants and issue guidelines to states to cover existing sources. Our

lackluster, middle-of-the-road and go-getter scenarios project reductions of annual GHG emissions of 13 percent, 56 percent, and 75 percent, respectively, compared to the business-as-usual projections.

FIGURE 14 Coal Mine Emissions

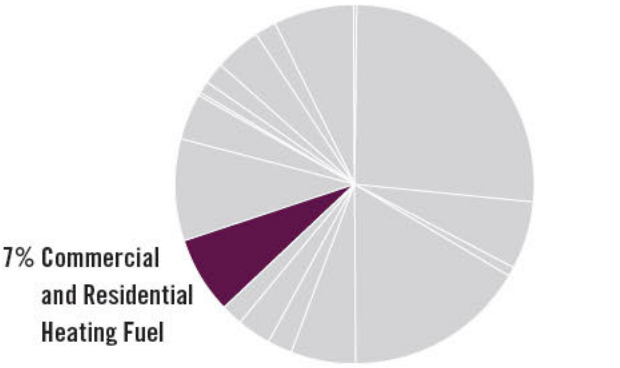


As a Share of U.S. Emissions in 2010

G. COAL MINES

Methane emissions from coal mines represented 1 percent of total U.S. global warming pollution in 2010. EPA may regulate coal mines as a source category under section 111 of the Clean Air Act. As discussed above for power plants and industry, this would entail EPA issuing performance standards for new coal mines and regulations to guide states in their regulation of existing coal mines. The statute does not prescribe the specific form of regulations applied to existing sources. For the lackluster, middle-of-the-road, and go-getter scenarios, we projected reductions from coal mines of 24 percent, 32 percent, and 39 percent, respectively, compared to business-as-usual projections.

FIGURE 15 Commercial & Residential Heating Emissions

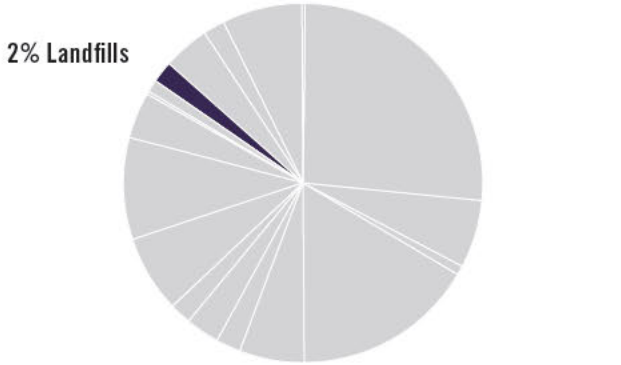


As a Share of U.S. Emissions in 2010

H. COMMERCIAL AND RESIDENTIAL HEATING

Carbon pollution from commercial and residential heating, mostly through natural gas combustion, accounted for 7 percent of U.S. emissions in 2010. This includes things such as home heating, cooking, and water heating. The most effective way to decrease emissions in this sector is to improve the building envelope—a path traditionally the province of state and local governments in the United States. However, the federal government can promulgate efficiency standards for appliances and equipment used to heat buildings. Based on our survey of the available literature, we conclude that efficiency standards implemented in 2015 could reduce natural gas demand by 126 Trillion British thermal units (TBtu) in 2025 and 235 TBtu in 2035, reducing GHG emissions by 6.7 million tons of CO_2 in 2025 and 12.5 million tons CO_2 in 2035 compared to business-as-usual projections. Due to limitations in the available literature, we project the same reductions level for all three scenarios.

FIGURE 16 Landfill Emissions



As a Share of U.S. Emissions in 2010

I. LANDFILLS

Methane emissions from landfills represented 2 percent of total U.S. global warming pollution in 2010. EPA already regulates emissions of volatile organic compounds from landfills under section 111 of the Clean Air Act. These standards provide the co-benefit of reducing methane emissions. EPA could either strengthen those standards or establish new standards for GHG emissions. The statute does not prescribe the form of regulations applied to existing sources. For the lackluster, middle-of-the-road, and go-getter scenarios, we projected reductions of 5 percent, 9 percent, and 9 percent, respectively, compared to our business-as-usual projections. The reductions we

project for landfills in this report are substantially smaller than the reductions projected in the 2010 report. These differences are attributable to changes in the EPA data used in the analysis.

V. Understanding the State Reduction Pathways

Policy action to address environmental challenges frequently begins at the state level, and greenhouse gases are no exception. States were the first to push ambitious emissions standards for vehicles, adopt greenhouse gas regulations for the power sector, and establish economy-wide reduction targets. Many states already have programs that reduce emissions from transportation, improve energy efficiency, and promote renewable generation. In the state scenarios, we examine what would happen if states continue to adopt policies that reduce their GHG footprint.

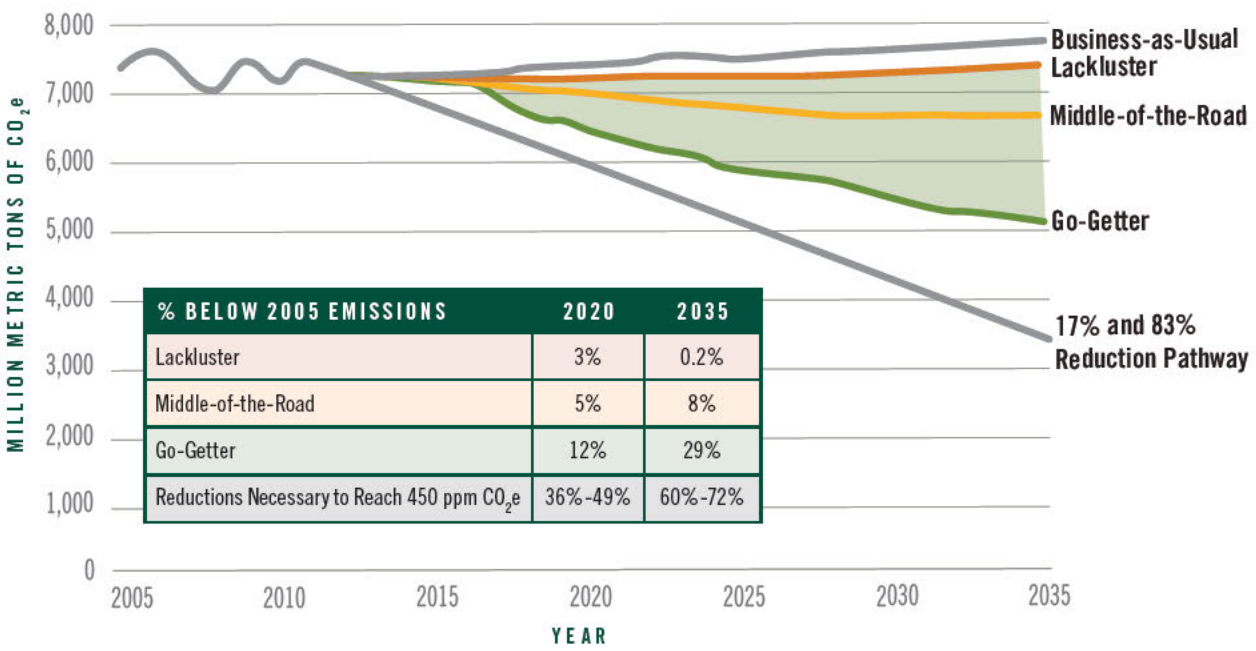
A. ABOUT THE STATES APPROACH

The state analysis takes a two-pronged approach. First, we project the potential greenhouse gas emissions reductions from transportation, end-use energy efficiency, and renewable electricity policies typically undertaken by states. Second, we consider the potential for state action in areas we also consider for the federal government, such as emissions standards for power plants and industry. This is based on the observation that the Constitution grants states broad authority to regulate their energy sources and emissions. States thus have the ability to implement many of the same policies as federal agencies.

In this analysis, the difference between lackluster and go-getter action at the state level is a function of the number and size of the states that adopt the measures modeled, and in some cases the ambition of the policies pursued. Unlike the federal analysis, in some cases state action would require new state legislation. However, we did not attempt to determine which states would require new legislation to implement the state measures and which states could implement without new legislation. A detailed discussion of our state methods is provided in Appendix II.

In addition to the direct emission reduction opportunities modeled here, state-level action can help trigger more ambitious action at the federal level. In the words of Justice Brandeis, states can serve as "laboratories of democracy," testing out approaches that provide possible models for federal action. Action at the state level can also lead to broader support for federal action, with the most ambitious states helping establish a floor for federal ambition.

FIGURE 17 Projected U.S Emissions when States Pursue the Full Range of Policies within their Authority (No Federal Action)



% BELOW 2005 EMISSIONS	2020	2035
Lackluster	3%	0.2%
Middle-of-the-Road	5%	8%
Go-Getter	12%	29%
Reductions Necessary to Reach 450 ppm CO_2e	36%-49%	60%-72%

Note: Due to modeling limitations, this figure depicts HFC consumption, which is generally thought to be equivalent to life-cycle emissions.

B. TRANSPORTATION

As noted above, the transport sector is responsible for about 30 percent of GHG emissions in the United States, making it the second largest emitting sector behind power plants. State and local policies have traditionally played a significant role in transportation, and as a result we project reductions that states might be able to achieve in this area, including through policies to encourage the use of lower carbon fuels and reduce vehicle miles traveled.

1. Lower Carbon Fuels

States may establish requirements for the fuels delivered in their jurisdictions to reduce the carbon profile of those fuels. To project potential reductions through state policies that reduce the life-cycle emissions of transportation fuels, we do not select specific policies in specific states. Rather, we model percent improvements in the carbon profile of fuels generally. These general improvements in the carbon profile of fuels are a proxy for what is likely to be a diverse set of measures across numerous states.

For modeling purposes, we assume that those policies further reduce the average life-cycle carbon intensity of transportation fuels by 1 percent per year between 2015 and 2035. In the lackluster scenario, we assume this annual reduction is achieved by states accounting for 15 percent of total energy consumption from U.S. transportation fuels. In the middle-of-the-road and go-getter scenarios, we assume that these policies are pursued by states accounting for 25 percent and 35 percent of total U.S. transportation fuel consumption, respectively.[18]

2. Reducing Vehicle Miles Traveled

States play a big role in designing and implementing policies that directly impact the number of vehicle miles traveled. These include smart growth strategies, such as targeting new development near public transportation, favoring infill, limiting sprawl, mixed-use development, and provision of smartly located affordable housing options. These strategies can be complemented by a variety of strategies, including improving and expanding public transportation options, bike and pedestrian pathways, car sharing, and HOV lanes, as well as through speed limit restrictions, intercity tolls, and strategies to limit driving within urban centers (e.g., parking restrictions).

In our lackluster and middle-of-the-road scenarios, we assume that states that implement policies and programs achieve VMT reductions of 0.5 percent per year beginning in 2016, leading to a 10 percent reduction below business-as-usual projections in 2035.

18. See Appendix II for context about what it would take to achieve the state uptake in this and the other state scenarios.

TABLE 7 State Transportation Measures

ACTION	POLICIES AND PROGRAMS DRIVING ACTION	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Reduce carbon content of fuels by 1 percent per year from 2015 to 2035	■ Low-carbon fuel standard ■ Clean fuel standard ■ Advanced biofuels standard ■ Infrastructure incentives	States accounting for 15 percent of transportation fuel consumption implement measures to achieve a reduction.	States accounting for 25 percent of transportation fuel consumption implement measures to achieve a reduction.	States accounting for 35 percent of transportation fuel consumption implement measures to achieve a reduction.
Vehicle miles traveled reductions of 0.5 or 1 percent per year from 2016 to 2035	■ Smart growth ■ Improved public transit ■ Pedestrian and biking infrastructure ■ Improved traffic systems operations	States accounting for 15 percent of GHG emissions from light-duty vehicles implement measures to achieve a reduction of 0.5 percent per year.	States accounting for 25 percent of GHG emissions from light-duty vehicles implement measures to achieve a reduction of 0.5 percent per year.	States accounting for 35 percent of GHG emissions from light-duty vehicles implement measures to achieve a reduction of 1 percent per year.

This is on the conservative end of the range found in the state programs under way. Therefore, in our go-getter scenario we assume that states reduce VMT 1 percent per year. We assume that these policies and programs are implemented by states accounting for 15, 25, and 35 percent of GHG emissions from light-duty vehicles in our lackluster, middle-of-the-road, and go-getter scenarios, respectively.

C. ENERGY EFFICIENCY

Energy efficiency measures avoid the need to use fossil fuels and save consumers money, creating significant economic benefits.[19] States are on the front lines in designing and implementing programs to enhance energy efficiency, both for end-use electricity and heating fuels. Our analysis projects the emissions reductions states may achieve implementing energy efficiency programs, building codes, and the increased penetration of combined heat and power. Each type of measure is outlined below.

1. Electricity Savings

States have been the primary drivers of end-use energy efficiency within their borders. Many states have implemented energy efficiency portfolio standards and/or other ratepayer-funded programs to fund energy efficiency investments. Other states have sought to integrate energy efficiency into the process for procuring new generation resources (e.g., in the context of long-term resource planning), so that energy efficiency can compete as a viable alternative to more traditional generating resources.

To project potential emissions reductions from increased state-level energy efficiency policies, we made different assumptions about states with and without such policies. We assume that some states with and without existing energy efficiency targets adopt policies and programs that lead to electricity savings beginning in 2015. Both the rate of savings and the number of states covered varies across the scenarios, as shown in Table 8.

2. Natural Gas Savings

A number of states have also begun to implement energy efficiency programs targeted at natural gas consumption. These programs can resemble those for electricity savings, taking the form of energy efficiency portfolio standards or system benefit charges. As with the electricity savings scenarios, we assume that some states with targets increase those targets, and that some states without targets implement those targets. The scenarios are shown in Table 8.

3. Improving Building Performance

States and municipalities are generally responsible for adopting and updating state and local building energy codes, which apply to new construction and major renovations. Responsibility for enforcing these codes is part of the states' police powers. In our lackluster scenario, we assume that states accounting for 10 percent of the energy consumed by the building sector implement more ambitious building codes. In our middle-of-the-road and go-getter scenarios, we assume that states accounting for 30 and 50 percent of the energy consumed by the building sector implement more ambitious building codes, respectively.

4. Increased Penetration of Combined Heat and Power

The U.S. electricity system is designed to accommodate large central station power plants located away from the electricity customers. Fossil-fuel generating plants operate at 30 to 60 percent efficiency, wasting significant energy in unused heat from the combustion process. Combined heat and power (CHP), or cogeneration, is a form of distributed generation located at or very near end-use customers that captures and puts waste heat to beneficial use.

States have been at the forefront in driving the spread of CHP. They have done so through a variety of policies, including standard interconnection rules, reduced standby rates, net metering policies, friendly air quality regulations (such as output-based emissions regulations), technical assistance programs, and various financial incentives.[20] In our lackluster, middle-of-the-road, and go-getter scenarios, we assume that state action results in deployment of an additional 10, 20, and 40 GW of new CHP by 2025, respectively, beyond business-as-usual projections.[21]

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19. *The Long-Term Energy Efficiency Potential: What the Evidence Suggests.* American Council for an Energy Efficient Economy, Research Report E121, January 2012. Accessible at: < http://www.aceee.org/research-report/e121>.
20. *Challenges Facing Combined Heat and Power Today: A State-by-State Assessment.* ACEEE Report Number IE111, September 2011.
21. In the go-getter scenario, we assume that state action results in deployment of 27 GW of CHP in 2020, in addition to the 13 GW built into our business-as-usual projections. Combined, they result in CHP deployment consistent with the executive order target of 40 GW of new CHP by 2020.

TABLE 8 State Energy Efficiency Measures

ACTION	POLICIES AND PROGRAMS DRIVING ACTION	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Electricity savings from states with EE targets	■ Energy efficiency resource standards ■ System benefit charge funds or other funds ■ Least-cost procurement requirements	States responsible for 75 percent of electricity consumption that have annual energy efficiency targets below 1.5 percent increase their annual target to 1.5 percent from 2015 to 2035.	States responsible for 75 percent of electricity consumption that have annual energy efficiency targets below 2 percent increase their annual targets to 2 percent from 2015 to 2035.	States responsible for 75 percent of electricity consumption that have annual energy efficiency targets below 2.5 percent increase their annual targets to 2.5 percent from 2015 to 2035.
Electricity savings from states without EE targets		States responsible for 25 percent of electricity consumption achieve electricity savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 25 percent of electricity consumption achieve electricity savings of 1.5 percent of total demand per year from 2015 to 2035.	States responsible for 50 percent of electricity consumption achieve electricity savings of 1.5 percent of total demand per year from 2015 to 2035.
Natural gas savings from states with EE targets	■ Energy efficiency resource standards ■ System benefit charge funds or other funds	States responsible for 25 percent of natural gas consumption that have energy efficiency targets below 1 percent achieve savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 50 percent of natural gas consumption that have energy efficiency targets below 1 percent achieve savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 75 percent of natural gas consumption that have energy efficiency targets below 1.5 percent achieve savings of 1.5 percent of total demand per year from 2015 to 2035.
Natural gas savings from states without EE targets		States responsible for 10 percent of natural gas consumption achieve natural gas savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 25 percent of natural gas consumption achieve natural gas savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 50 percent of natural gas consumption achieve natural gas savings of 1.5 percent of total demand per year from 2015 to 2035.
Reduced energy consumption in buildings	■ Commercial and residential building codes ■ Financial incentives	States accounting for 10 percent of the energy consumed by the building sector implement more ambitious building codes.	States accounting for 30 percent of the energy consumed by the building sector implement more ambitious building codes.	States accounting for 50 percent of the energy consumed by the building sector implement more ambitious building codes.
Increased penetration of combined heat and power	■ Standard interconnection rules ■ Reduced standby rates ■ Net metering policies ■ Output-based emissions regulations	State action results in deployment of an additional 10 GW of new CHP beyond business-as-usual projections by 2025.	State action results in deployment of an additional 20 GW of new CHP beyond business-as-usual projections by 2025.	State action results in deployment of an additional 40 GW of new CHP beyond business-as-usual projections by 2025.

TABLE 9 State Renewable Energy Policies

	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Increased renewables from states with renewables targets	States responsible for 25 percent of electricity consumption increase their renewable generation by 1 percent annually after the last year for which a standard is set.	States responsible for 50 percent of electricity consumption increase their renewable generation by 1 percent annually after the last year for which a standard is set.	States responsible for 75 percent of electricity consumption increase their renewable generation by 1 percent annually after the last year for which a standard is set.
Increased renewables from states without renewables targets	States responsible for 10 percent of electricity consumption increase their renewable generation 0.5 percent annually beginning in 2015.	States responsible for 25 percent of electricity consumption increase their renewable generation 0.5 percent annually beginning in 2015.	States responsible for 50 percent of electricity consumption increase their renewable generation 0.5 percent annually beginning in 2015.

D. RENEWABLE ELECTRICITY GENERATION

Similar to energy efficiency, state policies have been major drivers of renewable electricity generation in the United States. Twenty-nine states and the District of Columbia have renewable energy portfolio standards or advanced energy standards. Numerous states also support distributed or customer-sited renewables as part of their RPS or through other ratepayer-funded programs. In order to capture the reductions possible from states taking new or additional action to increase renewable generation serving their residents, we assumed that a certain number of states without renewable energy targets add 0.5 percent renewables per year beginning in 2015. For those states that already have renewables targets, we assumed they continued to add 1 percent a year to those targets after the target is achieved. Table 9 provides details on differences across the scenarios.

E. WHEN STATES TAKE A MORE EXPANSIVE TACK

States have broad authority to regulate energy sources and emissions within their boundaries. They may therefore implement many of the same policies that we ascribe to the federal government in the federal analysis. In determining what reductions states might make in the future, the analysis considers not only traditional state energy policies, but also scenarios in which states decide to approach carbon pollution more expansively. For example, the states participating in the Northeast and Mid-Atlantic Regional Greenhouse Gas Initiative (RGGI) have chosen to design and implement a multistate cap-and-trade program to reduce carbon pollution from power plants in their states. Other states could join them, or take alternative approaches to reducing carbon pollution from power plants. The most significant example of this is California, which has taken an expansive approach to reducing GHGs in its Global Warming Solutions Act of 2006 and the regulations adopted under that law.

Because it is hard to predict which other states, if any, will pursue ambitious standards for greenhouse gases, we modeled more broad-based action by assuming a portion of total national emissions within each sector would be covered by the reduction measures analyzed for the federal government in section IV above. In the lackluster, middle-of-the-road, and go-getter scenarios, we assume these measures are adopted by states accounting for 10, 25, and 50 percent of GHG emissions from a given sector, respectively.

These approaches include state action for all sectors discussed in the federal action section, except for those policies that are ill-suited for state implementation. We deemed policies that eliminate HFCs, regulate off-highway vehicles, adopt appliance and equipment efficiency standards where federal standards already exist, or regulate aviation to be ill-suited to state implementation because they are preempted by federal law.

It is important to note that we vary both the number of states taking action and the level of ambition they each pursue. In all sectors, the level of ambition pursued is the same as the ambition defined in the federal scenario described in Section IV. Therefore, in our lackluster scenario for power plants, we assume states accounting for 10 percent of GHG emissions from the power sector

implement policies equivalent to the lackluster scenario for federal action. In our go-getter scenario, we assume states accounting for 50 percent of GHG emissions from the power sector implement policies equivalent to the go-getter scenario for federal action.

VI. Conclusion: Finding Our Way to a Low-Carbon Future

The enormous economic and social costs of climate disruption are increasingly evident in the United States. Yet the urgency conveyed by the mounting evidence is not yet reflected in U.S. federal and state actions or climate policies. The United States is not currently on path to meet its international pledge to reduce GHG emissions to 17 percent below 2005 levels by 2020, though it could meet this goal with go-getter action by the U.S. Administration under current laws. In order to achieve adequate mid-century reductions, it appears almost certain that the U.S. Congress will eventually have to enact new legislation aimed at getting deep reductions. Ultimately, a cooperative approach bringing together Congress, states, and the executive branch will be necessary for the United States to do its part.

States can contribute to U.S. emissions reductions, both through state-level transportation, energy efficiency, and renewables programs, as well as through new legislative efforts to initiate a wide array of other policies aimed at reducing GHGs. It appears unlikely that state actions alone will put the United States on the necessary course. However, they can help complement federal action, and can enable the United States to meet its 17 percent target if federal agencies fail to pursue go-getter-level action.

KEY RECOMMENDATIONS

- In the short term, federal agencies and the states should aggressively move forward with a "go-getter" emissions reduction scenario. This will necessitate taking action in the following key areas that present the greatest opportunities for GHG emissions reductions through 2020:
  - EPA and the states should focus on achieving significant reductions in carbon pollution from power plants and natural gas systems.
    - For power plants, EPA should finalize its proposed greenhouse gas emissions standards for new power plants and should move ahead with flexible and ambitious standards for existing power plants. States should move ahead with measures to reduce emissions from the power sector, such as increasing the use of renewable power and cogeneration and reducing electricity demand.
    - For natural gas systems, EPA and the states should propose rules that address methane as a greenhouse gas pollutant, which can result in significant reduction of methane leakage throughout the natural gas life cycle. Such rules would complement the volatile organic compound and air toxics rules established in 2012 for natural gas systems that have the co-benefit of reducing methane leakage.
  - The State Department should continue to seek reductions in hydrofluorocarbons through amendments to the Montreal Protocol. But, in the meantime, EPA should begin reducing consumption in the United States using its authority under the Clean Air Act.
  - EPA and the states should also work to improve energy efficiency in the residential, commercial, and industrial sectors.
- Over time, we will need to see reductions from all sectors, and the Administration should use its existing authorities to achieve go-getter-level reductions across the economy.
- Even with go-getter-level action, however, reductions will fall short of the long-term targets necessary to avoid the worst impacts of climate disruption. As a result, congressional action will be necessary.

BOX 4 Risks and Uncertainties

Uncertainties associated with the methods and results of this analysis include:

- **Uncertainties inherent in the models.** As with any modeling analysis of this sort, there is significant uncertainty in projecting the future. The analysis relies heavily on the Energy Information Administration's *Annual Energy Outlook 2012*, which attempts to project energy and emissions trends into the future based on a number of assumptions, including likely fuel costs, economic activity, and source turnover rates. There are also considerable uncertainties in the estimates of fugitive emissions from natural gas systems. All projections are only as good as the assumptions that go into them and the quality of the data modeled.

- **Regulatory impetus.** As the different scenarios suggest, a major uncertainty in the analysis is whether the federal administration will carry out the regulatory actions in a manner sufficient to achieve the reductions that available studies suggest are technically feasible. The lackluster, middle-of-the-road, and go-getter scenarios stand for different levels of regulatory ambition. The go-getter scenario, it should be emphasized, will require steadfast resolve on the part of the Administration and the states.

- **Congressional action.** Federal agencies depend on the U.S. Congress for their budgets. In order to carry out a series of new regulatory actions, federal agencies will require sufficient resources through the annual budget process. In addition, it should be noted that existing authorities can be curtailed through new legislation.

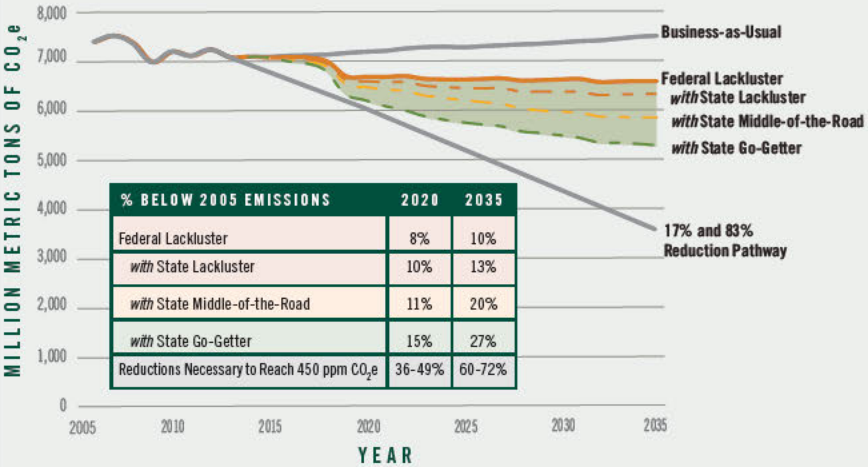
- **Legal risk.** The assumptions made in this analysis were informed by sound legal analysis and vetted with legal experts in the field. Nevertheless, when federal agencies take new actions under existing statutes, the new actions are often challenged in federal court on the grounds that the agency has exceeded the authority originally granted to it in the statute. It is impossible to predict with any precision whether the challenges will be successful.

- **Technological development.** The results modeled depend in part on the development and deployment of new technologies over time. Indeed, many of the regulatory policies are technology-based and must be revised by federal agencies as technology progresses. If technologies emerge rapidly, emissions reductions are more likely. Conversely, if technologies are slow to appear, emissions reductions will slow. This uncertainty is especially important further out into the future.

Supplemental Figures

BOX S-1 Greenhouse Gas Emissions Reductions from State Action Coupled with Lackluster Federal Action

FIGURE S-1 Projected U.S Emissions with State Action Coupled with Lackluster Federal Action



% BELOW 2005 EMISSIONS	2020	2035
Federal Lackluster	8%	10%
with State Lackluster	10%	13%
with State Middle-of-the-Road	11%	20%
with State Go-Getter	15%	27%
Reductions Necessary to Reach 450 ppm CO_2e	36-49%	60-72%

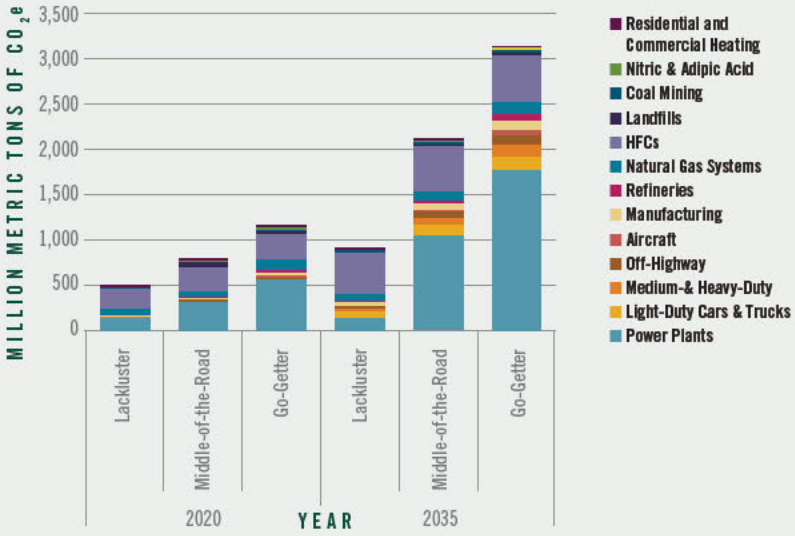
Note: Figure depicts changes in consumption of HFCs.

If the U.S. Administration pursues a lackluster effort, go-getter state action will not be sufficient to make up the emissions gap and reduce GHG emissions 17 percent below 2005 levels by 2020. However, as shown in Figure 2, the 17 percent GHG reduction goal can be achieved with a state go-getter effort along with middle-of-the-road federal action. State action with go-getter federal action is not shown, as it does not provide significant reductions above and beyond other combinations of state and federal action that were considered as a result of the way the scenarios are defined.

BOX S-2 Greenhouse Gas Emissions Reductions from Federal Action

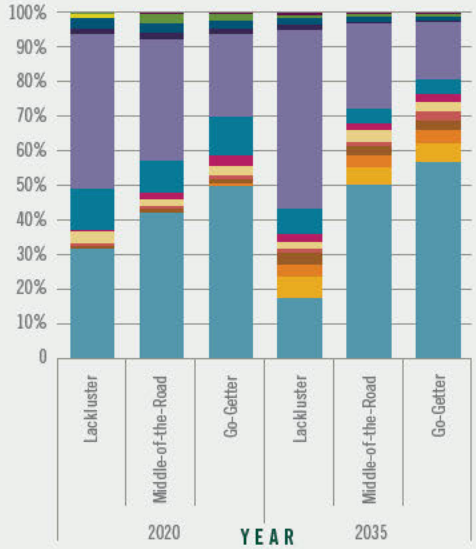
The majority of potential GHG benefits come from actions taken in the power sector, energy efficiency improvements, reducing HFC consumption, and reducing methane emissions from natural gas systems. These actions represent between 80 and 93 percent of potential GHG reductions across all scenarios in 2020 and 2035, and are necessary to achieve a 17 percent reduction below 2005 GHG emissions levels.

FIGURE S-2 Greenhouse Gas Emissions Reductions from Federal Action, in million metric tons



Note: Figure depicts changes in consumption of HFCs.

FIGURE S-3 Greenhouse Gas Emissions Reductions from Federal Action, as a percent of total reductions



Note: Figure depicts changes in consumption of HFCs.

BOX S-3 Greenhouse Gas Emissions Reductions from State Action Only

Improvements in the power sector largely drive reductions in all of the scenarios that examine the impact of state actions without any new federal actions. This is accomplished through a combination of GHG performance standards, renewable and energy efficiency standards, building codes, and policies to promote combined heat and power. In our scenarios those actions can alleviate the demand for up to 1,280 terra watt-hours of conventional sources of electricity in 2035. This is offset to a limited extent through increased vehicle electrification, which increases demand by up to 66 terra watt-hours of electricity in 2035.

States can implement many of the same types of policies as federal agencies. They can also take additional actions that increase electric efficiency, renewable electricity generation, building performance, and combined heat and power penetration.

However, states are less well-equipped to reduce HFC consumption, adopt appliance and equipment efficiency standards where federal standards already exist, and to drive reductions in GHG emissions from off-highway vehicles and aviation. As a result, under our scenarios, state action alone is insufficient to achieve the near-term and long-term GHG reduction targets.

FIGURE S-4 State Actions that Affect Electricity Supply and Demand

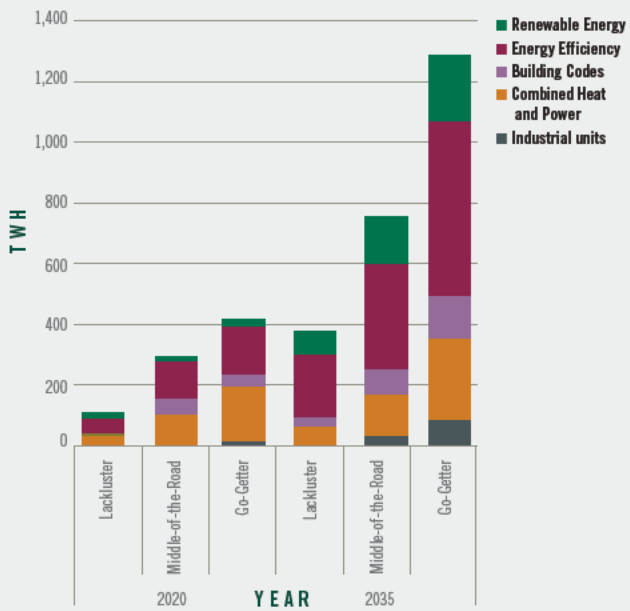


FIGURE S-5 Greenhouse Gas Emissions Reductions from State Action, in million metric tons

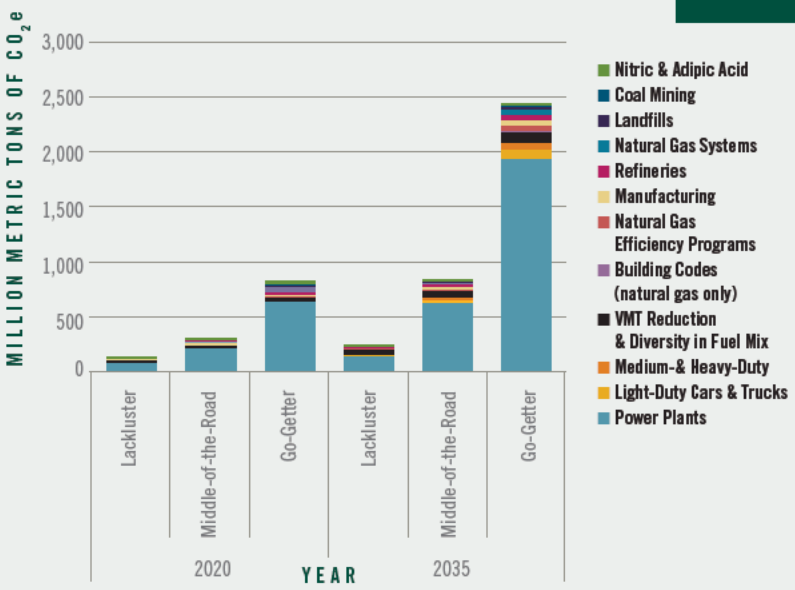
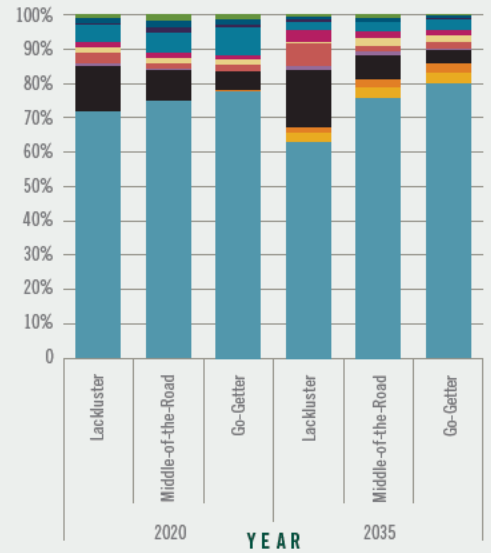


FIGURE S-6 Greenhouse Gas Emissions Reductions from State Action, as a percent of total reductions from state actions



Appendix I: Federal Methods

I. Overview

This analysis projects the range of greenhouse gas (GHG) emissions reductions achievable through regulations and policies implemented by federal agencies under existing federal law and by states under existing or new state laws. This assessment builds on our 2010 report, which began by examining the 2008 national emissions inventory to determine the major sources of emissions. The 2010 report examined both the boundaries of existing federal law and evaluated the published literature to determine the level of emissions reductions achievable from sources in key sectors and subsectors. Due to the difficulty in predicting how federal agencies will act within the bounds of their legal authority, we continue the approach from our 2010 report, which defines three scenarios meant to capture a range of potential reductions in each sector or subsector. Reflecting the available literature, we have defined the scenarios to span a range of different costs, technological assumptions, and types of policies.

Our literature survey examined government and independent reports. We focused on those analyses whose scale was translatable to our model inputs. For example, we focused on studies of entire industrial categories (such as pulp and paper) and not process components (such as steam cracking). We also relied more heavily on studies that provided some assessment of cost in order to provide a sense of the federal regulatory resolve necessary to achieve those reductions. Where a federal agency has provided preliminary estimates of the reductions achievable through regulatory activity, we have attempted to incorporate those estimates into one of the scenarios.

This analysis contains bottom-up analyses of both federal and state action, assessing the total emissions reductions achievable through regulatory actions and policies sector by sector. This appendix provides a summary of the federal analysis. Appendix II provides details on the state analysis.

We calculated the emissions reductions associated with each scenario using an Excel-based model that utilizes publicly available detailed emissions reports, as well as outputs from a publicly available off-the-shelf transportation model (Argonne National Laboratory's VISION model). Most sectoral analyses were independent and did not interact with each other; for example, reductions in coal or natural gas demand from one set of policies did not affect utilization of those fuels in another sector. We account for changes in electric demand through an electric demand module that selectively turned units on and off in a predetermined manner (see Section III.C for more information). We also account for changes in emissions from refineries and natural gas systems due to changes in demand for petroleum products and natural gas, respectively.

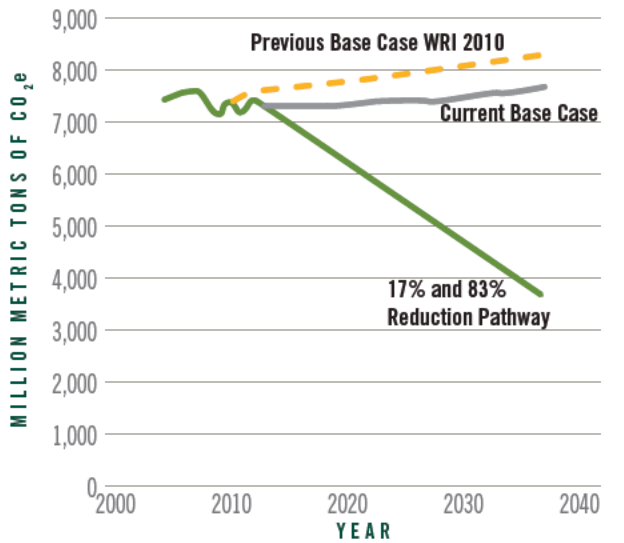
In the pages that follow we describe the base case, modeling assumptions, and scenarios.

II. Base Case

The base case, or "business-as-usual" case, was developed using several different projections. Carbon dioxide (CO_2) emissions from fossil fuel combustion come from the U.S. Energy Information's (EIA's) *Annual Energy Outlook 2012* (AEO2012). Non-CO_2 emissions projections were obtained from EPA's *Draft Global Non*-CO_2 Emissions Projections Report: 1990–2030.[1] Non-energy CO_2 emissions projections were obtained from EPA's ADAGE model reference scenario, as developed for their analysis of HR 2454, the American Climate and Energy Security Act of 2009.[2] The base case emissions projections for natural gas systems come from analysis conducted for *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas*, a forthcoming WRI working paper that examines emissions and abatement opportunities for natural gas systems.[3]

Base case emissions in this report are lower than the base case projections in our 2010 report *Reducing Greenhouse Gas Emissions in the United States Using Existing Federal Authorities and State Action* (see Figure A-1.1). This is largely due to reductions in CO_2 emissions from fossil fuel combustion, driven by a variety of factors, including lower natural gas prices, less optimistic economic projections, and new standards for power plants and light-, medium-, and heavy-duty vehicles. In addition, new standards for natural gas systems have reduced projections of methane emissions.

FIGURE A-1.1 Comparison of Base Case Emissions Projections (2010 v. 2013 Analysis)



A. EIA AEO2012

The AEO is updated annually and is one of the leading sources of economy-wide energy emissions projections through 2035. Data outputs are disaggregated, and more detailed data tables are publicly available upon request, making this an attractive starting point. The 2035 timeline provides enough time to see noticeable impacts from unit turnover. Longer time frames would allow for greater unit turnover, but were not desirable due to the considerable uncertainty in predicting technological availability in future time frames. AEO2012 incorporates updated economic projections, which include a slightly lower growth in GDP through 2035 compared to previous projections. Increases in the natural gas supply, along with lower natural gas prices, are also incorporated into this AEO. It also incorporates several new rules and regulations not included in AEO2009, which was used in our previous report. These include (in a side case) standards for light-, medium-, and heavy-duty vehicles, as well as several regulations affecting the power sector. AEO2012 is described in greater detail in the sections that follow.

B. EPA'S DRAFT GLOBAL NON-CO_2 EMISSIONS PROJECTIONS REPORT: 1990–2030

The AEO does not generally include non-energy and non-CO_2 emissions. Non-CO_2 emission projections for all sources, except for natural gas and petroleum systems and HFC consumption, came from EPA's *Draft Global Non-CO_2 Emissions Projections Report: 1990–2030.*[4] In this report, EPA developed country-specific emissions projections using assumptions about economic activity, technology development, emissions reduction programs and agreements, and other factors. Results were provided in five-year intervals. We estimated emissions between the five-year intervals by applying a linear rate of change. Emissions for 2030 through 2035 were estimated by applying the same rate of change observed from 2025 to 2030.

C. ADAGE

Non-energy CO_2 emissions projections come from the Applied Dynamic Analysis of the Global Economy (ADAGE) reference scenario of EPA's modeling of the American Clean Energy and Security Act of 2009 (ACES).[5] ADAGE is a dynamic computable general equilibrium model run by RTI International.[6] ADAGE projects emissions in five-year intervals from 2010 to 2050. To estimate emissions between those intervals, we applied a linear rate of change between intervals. EPA does not run the ADAGE model annually, but does so in response to congressional requests. For purposes of this report, we are using the most recent publically available results.

D. ADDITIONAL DATA SOURCES

Base case emissions projections for natural gas systems come from analysis conducted for *Clearing the Air on Shale Gas Emissions*, a forthcoming WRI working paper that examines emissions and abatement opportunities for natural gas systems.[7] Their base case projections were developed using EPA's *Inventory of Greenhouse Gas Emissions and Sinks 2012*[8], shale gas production projections from AEO2012, and emissions factors from *Life Cycle Carbon Footprint of Shale Gas: Review of Evidence and Implications.*[9] This report only considers abatement opportunities from natural gas systems. However, because EPA's *Draft Global Non-CO_2 Emissions Projections Report: 1990-2030* lumped natural gas systems with petroleum systems, we also developed projections for petroleum systems using historical emissions[10] and historical production data,[11] as well as projected production data.[12]

Base case projections for HFC consumption come from EPA's *Benefits of Addressing HFCs under the Montreal Protocol.*[13] Additional discussion of this approach is provided in Section V.C. on hydrofluorocarbons. Aspects of the transportation analysis require

assumptions about the vehicle fleet, including stock turnover. For this part of the analysis, we used Argonne National Laboratory's VISION model,[14] adjusting their base case to incorporate the latest EPA and NHTSA standards for light-duty vehicles.

E. NOTE ABOUT GLOBAL WARMING POTENTIALS

Where possible, we have attempted to provide emissions and consumption estimates using the latest state of the science, as reported in the Intergovernmental Panel on Climate Change's (IPCC) *Fourth Assessment Report.* Several data sources—including EPA's *Draft Global Non-CO_2 Emissions Projections Report: 1990-2030*—utilize the global warming potential estimates reported in IPCC's Second Assessment Report. This is done in order to be consistent with international reporting standards under UNFCCC. We do not follow this convention, however, and instead seek to use a more accurate accounting of the actual global warming impact of the different gases. This allows for a more accurate accounting of the actual GHG impacts of new policies as well as inaction.

Unfortunately, we could not update all gases to the global warming potentials reported in the *Fourth Assessment Report*. Detailed speciation is not available for projections of F-gases, and therefore it was not possible to accurately update their projections. Therefore, we did not update historical emissions for F-gases in order to remain consistent with our approach for projected emissions.

III. Power Plants

A. GREENHOUSE GAS PERFORMANCE STANDARDS

1. Base Case

Modeling of the electric sector was based on the AEO2012 reference case and utilized detailed AEO2012 outputs provided by the U.S. Energy Information Administration (EIA) that indicate annual capacity, generation, consumption, and emissions changes by technology type.[15] AEO2012 projects that end-use efficiency will increase over time, and the emissions intensity of generation will decrease. However, it also predicts that electric demand will grow from 3.8 trillion kWh in 2010 to 4.7 trillion kWh in 2035, resulting in an increase in CO_2 emissions to 2.3 billion metric tons in 2035, which is 3 percent above 2010 levels.[16]

The AEO2012 reference case includes mandatory state renewable portfolio standards, the Northeastern and Mid-Atlantic Regional Greenhouse Gas Initiative (RGGI), and California Assembly Bill 32 (AB32).[17] It also includes the Mercury and Air Toxics Standard (MATS) issued by the U.S. Environmental Protection Agency (EPA) in December 2011, as well as the Cross-State Air Pollution Rule (CSAPR) finalized by EPA in July 2011, which reduces sulfur dioxide (SO_2) and nitrous oxide (NO_x) emissions from power plants. CSAPR was vacated by the Federal Circuit Court for the D.C. Circuit in August 2012, marking an inconsistency between the model assumptions and real-world regulatory requirements for power plants. EPA has petitioned for a rehearing of the CSAPR appeal en banc and is expected to appeal the DC

BOX A-1 Modeling New Source Performance Standards under Section 111 of the Clean Air Act

Few performance standards for existing units have been issued to date, and thus far there are no such standards that cover greenhouse gases. In modeling the impact of any future standards, we made certain assumptions about the timing of the implementation of those standards. That timeline is described below. EPA announced their intention to establish emissions standards for existing power plants and refineries in December 2010. Therefore, for modeling purposes we assume that some of the background analysis has been done and that it would be possible for those standards to take effect within five years; that is, beginning in 2018.

TIMELINE
1.5–2 years to adopt federal standards & guidelines to states
1–2 years for states to develop standards for existing sources
3 years for existing units to comply
Total: 6-year lag

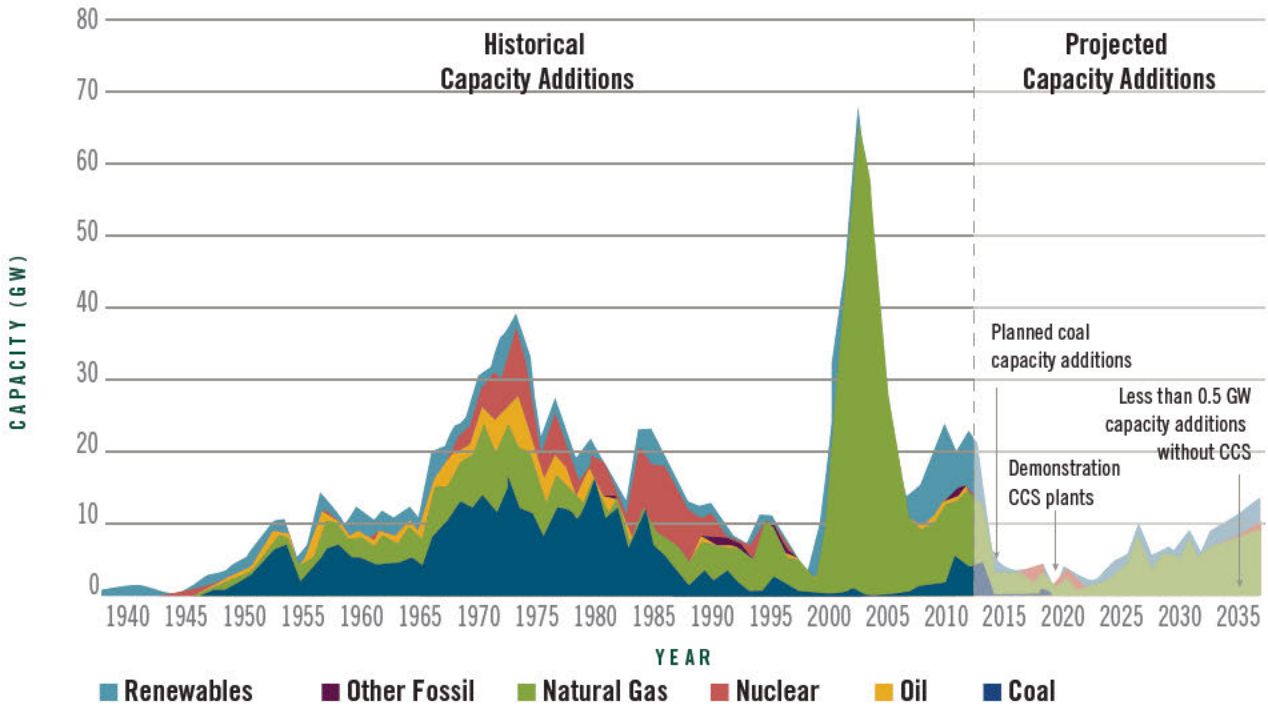
Circuit's decision if it stands. In the meantime, SO_2 and NO_x emissions will be regulated under the Clean Air Interstate Rule (CAIR), which remains in effect.

AEO2012 does not predict any new unplanned coal generation that does not include carbon capture and storage until 2030. This is consistent with trends in new power plant construction since the late 1990s (see Figure A-1.2).

2. Lackluster Scenario for Power Plants

In December 2010 EPA announced they would establish GHG performance standards for new and existing power plants using their authority under section 111 of the Clean Air Act, and that they would finalize those standards by May 2012.[18] In April 2012 EPA proposed performance standards for new power plants. These standards have not yet been finalized, and thus they do not meet the necessary criteria for

FIGURE A-1.2 New Electric Generating Capacity Additions by Fuel Type



Sources: This figure was developed using projections from U.S. EIA's AEO2012 and historical data from EIA Form EIA-860.
Notes: Planned units are defined in the AEO as those units that have commenced construction, but not yet begun operation.

TABLE A-1.1 New Source Performance Standards for Power Plants

	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Existing plants	NSPS are established for existing coal units that achieve fleet-wide average efficiency improvement of 5 percent starting in 2018.	Standards achieve an 18 percent reduction in emissions in 2021 compared to 2012 emission levels, and a 33 percent reduction in 2035.	Standards achieve a 38 percent reduction in emissions in 2021 compared to 2012 emission levels, and a 74 percent reduction in 2035.
New plants	EPA finalizes NSPS as proposed, which set a standard of 1,000 pounds of CO_2 per megawatt-hour of output. After eight years (2020), EPA updates these standards so that new unit performance gradually improves to 570 pounds of CO_2 per megawatt-hour in 2030.	EPA finalizes standards consistent with our lackluster scenario until 2028, at which time they establish new standards equivalent to CCS with a 90 percent capture rate.	EPA finalizes NSPS of 1,000 pounds of CO_2 per megawatt-hour of output. In 2020, they establish new standards equivalent to CCS with a 90 percent capture rate.

inclusion in the base case. EPA has not yet proposed performance standards for existing power plants. For the lackluster scenario (and all subsequent scenarios), we assume that EPA establishes performance standards for new and existing fossil-fuel-fired plants.

a. New Power Plants

In general, EPA's proposed New Source Performance Standards (NSPS) would require new power plants with a base load rating more than 73 MW to meet an annual emissions rate of 454 kgCO_2/MWh (1,000 lbs per MWh).[19] To achieve this emissions rate, new plants will need to employ natural gas, carbon capture and storage, waste heat recovery, or possibly biomass.[20] In all three scenarios, we assume that EPA finalizes an emissions standard that is equivalent to their proposed standards. The Clean Air Act stipulates that once the new standards are finalized they will apply to any covered source that commences construction after the date the **draft** rule was proposed. Therefore, the actual date of finalization is not relevant to this analysis. Consistent with EPA's proposed standards for new units, we assume that coal plants that have already broken ground will not be subject to the proposed standards for new power plants. We therefore do not apply the new standards to the 9.3 GW of "planned" coal units in EIA's reference case.

The Clean Air Act requires EPA to evaluate standards for new units every eight years. Thus, in the lackluster scenario we assume that EPA updates these standards after eight years, and that the new standard requires new units to gradually improve their emissions rate so that they reach 570 lbs/MWh by 2030. This target is consistent with increasing the efficiency of a natural gas unit to 70 percent, a target set by the Electric Power Research Institute (EPRI) in their 2009 Prism/MERGE analysis. This study identifies itself as a "technically and economically feasible roadmap for the electricity sector as it seeks to reduce its greenhouse gas emissions over the next few decades."[21] We assume EPA holds this 570 lbs per MWh emissions standard constant from 2030 through 2035.

As noted previously, AEO2012 does not predict any new unplanned coal generation that does not include CCS until 2030. We also note that GE has reported achieving 61 percent efficiency in their new combined cycle units, which is not required under the lackluster scenario until 2021.[22]

b. Existing Power Plants

In the lackluster scenario, we assume that performance standards achieve a modest 5 percent reduction in the emissions rate at existing coal plants through efficiency improvements. The average 5 percent improvement rate comes from EPA's *Advanced Notice of Proposed Rulemaking: Regulating Greenhouse Gas Emissions under the Clean Air Act* (ANPR) issued on July 11, 2008. In the ANPR, EPA noted that heat rate reductions of up to 10 percent are feasible at many coal-fired power plants, and that the potential average heat rate reduction for the entire coal fleet would likely be about 5 percent.[23] A 5 percent improvement in heat rate would reduce greenhouse gas emissions by 5 percent at existing coal plants. Alternatively, plants could achieve (or exceed) a 5 percent reduction in emissions by switching in whole or in part to lower carbon fuels such as natural gas and sustainably harvested biomass, or through greater use of waste heat.

The 5 percent improvement rate is assumed to be a fleet-wide average as some units may be able to achieve greater or fewer reductions. This average improvement rate could be realized through the establishment of unique standards for various subcategories of power plants.[24,25]

We assume that the new standards take effect in 2018. This is one year earlier than performance standards for most other source categories. We believe that this more expedited time frame is relevant, however, because EPA's December 2010 announcement about their development of performance standards for existing units (and for refineries) suggests that some of the regulatory analysis should already be completed.

After consulting with a variety of technical experts and conducting a literature review, we were unable to find a reliable public source that would support an assumption about immediately available opportunities for improving the efficiency of the existing natural gas fleet. As a result, we do not include reductions from existing gas plants in the reductions for the lackluster scenario.

c. Modeling Notes

To model reductions achieved through these standards, we made use of intermediary coal modeling results for the AEO2012 reference case, which were furnished upon request from EIA.[26] Those results show projected capacity, generation, consumption, and emissions by technology type for new, planned, and existing units through 2035.

We relied on the AEO2012 reference case for predictions of new unit construction and generation. We assume that all new units meet the new source standard applicable at the time of construction, with the exception of simple cycle units, which are excluded from EPA's new unit standards.

For modeling purposes, the 5 percent average improvement was applied evenly across all existing coal-fired units. We assumed that improving the efficiency of coal plants would decrease the marginal cost of generation, which would increase their competitiveness and lead to increased operation at those plants (and decreased generation by gas plants). This phenomenon has been examined by two recent studies by Resources for the Future, *Retail Electricity Price Savings from Compliance Flexibility in GHG Standards for Stationary Sources*,[27] and *Regulating Greenhouse Gases from Coal Power Plants under the Clean Air Act*.[28] The studies did not examine this precise scenario. However, based on conversation with the authors (Burtraw and Woerman), we decided that the greatest parallels were with the unit-specific subcategorization approach they presented at the annual meeting of the Association of Environmental and Resource Economists. Therefore, we modeled a 0.83 percent increase in coal generation as a result of the efficiency gains driven by the performance standards.[29]

3. Middle-of-the-Road Scenario for Power Plants

a. New Power Plants

The middle-of-the-road scenario builds off the assumptions in the lackluster scenario, establishing an initial standard of 1,000 lb/MWh, and the subsequent improvement period, which would achieve 570 lbs per MWh by 2030. Before reaching that 2030 goal, however, we assume that EPA updates their standards again (eight years after the previous update), so that in 2028 new units are held to a standard that is consistent with the utilization of carbon capture and storage at a 90 percent capture rate. We assume that this emissions rate would apply to all units regardless of fuel type. This treatment is consistent with EPA's proposed emissions standards for new power plants.

b. Existing Power Plants

For the middle-of-the-road and go-getter scenarios, we assume that EPA takes a more flexible approach when establishing performance standards for existing power plants. Thus, instead of requiring source-by-source compliance with a fixed emissions rate (as we did in the lackluster scenario), we assume that sources can comply through a range of other measures that reduce emissions from regulated emissions sources in the power sector. Such options could include fuel switching, low-carbon dispatch of existing power plants (e.g., operating a gas plant more and a coal plant less), increased generation by renewable sources, and energy efficiency, among other actions. These reductions could be recognized through a range of different programs such as fleet-wide averaging, rate-based trading programs, a portfolio of measures, or cap and trade.

In the middle-of-the-road scenario, we assume that standards take effect in 2018 and gradually improve, resulting in an 18 percent reduction in emissions in 2021 compared to 2012 emission levels. We assume that EPA would subsequently update these standards in 2026, which would lead to an additional 18 percent reduction in emissions in 2029 compared to 2021 emissions levels. These standards result in 33 percent fewer CO_2 emissions from power plants in 2035 compared to 2012.

Several recent proposals—introduced in conferences and meetings by academics and environmental organizations—have discussed potential approaches to regulating greenhouse gas emissions under the Clean Air Act. The level of reductions included here is comparable to a recently published proposal by the Natural Resources Defense Council (NRDC), though we did not model their specific proposal.[30] NRDC's proposal would allow for power plants to comply through onsite efficiency improvements, by shifting power generation to lower or non-emitting plants, and through demand-side efficiency improvements. However, we also note that analysis of EIA's AEO2012 projections of natural gas-fired plant capacity shows that there is sufficient slack capacity in existing natural gas units to achieve the initial 18 percent reduction entirely from re-dispatch of the existing fleet (i.e., increasing generation from natural gas plants and decreasing generation from coal plants).[31] Further reductions of the magnitude we model through 2035, however, would likely require new sources of carbon-free electricity (e.g., renewable or nuclear), increased deployment of carbon capture and storage, or a significant expansion of energy efficiency programs.

c. Modeling Notes

Note that due to the low projections of unit turnover in AEO2012, for modeling purposes we did not explicitly include additional NSPS for new units in the middle-of-the-road scenario; instead, we assumed that more stringent standards for new sources will make it easier to achieve the reductions required under the existing unit standards, as new units covered by the standard will emit fewer GHG emissions than the units that they are replacing.[32]

4. Go-Getter Scenario for Power Plants

a. New Power Plants

Similar to the lackluster and middle-of-the-road scenarios for new plants, the go-getter scenario assumes that EPA finalizes emissions standards for new units that mirror their proposed standards. The go-getter scenario assumes that EPA updates these standards again in 2020 to a standard that is consistent with the utilization of carbon capture and storage at a 90 percent capture rate, eight years earlier than assumed in the middle-of-the-road scenario.

b. Existing Power Plants

The go-getter scenario assumes EPA sets emissions standards for existing units that lead to a 38 percent and 74 percent reduction in energy CO_2 in 2020 and 2035 (respectively) compared to 2012. This level of reductions would likely require implementation of a flexible compliance program, such as the one described in the middle-of-the-road scenario. Because no NSPS for existing units have been proposed to date that cover greenhouse gases, we made the assumption that implementation of those standards would not start until 2018, and that EPA would provide a three-year glide path before achieving the emissions reduction target.

To establish the emission targets for this scenario, we used carbon price modeling results from EIA. Specifically, we utilized a side case from EIA's AEO2012 that examined the impact of an initial $25 price on carbon starting in 2013 that increases by 5 percent each year above inflation and reaches $35 per metric ton in 2020 and $73 per metric ton in 2035. It is clear that EPA does not have the authority to establish a carbon tax. These results are valuable, however, as they help elucidate the cost of abatement, and thus offer insight into the level of reductions that could be achieved through flexible standards under section 111(d).

c. Modeling Notes

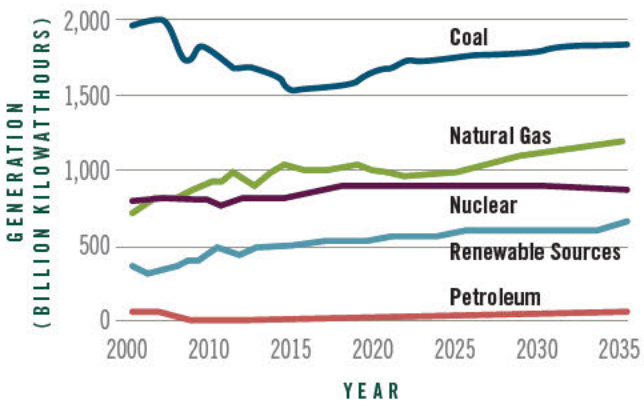
To model the existing standards for power plants, we assumed that generation and emissions would remain consistent with the base case (AEO2012 reference case) through 2017, and steadily change so that in 2021, generation and emissions would be the same as those projected in EIA's carbon price side cases.

The go-getter scenario assumes more than 2.5 times more new generation capacity will be built by 2035 compared to the base case scenario. The vast majority of this new capacity consists of renewable, nuclear and natural gas sources. The only coal units built under this scenario have carbon capture and storage technology installed. Because of the trend for installing low- or no-carbon emitting power units inherent under this scenario, for modeling purposes we did not explicitly include additional NSPS for new units; instead, we assumed that these standards help achieve the more flexible and ambitious existing unit standards.

5. Additional Notes for Power Plants

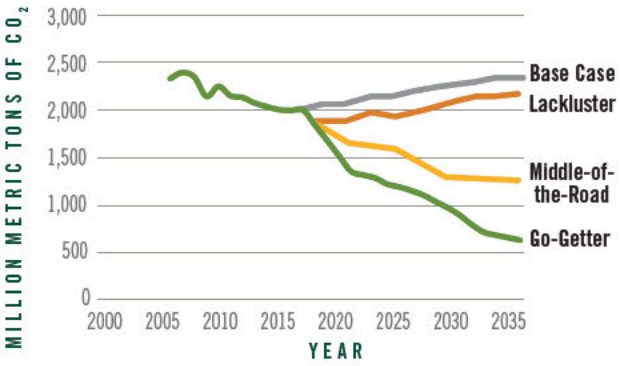
In addition to performance standards for new and existing power plants, emissions from electric generation are also affected by changes in the demand for electricity. We account for demand changes resulting from a wide-range of actions in an electric demand module, as described in section III.C.

FIGURE A-1.3 Base Case Electricity Generation by Fuel Type



Source: AEO2012, EIA

FIGURE A-1.4 Power Sector Emissions After Accounting for Changes in Demand



B. APPLIANCE AND EQUIPMENT EFFICIENCY STANDARDS (ELECTRIC)

1. Base Case for Appliance and Equipment Efficiency Standards (Electric)

The base case uses the AEO2012 reference case. The AEO2012 reference case assumes total electricity consumption in the residential sector increases over time, but the delivered energy per household declines at an average rate of 0.9 percent. About one-half of the decline in energy delivered per household can be attributed to more efficient space heating. Additional demand decreases for space heating is predicted to result from population shifts to warmer and drier climates. The reference case also assumes that despite growth in commercial floor space, improved commercial equipment efficiency slows the increase in purchased electricity through 2035.[33] Between 2009 and 2011, the Department of Energy established 17 new equipment standards that are expected to save 126 TWh in 2025 and 147 TWh in 2035.[34]

The Department of Energy may promulgate efficiency standards for consumer appliances and non-consumer equipment under existing federal law.[35] The law lists appliances and equipment that may be the subject of efficiency standards, prescribes minimum standards for certain appliances and equipment, and also prescribes a process through which the Secretary of Energy may add additional appliances and equipment to those regulated.[36]

2. Lackluster Scenario for Appliance and Equipment Efficiency Standards (Electric)

We identified three studies that quantify energy savings achievable through enhanced energy efficiency standards beyond the base case. Those three studies are summarized below. For the lackluster scenario, we chose the lowest range of energy efficiency improvements over the study period from all of the studies, which was estimated to result in 192 TWh of savings from the residential and commercial consumers in 2025, plus an additional 36 TWh of savings from the industrial sector.

In *The Efficiency Boom: Cashing In on the Savings from Appliance Standards*, the American Council for an Energy-Efficient Economy (ACEEE) and the Appliance Standards Awareness Project (ASAP)[37] quantified the benefits from potential new or updated standards for 34 product categories that could be adopted within the next several years. They estimate that those standards could result in 212 TWh savings from residential and commercial consumers in 2025, and 306 TWh savings in 2035. Energy savings were calculated as reductions compared to current units, assuming fixed demand for the appliances. The authors note that many important standards are due between 2013 and 2015. The standards included were found to save consumers money over the life of the product, with an average simple payback period of 3.3 years. Individual product payback periods range from less than a year to 10.1 years.

TABLE A-1.2 Appliance and Equipment Efficiency Standards (Electric)

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
192 TWh savings in 2025 from the residential and commercial sectors, plus additional savings from the industrial sector. Annual savings remain constant through 2035.	212 TWh savings in 2025 and 306 TWh savings in 2035 from the residential and commercial sectors, plus additional savings from the industrial sector.	364 TWh savings in 2025 and 525 TWh savings in 2035 from the residential and commercial sectors, plus additional savings from the industrial sector.

The Institute for Electric Efficiency's (IEE)[38] study—*Assessment of Electricity Savings in the U.S. Achievable through New Appliance/Equipment Efficiency Standards and Building Efficiency Codes (2010-2025)*[39]— examined what IEE deemed "moderate" and "aggressive" efficiency improvement scenarios. IEE's moderate scenario assumes existing efficiency standards are increased to levels consistent with currently available products, and efficiency standards are created for some appliances and equipment that do not currently have standards. The IEE moderate scenario was found to result in electricity savings of 228 TWh in 2025 from the AEO2011 reference case for the residential, commercial, and industrial sectors. Of those savings, 192 TWh were projected to come from the residential and commercial consumers, and 36 TWh were projected to come from the industrial sector. The IEE aggressive scenario contains "more aggressive efficiency assumptions onto those embedded in the moderate case." The IEE study concluded that 364 TWh could be saved in 2025 compared to the AEO2011 reference case under the IEE aggressive scenario for the residential and commercial sectors. Another 63 TWh of savings were projected to come from the industrial sector.

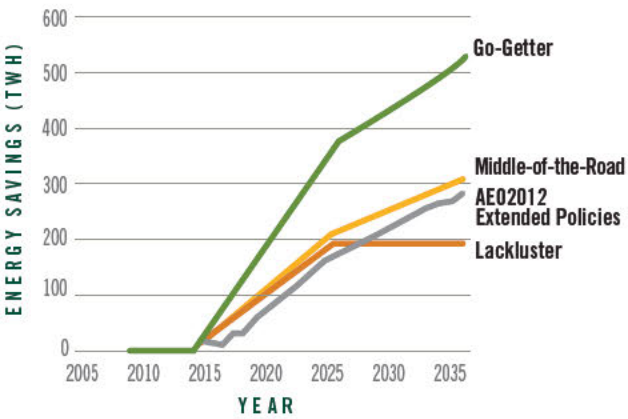
The third study we considered was the "extended policies" side case from AEO2012. This side case "examined updates to existing efficiency standards for residential and commercial products as well as the creation of efficiency standards for products not currently covered." Energy savings in this side case reach about 164 TWh in 2025 and nearly 280 TWh in 2035 from the residential and commercial sectors.

For the lackluster scenario, we chose the lowest range of energy efficiency improvements from all of the studies over the entire study period, which was the IEE moderate scenario. This scenario estimated 192 TWh of electricity savings in 2025 from the AEO2011 reference case in the residential and commercial sectors, and an additional 36 TWh of savings from the industrial sector. Applying these savings to the AEO reference case in 2025 results in a 5 percent reduction in electric demand. For this analysis, we assumed that standards commence in 2015 and result in a constant increase in savings between 2015 and 2025.Unfortunately, 2035 results were not provided. In order to develop intentionally conservative results, we hold the reported reductions achievable in 2025 constant through 2035. We do this even though stock turnover continues, in part because the AEO2012 reference case continues to increase appliance efficiency through 2035. While this study compares its savings to those modeled in AEO2011, we assumed that the potential energy savings reported in these studies can be applied to the base case, which utilizes AEO2012.[40]

3. Middle-of-the-Road Scenario for Appliance and Equipment Efficiency Standards (Electric)

The middle-of-the-road scenario is based on the middle range of energy efficiency improvements from the studies. Specifically, we use *The Efficiency Boom: Cashing In on the Savings from Appliance Standards*, which concluded that the 34 standards considered would save residential and commercial consumers 212 TWh in 2025 and 306 TWh in 2035. These savings amount to a 5 percent and 7 percent reduction in electric demand in 2025 and 2035, respectively, compared to the AEO2012 reference case. These results are comparable to those found by EIA in their side case. We relied on *The Efficiency Boom* because it lists specific product standards and dates, so that future actions can be easily compared. The EIA side case also included updated standards as well as new standards for products not yet covered by efficiency standards. AEO did not provide this same level of detail. For purposes of this analysis, we assumed that standards commence in 2015 and result in a constant increase in savings between 2015 and 2025 and from 2025 to 2035. The middle-of-the-road scenario for GHG performance standards for industry, as detailed in Section XI, includes considerable efficiency gains. Therefore, to avoid double counting, we do not assume any additional industrial efficiency gains are obtained as a result of appliance and equipment efficiency standards for industry. This does not mean that equipment efficiency standards would not be beneficial, just that we do not consider them here to ensure the development of conservative emissions reduction estimates.

FIGURE A-1.5 Energy Savings (TWh) from Residential and Commercial Appliance Efficiency Standards



4. Go-Getter Scenario for Appliance and Equipment Efficiency Standards (Electric)

The go-getter scenario is based on the highest level of reductions reported in the three reports, which was the aggressive scenario in the IEE study. IEE's aggressive scenario resulted in energy savings from equipment standards in the residential and commercial sectors of 364 TWh in 2025 from the AEO2011 reference case. It also resulted in 63 TWh of savings from industrial consumers in 2025. For the reasons outlined in the middle-of-the-road scenario for appliance and equipment efficiency standards, above, we did not include savings from industrial equipment standards.

We assumed that standards commence in 2015 and result in a constant increase in savings between 2015 and 2025. This study did not provide 2035 results. However, the other study we relied on—*The Efficiency Boom*—found that electricity savings increased between 2025 and 2035 due to stock turnover. We also note that additional standards are possible after 2020. Therefore, in our go-getter scenario, we take a less conservative approach to estimating savings in 2035 than we do in the lackluster scenario. We assume that annual energy savings increase between 2025 and 2035 at an annual rate consistent with the middle-of-the-road scenario (3.7 percent per year). This results in 525 TWh of savings in 2035. These savings amount to a 9 percent and 11 percent reduction in electric demand in 2025 and 2035, respectively, compared to the AEO2012 reference case.

5. Modeling Notes for Appliance and Equipment Efficiency Standards (Electric)

The energy savings from increased appliance and equipment efficiency standards in each of the three scenarios was fed into the electric demand module, which incorporates the full range of changes to electricity demand due to factors such as increased energy demand from electrification of light-duty and off-highway vehicles, and reduced demand for electricity as a result of increased deployment of combined heat and power (CHP) in the industrial sector. For more information about the electric demand model, see Section III.C.

Because we relied on EIA's AEO2012 $25 carbon tax scenario for the go-getter power sector generation projections, we had to make further adjustments to these efficiency savings. EIA's scenario predicts that the carbon price will increase electric rates and that this will lead to additional energy savings beyond the AEO2012 reference case. We assume that these savings will overlap with those resulting from increased appliance and equipment efficiency standards, and therefore discount them in the model. In 2035, for example, though the standards are predicted to result in 525 TWh of savings, we only model 270 TWh of incremental efficiency savings because the carbon price scenario already included 255 TWh of efficiency savings.

C. ELECTRICITY DEMAND

1. Lackluster Scenario for Electricity Demand

In order to provide a conservative estimate of the benefit of policies that reduce electricity demand, we begin by preventing the building of the "average" unplanned fossil-fired unit (i.e., new units that have not yet commenced construction). Through most years this is natural gas. In later years this affects the small amount of new coal plants that do not have carbon capture and storage in the AEO reference case (less than 0.5 GW). Next, we turn off the "average" existing fossil-fired unit. We reduce CO_2 emissions according to the average emissions rate because it is challenging to predict what the marginal emissions rate will be nationwide throughout the time frame considered. Furthermore, while marginal units tend to be natural gas in some regions of the country (such as New England),[41] they are coal in other regions. Due to the predominance of coal in the system, this results in the retirement of about 1.5 MW of electricity from coal plants for every 1 MW of electricity from every gas

plant. We do not turn off existing renewable or nuclear sources, as we assume that the bulk of the capital costs are already sunk, and the operational costs are lower than fossil units.

Depending on the specific combination of state and federal action, we account for four types of measures, which have slightly different impacts on the generation mix:

- Those that reduce overall electricity demand (e.g., appliance standards and building codes);
- Those that generate electricity that does not get put onto the grid (e.g., CHP programs where the electricity used is predicted to be behind-the-meter);
- Those that increase demand (e.g., vehicle electrification); and
- Those that generate electricity that is put onto the grid from other clean sources (e.g., renewable programs).

Policies that reduce demand or that generate electricity that does not get put onto the grid reduce the total amount of electricity sold onto the grid. This can reduce renewable generation driven by state renewable mandates because those mandates are typically set as a percentage of total electricity sales. Most of the renewable energy built through 2030 in the lackluster scenario (which is modeled off of the AEO2012 reference case) appears to be due to renewable standards. Therefore, we reduce new renewable generation in a manner that is proportional to the predicted reduction in electricity sales due to electricity demand reduction and programs and policies that generate electricity that does not get put onto the grid.

Policies that increase demand offset the impact of programs that reduce demand or that generate electricity that is not sold on the grid. In none of the modeled scenarios do we predict that demand reductions will be outstripped by electricity demand increase due to various policies considered.

Policies that generate electricity that is put onto the grid from other clean sources do not reduce total sales, and thus do not impact the renewable mandates. They do, however, reduce the demand for other sources of electricity, and thus affect the construction of new units and the operation of existing fossil units in a manner that is similar to policies that reduce electricity demand.

None of the scenarios shut down the lone carbon capture and storage project that is predicted to be built as this demonstration project is hardwired into the AEO, and is not the result of economic factors.

2. Middle-of-the-Road Scenario for Electricity Demand

To evaluate the middle-of-the-road scenario for electricity demand, we had to consider the dynamics of the middle-of-the-road scenario for performance standards for existing power plants, which is an amalgamation of a number of proposals being considered at the federal level. There are currently no detailed sector outputs for any of those proposals that display the predicted generation, consumption, and emissions from existing and new units by type. Therefore, we cannot readily turn off discrete types of new or existing units in response to changes in electricity demand. However, this may be less problematic than would otherwise appear. Several of the proposals under discussion establish a target emissions rate for fossil-fired power plants. Under such an approach, demand reductions could provide a benefit that is proportional to the emissions rate for regulated sources. In this scenario, the emissions rates ranged from 0.67 tons of CO_2/MWh in 2021 to 0.5 tons of CO_2/MWh in 2035.

3. Go-Getter Scenario for Electricity Demand

The go-getter approach is based on the $25 carbon tax scenario from EIA's AEO2012. Thus we have detailed sector outputs that allow us to follow a very similar process as the lackluster scenario, with one key difference. In this scenario renewable projects become cost competitive with fossil plants, and thus there is a three-fold increase in renewable energy development. Therefore, we treat new renewables the same as other new non-renewable resources, and prevent their construction on a proportional basis in response to reductions in demand, as long as the residual renewable generation meets the appropriate set of state renewable standards. This causes any change in demand to have a lower impact in terms of GHG emissions than it does in the lackluster and middle-of-the-road scenarios.

EIA's AEO2012 $25 carbon tax scenario predicts lower electric demand compared to their reference case due to higher electricity prices. We assume that much of that reduction will be driven by the purchase of more efficient appliances, and thus discount

electricity demand savings otherwise predicted by new efficiency standards for appliances and equipment.

4. Additional Modeling Notes for Electricity Demand

The state action scenarios result in a mixture of states with and without carbon policies for the electric sector and potentially a different mix of states with and without state-specific policies that affect electricity demand. Since we do not predetermine which states might pursue each of these policies, and since the scenarios assume that up to 50 percent of states pursue any particular policy, we assume for modeling purposes that the impact of policies that affect demand will be shared across all states.

Because we consider increases and decreases in electric demand associated with a number of activities (e.g., electrification of light-duty vehicles and improved industrial energy efficiency), we do not separately determine CO_2 emissions reductions associated with appliance efficiency standards. Instead, those reductions are included in the overall emissions reductions for electric generation.

IV. Transportation

A. LIGHT-DUTY VEHICLES

1. Base Case for Light-Duty Vehicles

In August 2012 EPA and the National Highway Traffic Safety Administration (NHTSA) finalized new GHG emissions standards and CAFE standards for light-duty vehicles.[42] EPA's GHG emissions standards affect vehicles sold from model years 2017 through 2025. Due to statutory limitations, NHTSA only finalized CAFE standards for vehicles of model years 2017 through 2021. NHTSA also announced possible CAFE standards for model year 2021 through 2025 vehicles, though finalization of those standards will require additional rulemaking. EPA's standards establish a CO_2 emissions standard of 163 grams per mile in model year 2025, which is equivalent to a fuel economy standard of 54.5 mpg (if met solely through fuel economy improvements). This is equivalent to a CAFE standard of 49.7 mpg because NHTSA considers only drive train improvements and does not consider improvements in air conditioning leakage of HFCs for purposes of establishing CAFE standards.[43] To avoid double counting, we account for the HFC benefits in the HFC module and do not account for them in the figures that follow.

For the analysis, we used Argonne National Laboratory's VISION model,[44] which relies on the EIA *Annual Energy Outlook 2012* and does not include the latest EPA and NHTSA standards for light-duty vehicles.[45] Thus, we developed our own base case scenario by inputting the new federal standards into the VISION model. We note that EPA has the ability to revisit the standards for model years 2022 to 2025, and adjust them based on the best and most current information available at that time. In the base case scenario, however, we assumed that the standards through model year 2025 are achieved as outlined in the most recent rulemaking, and are not revised upwards or downwards. We further assume that the 2025 model year standards remain constant through 2035.

The recently finalized emissions standards for model years 2017 through 2025 include incentives for electric vehicles (EVs), plug-in hybrid electric vehicles (PHEVs), fuel cell vehicles (FCVs), and compressed natural gas (CNG) vehicles. The incentives include a temporary per-vehicle multiplier that allows EVs, PHEVs, FCVs, and CNG vehicles to "count" as more than one vehicle in the manufacturer's compliance calculation for model years 2017 through 2021. The standards also provide for the temporary use of an increased fuel economy value and a reduced GHG emissions compliance value in order to spur deployment of vehicles that consume less gasoline and emit fewer GHG emissions.[46] We incorporate each of these credits into the model.

2. Lackluster Scenario for Light-Duty Vehicles

For all of the scenarios, we relied on the *Interim Joint Technical Assessment Report* (TAR) produced by EPA, NHTSA, and the California Air Resource Board (CARB).[47] The agencies analyzed four scenarios of future stringency for model years 2020 and 2025, starting with a 250 gram/mile estimated fleet-wide level in model year 2016 and four different levels of CO_2 standard improvement rates: 3 percent per year, 4 percent per year, 5 percent per year, and 6 percent per year. For reference, the 4 percent improvement rate results in a 51 mpg standard by model year 2025, while the 6 percent improvement rate results in a 62 mpg standard by model year 2025. For each of these rates of increased stringency, the agencies considered the effects of the industry following four potential "technology pathways." Each of these rely on varying market penetrations of different sets of technology, including HEV, PHEV, EVs, and mass reduction. The agencies'

TABLE A-1.3 Vehicle Emissions and Efficiency Standards Scenarios, Light-Duty Vehicles

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
August 2012 Joint EPA-DOT Standards: 54.5 mpg by model year 2025 (Included in the base case)		
Standards continue to improve from 2026–2035 at roughly half the rate of the 2017–2025 standards (2 percent). This results in a 131 grams per mile emissions standard and a 61 mpg CAFE standard by 2035. Under this scenario, 9 percent of the miles traveled by MY 2035 vehicles are powered by electricity.	Standards continue to improve from 2026–2035 at roughly the same rate as the 2017–2025 standards. This equates to about a 4 percent annual improvement through 2035, and results in a 104 gram per mile emissions standard and a 74.6 mpg CAFE standard. Under this scenario, 12 percent of the miles traveled by MY 2035 vehicles are powered by electricity.	Six percent annual improvement rate in emissions standards. This results in a 81 grams per mile emissions standard and a 92 mpg CAFE standard. Under this scenario, 34 percent of the miles traveled by MY 2035 vehicles are powered by electricity.

Note: CAFE standards do not include benefits from HFC emissions reductions, which EPA projects to result in credits amounting to 14.3 grams CO_2 per mile in 2025. Also note that the rate of change for the standards is applied to the GHG emissions standards (grams per mile) and fuel consumption rate (gallons per mile).

results illustrate that a variety of technologies can be used to meet each of the standards.

Our lackluster scenario assumes vehicle standards achieve a 131 gram per mile emissions standard in 2035, and a 61 mpg CAFE standard.[48] This is equivalent to a 2 percent annual improvement rate from 2026 through 2035, which is about half the rate required in the finalized standards for model years 2017 through 2025. The 2 percent rate of improvement is only applied to vehicle efficiency improvements and not HFCs because the opportunities to achieve incremental HFC benefits beyond those driven by the current round of standards are more limited. Consistent with EPA and NHTSA's *Interim Joint Technical Assessment Report*, in all of our scenarios the rate of change is applied to the GHG emissions standards (grams per mile) and fuel consumption rate (gallons per mile).

We assume that under this scenario, 9 percent of the miles traveled by MY 2035 vehicles are powered by electricity. We made this assumption because we are unable to predict exactly how these alternative vehicles will penetrate the market and wanted to account for a range of possible outcomes. However, for modeling purposes, we assume that EVs reach 4 percent of sales by 2025. This is consistent with one of the technology pathways the agencies found could achieve a set of standards with similar stringency to those finalized in August. We assumed that sales would escalate over time, so that in 2035 EV's accounted for 8 percent of total sales and PHEVs accounted for 1.5 percent of total sales. This is consistent with the average penetration rates assumed in the four scenarios analyzed by the agencies that achieve 62 mpg in their *Interim Joint Technical Assessment Report*.

3. Middle-of-the-Road Scenario for Light-Duty Vehicles

We assume that vehicle standards continue to improve though 2035 at roughly the same rate as the 2017–2025 standards (4 percent), and achieve an emissions standard of 104 grams of CO_2 per mile traveled and a fleet-wide CAFE standard of 74.6 mpg in 2035. Like the lackluster scenario, the middle-of-the-road scenario assumes that EVs reach 4 percent of new vehicle sales by 2025. Consistent with the lackluster scenario, we only apply the rate of improvement to vehicle efficiency improvements, and do not include HFC emissions in those calculations because there are limited opportunities to achieve incremental HFC benefits beyond those driven by the current round of standards.

Under this scenario, the light-duty fleet achieves approximately 63 mpg in 2031. The TAR considered a scenario where roughly the same fuel economy was achieved in 2025, and examined several technology pathways for achieving that standard. For modeling

purposes, we assumed that EV and PHEV penetration would follow the average of these pathways. This results in EV and PHEV penetration of 8 percent and 1.5 percent of sales in 2031, respectively, when the light-duty fleet reaches 62 mpg. We assume that EV and PHEV sales continue to increase at a constant rate so that in 2035, EV's reach 10.7 percent and PHEV's reach 2.5 percent of vehicle sales. In order to account for a wider range of possible outcomes, we assume that 12 percent of the miles travelled by MY 2035 vehicles are powered by electricity.

4. Go-Getter Scenario for Light-Duty Vehicles

Our go-getter scenario assumes that the EPA GHG emissions standard improves 6 percent per year between 2025 and 2035. This is the highest improvement rate EPA and NHTSA considered in the proposed model year 2017–2025 standards. Consistent with the other scenarios, we only apply the rate of improvement to vehicle efficiency improvements, and do not include HFC emissions in those calculations because there are limited opportunities to achieve incremental HFC benefits beyond those driven by the current round of standards.

This would lead to a greenhouse gas emissions standard of 81 grams of CO_2 per mile traveled and a CAFE standard of 92 mpg in 2035. For modeling purposes, we assume that EVs reach 14 percent of new vehicle sales by 2025 and 31.5 percent by 2035, and that PHEVs reach 2 percent of new vehicle sales by 2025 and 4.5 percent by 2035. These rates were determined in a manner consistent with the middle-of-the-road scenario. However, instead of applying the average EV and PHEV penetration rate from the TAR, we applied the highest EV and PHEV penetration rate in 2025 and assumed that penetration rates continued through 2035 at a continuous rate.[49] In order to account for a wider range of possible outcomes, we assume that 34 percent of the miles traveled by MY 2035 vehicles are powered by electricity.

5. Modeling Notes for Light-Duty Vehicles

The VISION model allows users to edit the default fuel economies of light-, medium-, and heavy-duty vehicle categories between 2000–2100. We estimated fuel economies (mpg) for each major vehicle technology (e.g., internal combustion vehicles, EVs, PHEVs) using each vehicle technology's annual sales, applicable incentives for EVs and PHEVs, and VISION's assumed relative efficiency of vehicle types (e.g., EVs versus internal combustion engines).

In addition, for purposes of this analysis we made the following assumptions for all scenarios:

- We assume that the incentives and credits for electric vehicles (EVs), plug-in hybrid electric vehicles (PHEVs), fuel cell vehicles (FCVs), and compressed natural gas (CNG) vehicles expire, or wind down, as scheduled. This results in the evaluation of EV and PHEV emissions on the basis of the GHG emissions associated with electricity generation, which relates to the GHG performance standards in place for the power sector.
- PHEVs on average drive 50 percent of their miles using electricity, which is consistent with the assumptions in EPA's *Analysis of the Transportation Sector: Greenhouse Gas and Oil Reduction Scenarios,*[50] as well as the upper estimate in Argonne National Laboratory's VISION 2012 AEO base case. The emissions from electricity associated with the operation of these vehicles are accounted for in the electric sector through increased demand.
- Any differences in driving habits between EVs and internal combustion vehicles were not incorporated into the model because these trends are not considered in the VISION model.
- GHG benefits from reduced HFC emissions were not included in tailpipe emissions estimates, and instead were calculated separately in the HFC module.
- On-road mpg remains approximately 80 percent of the test mpg in accordance with standard practice and VISION model design.
- Consistent with common accounting practice and EIA's *Annual Energy Outlook*, we do not include emissions associated with the combustion of biofuels in emissions estimates for light-duty vehicles. This is commonly done due to an assumption that such fuels are carbon neutral. While recent studies suggest that this is not actually the case, for purposes of our analysis we do not include those emissions here.

FIGURE A-1.6 Fuel Economy Improvements Modeled for Light-Duty Vehicles

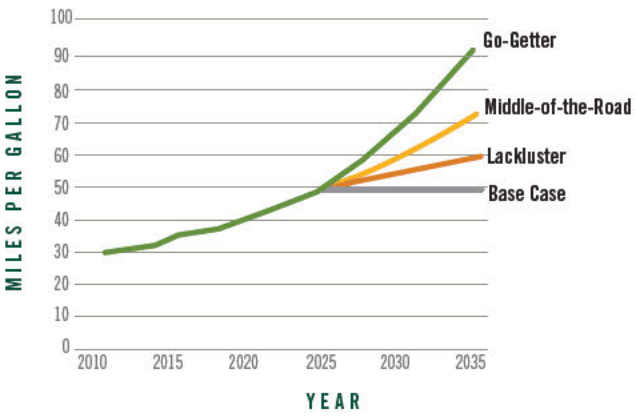
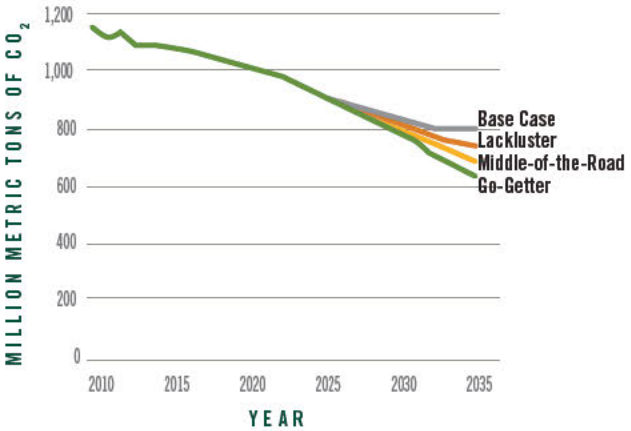


FIGURE A-1.7 Tailpipe Carbon Dioxide Emissions from Light-Duty Vehicles



B. MEDIUM- AND HEAVY-DUTY VEHICLES

1. Base Case for Medium- and Heavy-Duty Vehicles

In August 2011 EPA and NHTSA finalized a joint rulemaking that established the first-ever standards for GHG emissions and fuel consumption for medium- and heavy- duty vehicles.

Medium-duty vehicles (class 2b-6) are defined as those with a gross vehicle rate between 8,500 and 26,000 pounds, while heavy-duty vehicles (class 7-8) have a gross vehicle rate above 26,000 pounds. These vehicles are commonly divided into the following categories:

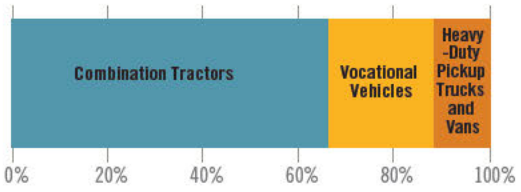
- **Combination tractors** (class 7-8): used for freight transportation and usually pull one or more trailers and emit about two-thirds of medium- and heavy-duty CO_2 emissions (Figure A-1.8);[51]
- **Vocational vehicles** (class 2b-8): used for a wide range of purposes, including fire trucks, dump trucks, refuse trucks, and others;[52] and
- **Heavy duty pick-up trucks and vans** (class 2b-3): used mainly for work purposes, as well as shuttle vehicles.[53,54]

The EPA and NHTSA standards, however, divide these medium- and heavy-duty vehicle categories into 13 subcategories, and establish vehicle GHG emissions and fuel consumption standards for each. Because the manufacturer of the vehicle can differ from the manufacturer of the engine, in some cases EPA and NHTSA established separate engine standards. However, these engine standards are built into the vehicle standards, and thus we do not separately consider them in our scenario development or modeling.

The rule covers vehicles sold from model years 2014 through 2018. EPA's standards are mandatory for model years 2014–2018. NHTSA's fuel consumption standards, however, are voluntary for model years 2014 and 2015 and don't become mandatory until model year 2016.[55] This is due to the regulatory lead-time requirements built into the Energy Independence and Security Act of 2007 (EISA), which cites a need for "regulatory stability."[56]

EPA established a separate standard for HFC leakage from AC systems in heavy-duty pickup trucks and vans as well as class 7 and 8 tractors, based on the

FIGURE A-1.8 Medium- and Heavy-Duty Carbon Dioxide Emissions by Vehicle Type, 2005



Source: *Final Rulemaking to Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles: Regulatory Impact Analysis*, U.S. EPA and NHTSA, August 2011.

refrigerant capacity of the installed AC system. For purposes of this analysis, we applied EPA's estimated GHG benefits from this standard to base case emission projections for HFCs. Thus HFC benefits are not reflected in the GHG emissions projections from this sector shown in the figures that follow.

In the base case scenario, we assumed that the standards are not updated after the current regulatory period and thus the 2018 model year standards remain unchanged through 2035.

2. Lackluster Scenario for Medium- and Heavy-Duty Vehicles

Our lackluster scenario assumes that improvement in the standards continues at a rate consistent with half the rate of improvement achieved by the recent standards, or on average, 1.3 percent annually.[57] This would lead to an average fuel economy of 11 mpg and a GHG emissions standard of 949 grams CO_2 per mile across all medium- and heavy-duty vehicles in 2035.[58] As a result of the standards, we estimate that medium and heavy-duty vehicles sold in 2035 will consume 21 percent less fuel than vehicles sold in 2010.

The Energy Independence and Security Act of 2007 (EISA) requires at least three years of "regulatory stability" whereby standards for medium- and heavy-duty vehicles remain fixed. Therefore, in all three of the scenarios, we assume that CAFE standards are updated as frequently as possible, and that updates to the GHG emissions standards occur at the same time interval—once every three years.

3. Middle-of-the-Road Scenario for Medium- and Heavy-Duty Vehicles

In the middle-of-the-road scenario, we assume that the standards increase at the same rate as the standards for model years 2014–2018 (roughly 2.6 percent annually). This would lead to an average fuel economy of 13.3 mpg and a GHG emissions standard of 781 grams CO_2 per mile across all medium- and heavy-duty vehicles in 2035. As a result of the standards, medium- and heavy-duty vehicles sold in 2035 will consume 35 percent less fuel than vehicles sold in 2010.

4. Go-Getter Scenario for Medium- and Heavy-Duty Vehicles

The go-getter scenario for medium-duty and most heavy-duty vehicles assumes that the GHG emissions standards improve by an average 42 percent in 2023 across all vehicle categories compared to 2010 vehicles. This magnitude of improvement is likely only possible if EPA begins to regulate trailers, which are not covered by current standards. We assume standards for 2020 to 2022 split the difference between the standards set in 2019 and 2023 for each vehicle category, which results in an average improvement rate of 26 percent across all vehicle types. We assume that emissions standards increase by 3 percent every three years (1 percent annually) thereafter. This would lead to an average fuel economy of 16.0 mpg (657 grams CO_2 per mile) across all medium- and heavy-duty vehicles in 2035. As a result of the standards, medium- and heavy-duty vehicles sold in 2035 will consume 46 percent less fuel than vehicles sold in 2010.

TABLE A-1.4 Vehicle Emissions and Efficiency Standards, Medium- and Heavy-Duty Vehicles

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Joint EPA-DOT Standards from August 2011 will improve the GHG emissions rate for vehicles by approximately 2.6 percent per year from 2013–2019		
Standards continue to improve through 2035 at half the rate of the 2014–2018 standards by vehicle category. This equates to an average annual improvement of 1.3 percent across all medium- and heavy-duty vehicles.	Standards continue to improve through 2035 at the same rate as the 2014–2018 standards by vehicle category. This equates to an average annual improvement of 2.6 percent across all medium- and heavy-duty vehicles.	By 2020–2022, the medium- and heavy-duty fleet reduces its emissions rate by an average 26 percent and by 42 percent in 2023–2025 compared to 2010. Standards continue to improve annually by 1 percent through 2035.

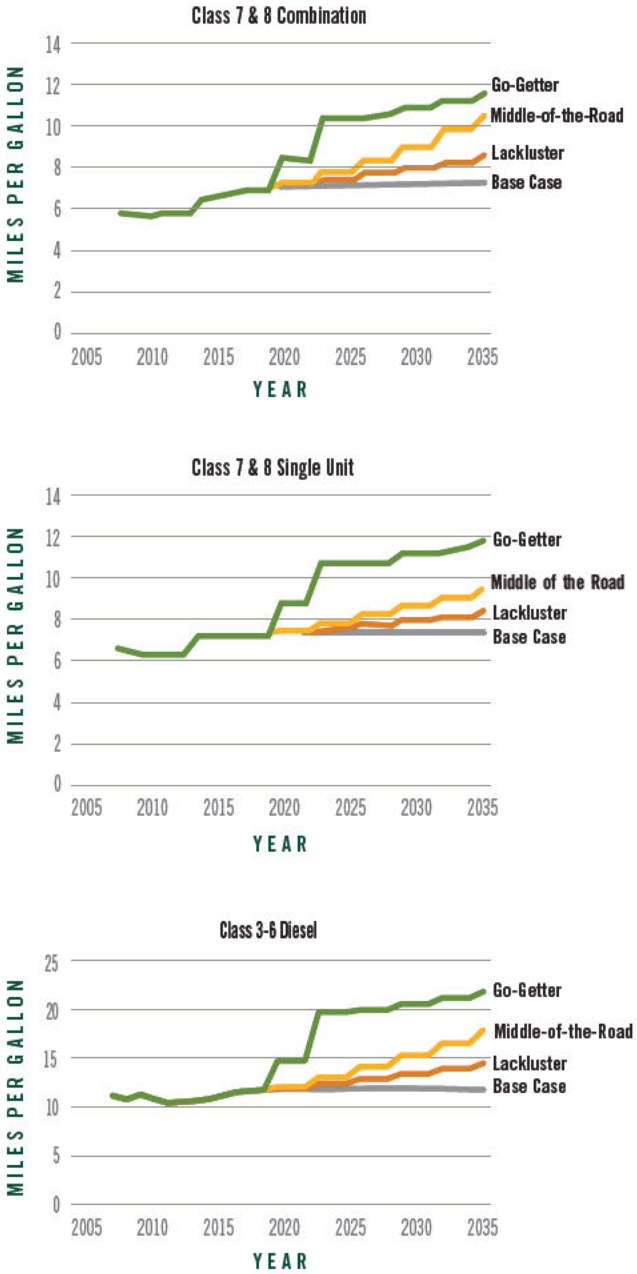
The go-getter scenario for medium- and heavy-duty vehicles was derived from the National Academy of Sciences *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.*[59] That study examines several types of medium- and heavy-duty vehicles, and determines that they can reduce fuel consumption between 32 and 51 percent in the 2015–2020 timeframe by utilizing different technologies, depending on the vehicle class and purpose.[60] These ranges were used to develop average improvement rates for each of the major vehicle classes.

The 2020–2022 standards would reduce fuel consumption by an average 28 percent from 2008 levels. This is slightly higher than the potential fuel savings described in the Presidential Memorandum Regarding Fuel Efficiency Standards from May 21, 2010.[61,62]

5. Modeling Notes for Medium- and Heavy-Duty Vehicles

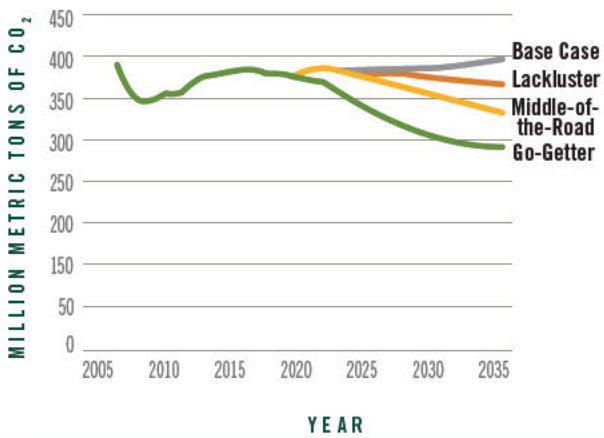
Our analysis relies on Argonne National Laboratory's VISION 2012 model,[63] which includes the latest EPA and NHTSA standards. The VISION model allows users to edit the default fuel economies of new light-, medium-, and heavy-duty vehicles sold from 2000 to 2100. However, VISION breaks the fleet up into different categories than those used by EPA and NHTSA. We therefore relied on EPA's estimated fleet-wide fuel efficiency for model years 2010–2018 under the finalized standards for heavy-duty pickups and vans, vocational vehicles, and combination tractors to help inform the average improvement in fuel efficiency in each of the VISION vehicle categories.[64] Similar to our approach for light-duty vehicles, we applied the improvement rates to the GHG emissions standards (grams per mile) and fuel consumption standards (gallons per ton-mile). These values were converted to fuel economy (miles per gallon) for modeling purposes. Figure A-1.9 shows fuel economy improvements for the three largest vehicle categories, which together account for roughly 94 percent of total GHG emissions from medium- and heavy-duty vehicles in 2010 and 2035.

FIGURE A-1.9 Efficiency Improvements Modeled for Medium- and Heavy-Duty Vehicles



Note: Fuel economy for class 3-6 gasoline, natural gas, and LPG vehicles, as well as class 7-8 single unit natural gas and LPG vehicles, are not shown here. Together, they account for only 6 percent of total GHG emissions in 2010.

FIGURE A-1.10 Tailpipe Carbon Dioxide Emissions from Medium- and Heavy-Duty Vehicles



C. OFF-HIGHWAY MOBILE SOURCES

1. Base Case for Off-Highway Mobile Sources

Off-highway mobile sources include a variety of emissions sources such as engines and equipment used for agriculture (tractors and combines), construction (cranes and bulldozers), lawn and garden, and mining. There is no specific off-highway category in the AEO, and it is beyond the scope of this analysis to reconstruct this sector's emissions from the ground-up. Therefore, we relied on the business-as-usual projections from the *EPA Analysis of the Transportation Sector: Greenhouse Gas and Oil Reduction Scenario*s for the base case, which projects that emissions from these sources will rise from roughly 200 mmtCO_2e in 2012 to roughly 275 mmtCO_2e in 2030.

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Off-Highway Sources

The EPA *Analysis of the Transportation Sector* concludes that there are significant opportunities to reduce GHG emissions from this sector.[65] In the report, EPA posits two greenhouse gas emissions reductions scenarios that are technically achievable. In this analysis, EPA was clear that the "illustrative example scenarios do not imply that EPA considers these to be the appropriate levels or dates for standards."[66] However, we were unable to identify other studies to complement EPA's work, and thus based all three of the scenarios on EPA's study. Therefore, we made the lackluster scenario more conservative by modeling one-half the reductions achieved by EPA's least ambitious scenario, scenario A. The middle-of-the-road scenario was modeled to match EPA's scenario A. The go-getter scenario was modeled to match EPA's most ambitious scenario, scenario B.

Unlike the reductions for light-, medium-, and heavy-duty vehicles, off-highway mobile sources were not independently modeled for this analysis, as sufficient information about the sources and policies is not available. Instead, reductions were taken directly from EPA's study. These reductions were adjusted to remove the contribution from operational improvements because EPA has not mandated such operational improvements to date in these standards. Therefore, for the lackluster, middle-of-the-road, and go-getter scenarios, we assumed that new standards can achieve an additional 0.9 percent, 1.8 percent, and 2.4 percent annual improvement, respectively, in the emissions rate for new equipment and engines from 2018 to 2035.

3. Modeling Notes for Off-Highway Sources

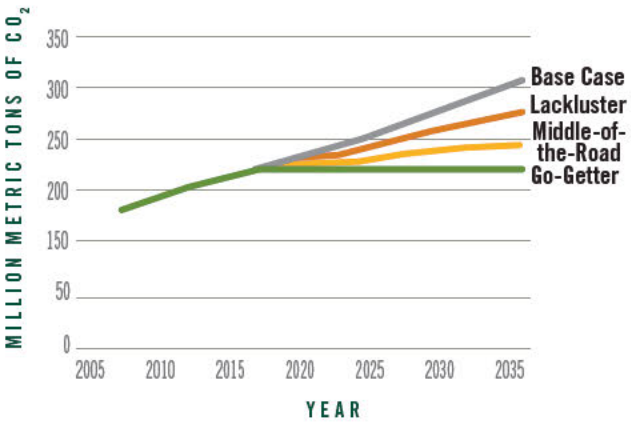
EPA's scenarios result in emissions reductions through increased equipment electrification. We therefore estimated increased electric demand and fed that into the electricity demand module to capture the resulting increases in electricity emissions. For off-highway electrification, the increase in electricity demand in 2035 is 12, 23, and 80 TWh for the lackluster, middle-of-the-road, and go-getter scenarios, respectively. These increases represent 0.3 percent to 1.8 percent of total electricity demand in 2035 under the AEO2012 reference case.

TABLE A-1.5 Vehicle Emissions and Efficiency Standards Scenarios, Off-Highway

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
0.9 percent annual improvement in the emissions rate for new equipment and engines from 2018 to 2035	1.8 percent annual improvement in the emissions rate for new equipment and engines from 2018 to 2035	2.4 percent annual improvement in the emissions rate for new equipment and engines from 2018 to 2035

EPA's analysis was based on AEO2009. We were unable to adjust these results to account for any differences between AEO2012 and AEO2009 because the analyses do not clearly break out emissions from off-highway mobile sources.

FIGURE A-1.11 Carbon Dioxide Emissions from Off-Highway Mobile Sources



D. AVIATION

1. Base Case for Aviation

The emissions base case for aviation emissions was developed using projected energy use as found in the AEO2012 table, *Transportation Sector Key Indicators and Delivered Energy Consumption*. AEO2012 builds in a steady improvement in energy efficiency. Nevertheless, emissions are expected to increase through 2035 due to increased miles traveled; in 2035, aircraft CO_2 emissions are about 11 percent higher than 2010 levels.

2. Lackluster & Middle-of-the-Road Scenarios for Aviation

The FAA can reduce GHG emissions from aircraft by enhancing the way that air travel is managed in the United States. Through its Next Generation Air Transport Systems (NextGen), FAA is proactively managing aviation environmental issues with several programs and initiatives.[67]

Operational improvement scenarios were developed using the *EPA Analysis of the Transportation Sector*.[68] In this report, EPA concluded that it was possible to achieve operational improvements in the range of 0.7 percent to 1.4 percent per year, but noted that the FAA thought that operational improvements realized through NextGen would only reach between 0.17 and 0.4 percent per year. To remain conservative in the lackluster scenario, we modeled a 0.17 percent annual improvement starting in 2014. This results in emissions that are 3 percent below base case levels in 2035, but which are 7 percent greater than 2010 levels. In the middle-of-the-road scenario, we use the higher range reported by FAA, 0.4 percent per year. This results in an 8 percent reduction in emissions compared to the base case in 2035, which is 2 percent above 2010 levels.

3. Go-Getter Scenario for Aviation

In the go-getter scenarios, we relied on the most ambitious estimates from the *EPA Analysis of the Transportation Sector* (scenario B), which concludes that it is possible to achieve a 1.4 percent annual operational improvement. We assume that this rate of change remains constant through 2035.

In addition, we assume that EPA implements GHG emissions standards for airplanes under Title II of the Clean Air Act in 2018. (Note that while EPA may

TABLE A-1.6 Vehicle Emissions, Efficiency Standards, and Operational Improvements Scenarios, Aviation

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
0.17 percent annual emissions reduction through 2035 via operational improvements through the FAA NextGen program.	0.4 percent annual emissions reduction through 2035 via operational improvements through the FAA NextGen program.	1.4 percent annual operational improvement via FAA's NextGen program, plus a 2.3 percent annual improvement in the performance of new aircraft and engines. Both rates remain constant through 2035.

implement GHG emissions standards, FAA enforces those standards.) This also comes from EPA's transportation analysis, which concludes that by 2030, it may be possible to see engine improvements around 20 percent, and airframe weight and drag reductions between 5 and 20 percent. They model this as a 2.3 percent per year annual improvement in aircraft efficiency.

EPA's estimates are comparable to the International Civil Aviation Organization (ICAO) *Report of the Independent Experts of Fuel Burn Reduction Technology Goals*, which suggests efficiency gains of 19–25 percent (in fuel-burn) could be achieved by 2020, and efficiency gains between 26 and 41 percent could be achieved by 2030.[69] In addition, the *International Air Transport Association Technology Roadmap Report* concludes that it might be possible to reduce emissions 23–30 percent in the 2020 time frame, and 25–50 percent in later years.[70] FAA's Continuous Lower Emissions, Energy, and Noise (CLEEN) program has a near-term goal of a 33 percent reduction in fuel burn relative to current technology.[71]

We acknowledge that EPA has never before established aircraft emissions standards for any air pollutant that are more stringent than those set by ICAO, and therefore do not include aircraft standards in the lackluster or middle-of-the-road scenarios. However, the ability to establish aircraft emissions standards lies soundly within their authority under Title II of the Clean Air Act. It is worth noting that there may be other paths forward to achieve these improvements in new aircraft standards. ICAO's Committee on Aviation Environmental Protection is also in the process of developing a new international standard for aircraft carbon dioxide emissions levels and is aiming for a 2013 completion date for the standard.[72]

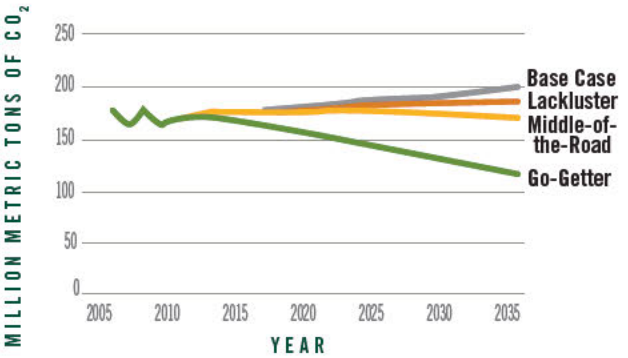
As a point of comparison, the European Union's (EU's) Emission Trading System (ETS) for aircraft requires a 3 percent reduction in 2005 emission levels starting in 2012 and a 5 percent reduction from the same base year from 2013 through 2020. This is comparable to the results for the middle-of-the-road scenario. In November 2012, the EU ETS proposed deferring participation in these emissions reductions for flights to and from Europe in anticipation of progress toward an international market-based approach to regulating GHG emissions from aviation by ICAO in 2013. The legislation still applies to all flights within and between the 30 participating European countries within the EU ETS.[73]

4. Model Uncertainty for Aviation

There are uncertainties regarding projected unit turnover, aircraft efficiency, and demand. In addition, based on EPA's analysis there appear to also be considerable uncertainties about the actual benefits from FAA's NextGen program. All of these will impact actual CO_2 emissions in the future.

There is no guarantee that the level of efficiency improvements (and thus emissions reductions) built into the AEO2012 will occur without regulations. Emissions standards on aircraft may therefore be necessary to capture efficiency improvements assumed by AEO2012, and thus in the base case as well as lackluster and middle-of-the-road scenarios.

FIGURE A-1.12 Carbon Dioxide Emissions from Aircraft



V. Non-Energy CO_2 and Non-CO_2 Emissions

A. BASE CASE FOR NON-ENERGY EMISSIONS

According to EPA's latest emissions inventory, non-energy emissions accounted for roughly 20 percent of 2010 emissions. Due to data limitations and an evolving understanding of natural gas systems, the base case projections for non-energy CO_2 emissions and non-CO_2 gases come from several different sources. We project that non-energy emissions will increase roughly 18 percent above 2005 levels by 2020 and 36 percent above 2005 levels by 2035, even after accounting for recently finalized regulations that affect natural gas systems and HFCs emissions from vehicles (based on HFC emissions, not consumption).[74]

Non-CO_2 gas projections for all sources except for natural gas systems and HFCs came from EPA's *Draft*

Global Non-CO_2 Emissions Projections Report: 1990-2030.[75] In this report, EPA developed country-specific emission projections using assumptions about economic activity, technology development, emissions reductions from well-established programs or international sector agreements, and other factors. Results were provided in five-year intervals. We estimated emissions between the five-year intervals by applying a linear rate of change. Emissions for 2030 through 2035 were estimated by applying the same rate of change observed from 2025 to 2030.

The technical understanding of emissions from natural gas systems is continually evolving, particularly with regard to shale gas. Therefore, historical emission levels and base case projections utilized analysis conducted for a forthcoming working paper by WRI, *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas.*[76] This report builds on the synthesis of recent lifecycle analyses by Weber and Clavin, *Life Cycle Carbon Footprint of Shale Gas: Review of Evidence and Implications,*[77] EPA's Inventory of Greenhouse Gas Emissions and Sinks 2012,[78] and AEO2012.

Because EPA's *Draft Global Non-CO_2 Emissions Projections Report: 1990–2030* lumped natural gas systems with petroleum systems, we projected methane emissions from petroleum systems separately using historical emissions,[79] historical production data,[80] as well as projected production data.[81]

For the base case, we rely on projections of HFC consumption estimated by EPA in *Benefits of Addressing HFCs under the Montreal Protocol.*[82] Consumption is roughly equal to life-cycle emissions due to low rates of HFC reclamation and destruction. The main difference is that emissions for some products can be delayed many years after their production. As discussed below, annual emissions estimates could be developed using more detailed models of equipment and products. However, those models and underlying data are proprietary.

Non-energy CO_2 emissions projections were not provided in EPA's *Draft Global Non-CO_2 Emissions Projections Report: 1990–2030*, and so instead come from the Applied Dynamic Analysis of the Global Economy (ADAGE) reference scenario of EPA's modeling of the American Clean Energy and Security Act of 2009 (ACES).[83] ADAGE is a dynamic computable general equilibrium model run by RTI International.[84] ADAGE projects emissions in five-year intervals from 2010 to 2050. To estimate emissions between those intervals, we applied a linear rate of change between intervals.

The sources of the base case projections do not present the same level of detail as does the AEO reference case for energy-related CO_2 emissions. Therefore, in the sections that follow we simply describe the reported output for each of the base case emissions projections and where appropriate, describe any steps we took to adjust these projections.

B. NATURAL GAS SYSTEMS

1. Base Case for Natural Gas Systems

Natural gas production has increased by over 20 percent over the past five years[85] on account of rapid development of shale gas resources. Technology advancements in horizontal drilling and hydraulic fracturing have enabled access to vast supplies of natural gas deposits in shale rock formations.[86] The climate implications of shale gas development have been a point of particular controversy due to uncertainty around the methane emissions associated with development of shale gas wells and other portions of the natural gas system.

Our base case emissions projections come from analysis conducted for *Clearing the Air on Shale Gas Emissions,* a forthcoming WRI working paper that examines emissions and abatement opportunities for natural gas systems. Their base case projections were developed using EPA's 2012 *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010,*[87] shale gas production projections from AEO2012, and fugitive emissions rates from *Life Cycle Carbon Footprint of Shale Gas: Review of Evidence and Implications.*[88]

Our base case includes a suite of standards finalized by EPA in April 2012, including New Source Performance Standards (NSPS)[89] for volatile organic compound (VOC) emissions and National Emissions Standards for Hazardous Air Pollutants (HAP) from U.S. natural gas systems.[90] While not explicitly addressing GHGs, the NSPS will reduce methane emissions from natural gas systems by requiring "green completions" that capture gases leaked from wells.[91] The NSPS will result in further reductions of GHGs and VOCs from high-bleed

TABLE A-1.7 Performance Standards for Natural Gas Systems

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
EPA performance and emissions standards achieve 21-29 percent reduction in CH_4 emissions compared to projections without standards through the use of green completions and dry seal processors		
Emissions reductions of 26 percent from base case starting in 2019. Assumes implementation of plunger lift systems to reduce emissions from liquids unloading at new and existing wells, and leak monitoring and repair to reduce fugitive emissions from production, processing, and compressor stations.	Emissions reductions of 37 percent from base case in 2019. Assumes implementation of measures in lackluster scenario and conversion of existing high-bleed pneumatic controllers to low-bleed or no-bleed controllers to reduce emissions from production, processing, and transmission.	Emissions reductions of 67 percent from base case starting in 2019. Assumes implementation of measures in middle-of-the-road scenario as well as: desiccant dehydrators to reduce emissions during dehydration of wet gas; improved compressor maintenance to reduce emissions during processing; hot taps in maintenance of pipelines during transmission; and vapor recovery units to reduce emissions during storage.

compressors. The NSPS and emission standards for HAPs from storage tanks will also reduce GHGs and VOCs, though to a lesser extent.[92]

Clearing the Air on Shale Gas Emissions projects that the new standards will reduce methane emissions by approximately 65 mmtCO_2e in 2020 and 85 mmtCO_2e in 2035, and as a result total base case emissions (methane and carbon dioxide) will be 240 mmtCO_2e in 2020 and 250 mmtCO_2e in 2035.

2. Lackluster Scenario for Natural Gas Systems

Our lackluster scenario assumes that EPA implements regulations that require natural gas systems to employ:

1. Plunger lift systems to reduce emissions from liquids unloading at new and existing wells; and
2. Leak monitoring and repair to reduce fugitive emissions from production, processing, and compressor stations.[93]

These emissions control technologies are projected to pay for themselves within one to two years, even without a price on carbon.[94] *Clearing the Air on Shale Gas Emissions* projects that widespread adoption of these technologies would reduce methane emissions 26 percent below base case projections.[95] We assume that reductions commence in 2019.

3. Middle-of-the-Road Scenario for Natural Gas Systems

Our middle-of-the-road scenario assumes that EPA implements regulations that require natural gas systems to employ the above emissions control technologies—as well as conversion of existing high-bleed pneumatic controllers to low-bleed or no-bleed controllers—to reduce emissions from processing and transmission. This technology is predicted to have a payback period of less than two years with a $20 price on carbon, and is projected to pay for itself within three years even without a price on carbon. Clearing the Air on Shale Gas Emissions projects that widespread adoption of these three technologies would reduce methane emissions roughly 37 percent below base case projections.[96] We assume that these reductions commence in 2019.

4. Go-Getter Scenario for Natural Gas Systems

Our go-getter scenario assumes that EPA implements regulations that require natural gas systems to employ all of the emission control technologies identified in the lackluster and middle-of-the-road scenarios, as well as:

1. Hot taps to reduce emissions from pipeline maintenance and repair during transmission;
2. Desiccant dehydrators to reduce emissions during dehydration of wet gas;
3. Improved compressor maintenance to reduce emissions during processing; and
4. Vapor recovery units to reduce emissions during storage.

The technologies were identified by the Natural Resource Defense Council's Leaking Profits report as being both technically feasible and profitable, each with a payback period of less than three years under NRDC's assumptions.[97] Using the same methodology

and conservative assumptions as were employed in the WRI working paper Clearing the Air on Shale Gas Emissions, these emission control technologies are found to achieve 67 percent reduction in emissions from the base case projections.[98] We assume that the standards lead to reductions beginning in 2019.

5. Modeling Notes for Natural Gas Systems

Emissions from natural gas systems are related to the amount of natural gas produced. While the AEO2012 reference case shows the U.S. going from being a net importer to a net exporter of natural gas by the early 2020s, consumption and production levels remain within 5 percent of each other through most of our study period.[99] Based on this observation, in this analysis we employ the simplifying assumption that changes in natural gas demand will result in equivalent changes in natural gas production in the United States. In each of the scenarios, methane and carbon dioxide emissions levels were adjusted to account for changes in natural demand from electricity generation, residential and commercial appliances, and industry.

We do not attempt to sort out the relative change in conventional and unconventional production. This is not expected to significantly impact the results, as we project the emissions rate for conventional and unconventional sources to be within 5 to 30 percent of one another across all scenarios.[100] Across all scenarios, natural gas demand is not expected to change by more than 12 percent,[101] and changes in upstream emissions of natural gas are estimated to be less than 0.1 percent of total economy-wide GHG emissions reductions.

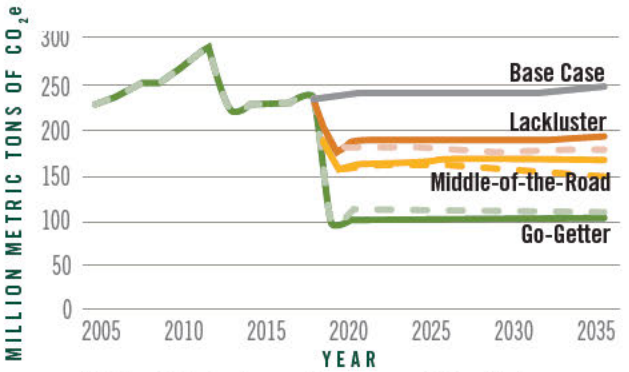
6. Uncertainties for Natural Gas Systems

WRI analysis of greenhouse gas emissions from natural gas systems relies in large part on activity data from EPA's 2012 Inventory, as well as on lifecycle analyses that utilize data from that inventory. However, The American Petroleum Institute (API) and America's Natural Gas Alliance (ANGA) published a joint study in September, 2012 that calls into question some of EPA's assumptions and methodologies in the agency's calculations for the largest sources of leaked and vented methane from natural gas systems. This industry-led study is noteworthy because it presents measurement data from 19 of the 21 largest basins across the U.S. Additional measurement data will be published over the course of the next year – including a study led by Environmental Defense Fund[102] and measurement data provided to the EPA under Subpart W of the Greenhouse Gas Reporting Program[103] – that will help clarify the still-murky picture of natural gas systems emissions.

Specifically, the API and ANGA study reports a much lower frequency of liquids unloading, and a much lower emissions factor for the venting associated with this process, than does EPA in the 2012 Inventory. API and ANGA also estimate a much lower refracture rate for hydraulically fractured wells than is used in the 2012 Inventory.

Using the results from the API/ANGA study in place of the activity data from EPA's 2012 Inventory would reduce historical estimates of methane and carbon dioxide emissions from natural gas systems, the base case projection of those emissions, and the reductions from that baseline from EPA's existing standards and from our three reduction scenarios. The baseline projections would be reduced by 14-21 percent from 2020-2035. The EPA performance and emissions standards finalized in 2012 would achieve a 21-26 percent reduction in methane emissions starting in 2013 compared to projections without standards, compared to 21-29 percent using the 2012 Inventory. Likewise, implementing regulations consistent with our lackluster, middle-of-the-road, and go-getter scenarios

FIGURE A-1.13 Total Methane and Carbon Dioxide Emissions from Natural Gas Systems (Federal)



Solid lines indicate changes in base case emissions due to new emissions standards for natural gas systems.

Dashed lines indicate changes in emissions after accounting for changes in demand.

Note: Carbon dioxide emissions range from around 30MMtCO_2e to 43MMtCO_2e across all scenarios.

described above would lead to reductions in methane emissions from the base case between 2019 and 2035 that are equivalent to roughly 22 percent, 35 percent, and 51 percent, respectively. These compare to 26, 37, and 67, respectively, using the 2012 Inventory. Using the results from the API/ANGA study, the federal go-getter scenario only reduces emissions 16.3 percent below 2005 levels, and thus additional state (or legislative) action would be needed to achieve the 17 percent reduction target.

C. HYDROFLUROCARBONS (HFCS)

1. Base Case Scenario for Hydrofluorocarbons

Emissions of HFCs have been increasing due to the phaseout of chlorofluorocarbons (CFCs) and other ozone-depleting substances under the Montreal Protocol and Clean Air Act. This trend is expected to continue as the interim substitutes, HCFCs, are also phased out as they are currently being replaced with gases that have a high global warming potential.[104] EPA's *Draft Global Non-CO_2 Emissions Projections Report: 1990-2030* projects that if current trends continue, hydroflourocarbon (HFCs) emissions will increase from 143 mmtCO_2e in 2010 to roughly 411 mmtCO_2e in 2035.[105]

EPA's projections were developed using the Vintaging model, a proprietary bottom-up model of "ozone-depleting substances (ODS) and ODS-substitute-containing equipment and products to estimate the use and subsequent emissions of ODS substitutes in the U.S."[106] Without this model, we were unable to develop robust estimates of actual emissions due to changes in consumption. Therefore, we relied on projections of HFC consumption estimated by EPA in *Benefits of Addressing HFCs under the Montreal Protocol* for the base case.[107] In this report, EPA projects that HFC consumption in the U.S. will increase from 300 mmtCO_2e in 2010 to roughly 580 mmtCO_2e in 2035.

These projections do not, however, account for the HFC benefits projected from EPA's GHG emissions standards for light-, medium-, and heavy-duty vehicles. For light-duty vehicles, EPA offers a credit to manufacturers that reduce HFC leakage from AC systems. The emissions standards for medium- and heavy-duty vehicles, on the other hand, establish specific standards for HFC leakage from heavy-duty pickup trucks and vans as well as combination tractors. We adjusted these projections using estimated HFC abatement from light-duty vehicles as reported in EPA's OMEGA model outputs[108] and from medium- and heavy-duty vehicles using EPA and NHTSA's regulatory impact analysis (RIA).[109] We assumed that reported lifetime reductions in HFC emissions for each vehicle model year corresponded to the same level of reductions in consumption. After accounting for these new regulations, we project in the base case that HFC consumption will only increase to 543 mmtCO_2e in 2035 (37 mmtCO_2e less than the 580 mmtCO_2e predicted in *Benefits of Addressing HFCs under the Montreal Protocol*).

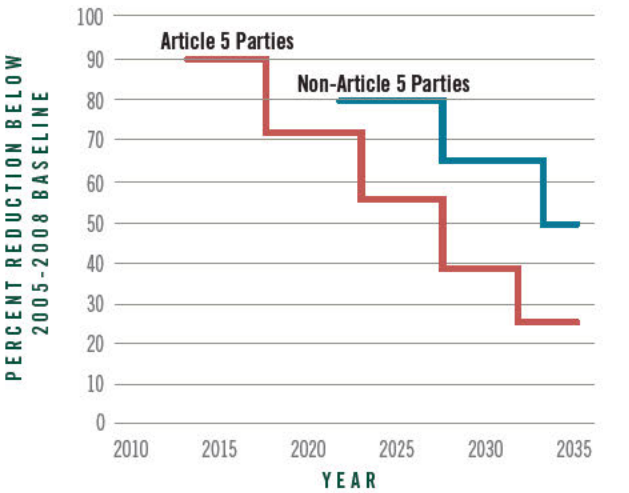
2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Hydrofluorocarbons

On May 9, 2012, the U.S. filed a joint proposal with Canada and Mexico to amend the Montreal Protocol. That proposal calls for a ramp-down of emissions of high global warming potential (GWP) HFCs, so that in 2033 production and consumption of HFCs on a GWP-weighted basis are 15 percent of base case emissions in the U.S. and other developed countries (specifically, non-Article 5 Parties). The baseline is defined as the average of 2005–2008 HFC consumption plus 85 percent of the average 2005–2008 HCFC consumption. The proposal puts forth a separate, slightly less aggressive reduction schedule for developing countries listed under Article 5 of the Montreal Protocol (see Figure A-1.14).

TABLE A-1.8 Emissions Reduction Schedule for Hydrofluorocarbons

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Consumption ramp-down occurs three years later than the schedule detailed in the joint North American Proposal.	Consumption is ramped-down in a manner consistent with the joint North American Proposal, which calls for an 85 percent reduction below 2005–2008 levels by 2033.	Consumption is ramped-down more rapidly than in the joint North American Proposal, achieving the 85 percent reduction target in 2028, five years earlier than detailed in the joint North American Proposal.

FIGURE A-1.14 HFC Reduction Schedules



Source: *Benefits of Addressing HFCs under the Montreal Protocol*, U.S. EPA, June 2012.

EPA's authority for regulating emissions of ozone-depleting substances comes from Title VI of the Clean Air Act. The phasedown of HFCs could be implemented through its Significant New Alternatives Policy (SNAP) program. The SNAP program implements section 612 of the Clean Air Act, which calls for the replacement of ozone-depleting substances with substitutes that reduce the overall risk to human health and the environment. Under the SNAP program, EPA may restrict or prohibit the use of unacceptable substitutes and classify substitutes that are acceptable.[110] In its report, *Benefits of Addressing HFCs under the Montreal Protocol*,[111] EPA notes that the most promising options for reducing HFC consumption through the SNAP program include:

- "Substituting HFCs with low-GWP or no-GWP substances in a variety of applications (where safety and performance requirements can be met);
- Implementing new technologies that use, at installation and/or over the lifetime of the equipment, no or significantly lower amounts of HFCs; and,
- Various process and handling options—including the principles of refrigerant recovery and management implemented during the CFC phaseout—that reduce consumption during the manufacture, use, and disposal of products that contain or use HFCs."

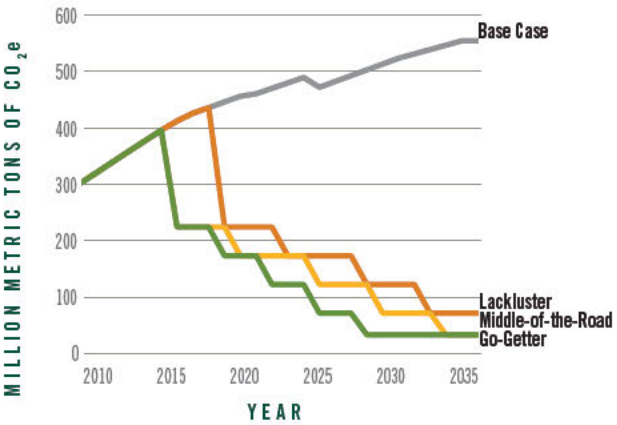
We note that Title VI provides additional authority to EPA to reduce HFCs beyond the SNAP program, including sections 608 and 609. We assume that EPA will either implement the ramp-down schedule after it is included in an international agreement, or will seek to achieve similar reductions through existing authority absent such an agreement. Because the reduction schedule proposed by the United States achieves relatively large reductions from the base case, and because they have signaled a strong intention to pursue this long-term path, in the middle-of-the-road scenario we assume that EPA takes action to achieve the reduction schedule proposed for non-Article 5 Parties.[112] In the lackluster scenario, we assume that a similar reduction schedule is followed, except that the reductions commence beginning in 2019 instead of 2016.

Our go-getter scenario assumes that EPA sets standards that result in a more aggressive reduction schedule so that an 85 percent reduction in consumption is achieved five years before the middle-of-the-road scenario. This results in a 61 percent reduction in consumption in 2020 compared to the base case projections in the same year. The full schedules are detailed in Figure A-1.14.

3. Modeling Notes for Hydrofluorocarbons

Using these HFC consumption-based estimates, we find that go-getter action for HFCs and other sectors will result in economy-wide U.S. GHG emissions that are 17 percent below 2005 levels in 2020. As noted above, we did not have access to the Vintaging model or similar models that would have allowed us to develop robust estimates of actual emissions due to changes in consumption. However, we developed a basic emissions model to provide rough estimates of 2020 emissions. This was only possible due to the relatively short time considered (i.e., 2020 as opposed to emissions through 2035), as it allowed us to minimize the variables of

FIGURE A-1.15 HFC Consumption



equipment turnover and recharging. The results of this analysis, showing economy-wide reductions in the range of 15 to 19 percent, were generally consistent with the consumption-based estimates we used in this study.[113]

D. COAL MINES

1. Base Case for Coal Mines

The base case utilizes EPA's *Draft Global Non-CO_2 Emissions Projections Report: 1990–2030*, which projects methane emissions will increase from 70 mmtCO_2e in 2010 to 87 mmtCO_2e in 2035.

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Coal Mines

All scenarios assume that EPA establishes performance standards for new and existing coal mines in a manner that results in abatement of methane emissions consistent with the cost-effective reductions identified in EPA's marginal abatement cost curves. For example, reductions from coal mines can be achieved through degasification and pipeline injection and through oxidation of ventilation air methane. For simplicity, we assumed that relatively few new coal mines would come online between 2012 and 2017, and thus do not model any reductions until 2019, the earliest expected date that performance standards could be in place for existing coal mines. Table A-1.9 shows the level of GHG emissions reductions achieved under the three scenarios, and the corresponding cost per ton from EPA analysis.

We based our assessment of achievable emissions reductions using these measures on the marginal abatement cost curves found in EPA's *Preliminary Draft Global Mitigation of Non-CO_2 Greenhouse Gases Report (March 2012)*.[114] Marginal abatement cost curves can serve as a useful point of reference because EPA will consider the cost of abatement when setting prescribed emissions rates for new and existing coal mines. EPA's marginal abatement curves provide cost information per ton of emissions reduced, and have been used by EPA with ADAGE emissions forecasts in various analyses. EPA's *Preliminary Draft Global Mitigation of Non-CO_2 Greenhouse Gases Report (March 2012)* represents an update to their 2006 report. Their 2012 analysis incorporates updated mitigation technologies, labor and energy costs, and emissions baselines with an updated modeling approach.

We based the lackluster scenario on the reductions achievable at a cost of $5 per ton of CO_2e. The middle-of-the-road scenario was based on the reductions achievable at a cost of $20 per ton of CO_2e. The go-getter scenario was based on the reductions achievable at a cost of $61 per ton of CO_2e.

The selected costs cover the range of prices that were considered at the federal and state level in cap-and-trade program design.[115] They also cover the range of prices considered in the report— *Technical Support Document: Social Cost of Carbon Regulatory Impact Analysis Under Executive Order 12866*, released in February 2010—prepared by the Interagency Working Group on the Social Cost of Carbon.[116] The social cost of carbon is meant to provide an estimate of the monetized damages associated with the incremental emissions of greenhouse gases. The estimates contained in the report are intended to provide guidance to agencies as they incorporate the benefits of reducing greenhouse gas emissions into the cost-benefit analyses associated with future regulatory actions. The reported range was $6–$73 in 2015 and $10–$100 in 2030.

It bears noting that there may be barriers to achieving the full technical reduction potential for emissions reductions through direct regulation as compared to a voluntary offsets program. According to EPA's inventory of coal mines for 2010, abandoned coal

TABLE A-1.9 Methane Emissions from Coal Mines

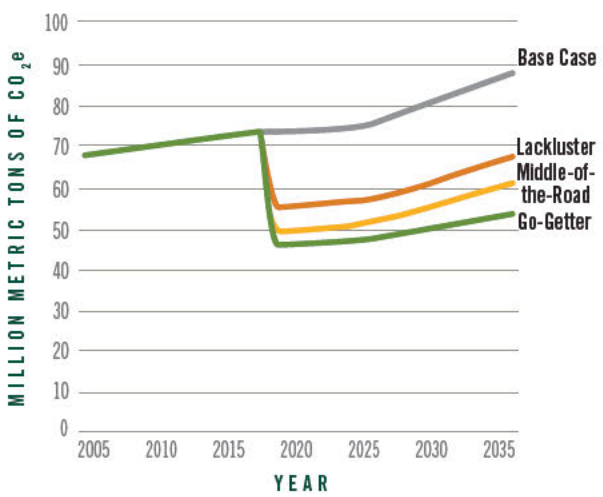
	ABATEMENT COST ($/TON CO_2e)	PERCENT REDUCTION FROM BASE CASE IN 2020 (PERCENT)	EMISSIONS (MMTCO_2e)		
			2010	2020	2035
Base Case	-	-	70	73	87
Lackluster	5	24 percent	-	55	66
Middle-of-the-Road	20	32 percent	-	50	59
Go-Getter	61	39 percent	-	44	53

mines (i.e., those that are not producing coal) account for approximately 6 percent of coal mine emissions.[117] Abandoned mines pose significant challenges to enforcement of standards. Therefore, we assume that only the 94 percent of coal mine methane that comes from active mines is abated in response to NSPS. This is consistent with EPA's P*reliminary Draft Global Mitigation of Non-CO_2 Greenhouse Gases Report (March 2012)*, which derives the abatement curves based on reductions of methane emissions from active mines only.

3. Uncertainties for Coal Mines

Our scenarios establish new standards for new and existing coal mines. EPA's marginal abatement cost curves, however, do not differentiate between new and existing mines. They also do not show significant changes in abatement over time (from 2020 to 2030). This means that the rate that new mines come into production should not significantly affect the abatement rate. Emissions will change, however, if production increases or decreases differently than is predicted by EPA. There is also uncertainty about what percentage of mines will be abandoned in future years. If that percentage increases above 6 percent, then emissions from this sector may increase beyond what is modeled here.

FIGURE A-1.16 Methane Emissions from Coal Mines



E. NITRIC AND ADIPIC ACID MANUFACTURING

A. Base Case for Nitric and Adipic Acid Manufacturing

Nitric acid (HNO_3) is primarily used as a feedstock for synthetic fertilizer, though it is also used in the production of adipic acid and explosives. Adipic acid ($C_6H_{10}O_4$) is used in the production of nylon and as a flavor enhancer in certain foods. The manufacture of nitric and adipic acid generates nitrous oxide (N_2O) as a byproduct, which according to the IPCC's *Fourth Assessment* has a global warming potential 298 times that of carbon dioxide over a 100-year timeframe.[118] For the base case we relied on EPA's *Draft Global Non-CO_2 Emissions Projections Report: 1990-2030*, estimating emissions for 2030 through 2035 by applying the same rate of change from 2025 to 2030. We project that N_2O emissions from nitric and adipic acid production will increase from 28 mmtCO_2e in 2010 to 38 mmtCO_2e in 2035.

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Nitric and Adipic Acid Manufacturing

All three scenarios assume that EPA establishes performance standards for new and existing nitric acid manufacturers in a manner that results in abatement of N_2O emissions consistent with the cost-effective reductions identified in EPA's marginal abatement cost curves. This generally would require some form of catalytic reduction for nitric acid manufacturers. For adipic acid manufacturers, this would likely require thermal destruction using reducing flame burners with premixed methane or natural gas.[119]

TABLE A-1.10 Nitrous Oxide Emissions from Nitric Acid and Adipic Acid Manufacturing

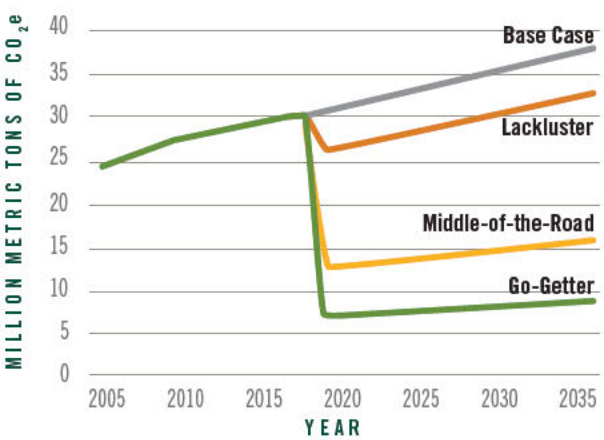
	ABATEMENT COST ($/TON CO_2e)	PERCENT REDUCTION FROM BASE CASE IN 2020 (PERCENT)	EMISSIONS (MMTCO_2e)		
			2010	2020	2035
Base Case	-	-	28	31	38
Lackluster	5	13 percent	-	27	33
Middle-of-the-Road	20	56 percent	-	14	16
Go-Getter	61	75 percent	-	8	9

For simplicity, we assumed that relatively few new production facilities would come online between 2012 and 2017, and thus do not model any reductions until 2019, the earliest expected date that performance standards could be in place for existing production facilities. Table A-1.10 shows the level of GHG emissions reductions achieved for both nitric and adipic acid facilities under the three scenarios, and the corresponding cost per ton from EPA analysis as discussed above in the coal mine section.

3. Uncertainties for Nitric and Adipic Acid Manufacturing

In this section, we model the impact of performance standards on new and existing units. EPA's marginal abatement cost curves do not differentiate between new and existing units, and do not predict significant changes in abatement over time (from 2020 to 2030). This means that the rate that new units come into production should not affect the abatement rate. However, if production increases or decreases differently than predicted by EPA, then emissions will change accordingly.

FIGURE A-1.17 Nitrous Oxide Emissions from Nitric and Adipic Acid Manufacturing



F. LANDFILLS

1. Base Case for Landfills

For the base case, we relied on EPA's D*raft Global Non-CO_2 Emissions Projections Report: 1990-2030*, which projects that methane emissions from landfills will remain relatively constant between 2010 (154 mmtCO_2e) and 2035 (152 mmtCO_2e).

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Landfills

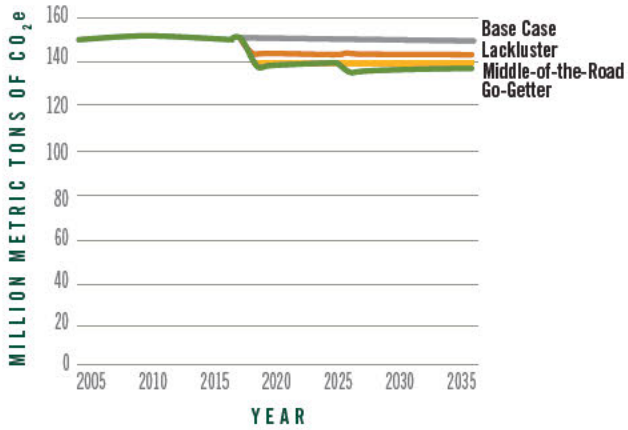
All three scenarios assume that EPA establishes performance standards for new and existing landfills in a manner that results in methane abatement consistent with the cost-effective reductions identified in EPA's marginal abatement cost curves. Abatement at landfills is accomplished through methane capture and destruction. For simplicity, we assumed that relatively few new landfills would come online between 2012 and 2018, and thus do not model any reductions until 2019, the earliest expected date that performance standards could be in place for existing landfills. Table A-1.11 shows the level of GHG emissions reductions achieved under the three scenarios, and the corresponding cost per ton from EPA analysis, as discussed above in the coal mine section.

Our previous analysis suggested that 44 to 74 percent of methane emissions from landfills could be abated under the three scenarios, based on data from EPA's 2006 release of its *Global Mitigation of Non-CO_2 Greenhouse Gases* report.[120] EPA's updated analysis, *Draft Global Non-CO_2 Emissions Projections Report: 1990-2030*, is thought to be more accurate as it includes more information on gas capture rates, mitigation options and costs, and labor costs. It also projects decreased prices for landfill methane gas, which reduces the benefit for methane capture.

TABLE A-1.11 Methane Emissions from Landfills

	ABATEMENT COST ($/TON CO_2e)	PERCENT REDUCTION FROM BASE CASE IN 2020 (PERCENT)	EMISSIONS (MMTCO_2e)		
			2010	2020	2035
Base Case	-	-	154	152	152
Lackluster	5	5 percent	-	145	144
Middle-of-the-Road	20	9 percent	-	139	138
Go-Getter	61	9 percent	-	138	135

FIGURE A-1.18 Methane Emissions from Landfills



3. Uncertainties for Landfills

EPA's marginal abatement cost curves do not differentiate between new and existing units, and predict minimal changes in abatement over time (from 2020 to 2030). This means that changes in the percentage of emissions attributable to new landfills (as opposed to older landfills) should not affect the abatement rate. However, if methane production increases or decreases due to changes in the quantities of waste going to landfills or landfill management practices, then emissions will change accordingly.

VI. Industry

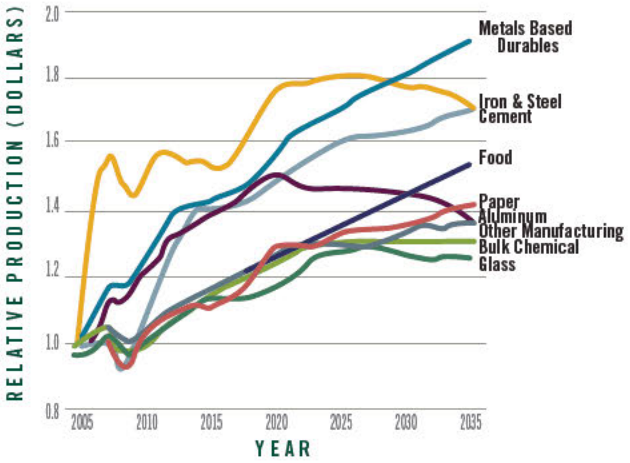
A. MANUFACTURING

1. Base Case for Manufacturing

Baseline emissions for energy-related CO_2 emissions come from EIA's AEO2012. Under the AEO2012 reference scenario, each major manufacturing sector is projected to see an upward trend in production.[121] As a result, in 2035 total production exceeds production levels in 2009. The AEO reference case assumes that overall process efficiency will gradually improve over time. However, overall energy use and emissions are forecast to increase in most subsectors.[122] Due to mature technology and low turnover rates, boiler efficiency, however, remains relatively constant over time.[123]

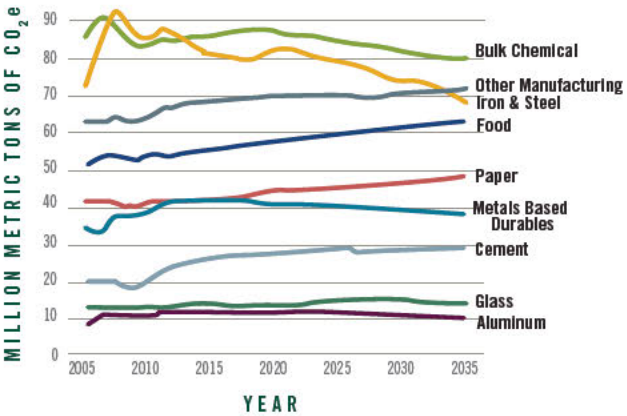
Emissions from onsite combustion and other industrial processes—such as those from limestone calcination in the cement production process—in the manufacturing sector are projected to grow from 527 mmtCO_2e in 2009 to 566 mmtCO_2e in 2035, amounting to a 7 percent increase in emissions over this time period (roughly three-quarters of these emissions result

FIGURE A-1.19 Relative Changes in Production from 2009 for Major Manufacturing Sectors, Expressed in Inflation-adjusted Dollar Value of Shipments



Source: *AEO2012*, U.S. EIA

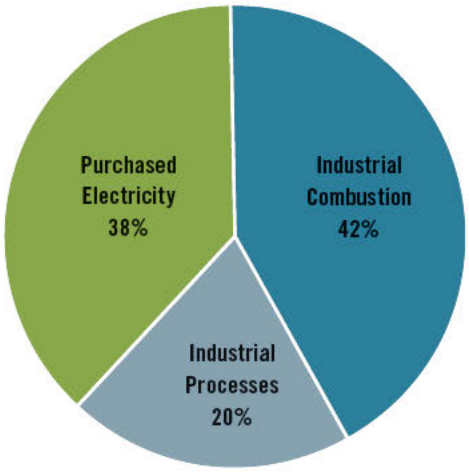
FIGURE A-1.20 Base Case Carbon Dioxide Emissions from Fossil Fuel Combustion at Manufacturing Facilities



Source: *AEO2012*, U.S. EIA

from onsite combustion, while the remainder are process emissions). Increases in emissions from the food, cement, and paper industries offset emissions reductions in the bulk chemical and iron and steel industries. More detailed sector breakdowns are depicted in Figure A-1.20. However, it is important to note that onsite combustion and other industrial processes account for only 62 percent of total emissions. The other 38 percent is due to emissions associated with purchased electricity (see Figure A-1.21).

FIGURE A-1.21 Industrial Greenhouse Gas Emissions by Source, 2010



Source: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010*, EPA.

2. Lackluster Scenario for Manufacturing

In its ANPR, EPA concluded that existing industrial boilers could achieve efficiency improvements of 1–10 percent, and that efficiency improvements of 10–33 percent could be obtained by replacing an existing boiler with a CHP unit.[124]

For the lackluster scenario, we assume that EPA establishes performance standards for new and existing industrial boilers. To simplify the modeling of this scenario, we assume that EPA establishes emissions limits for new and existing industrial boilers that achieve a 10 percent reduction in emissions beyond base case projections. This was modeled as a 10 percent reduction in fuel use across all boilers and fuel types in the manufacturing sector, which includes food, paper, bulk chemical, glass, cement, iron and steel,[125] aluminum, metals-based durables, and other manufacturing.[126] A comparable level of emissions reductions could be achieved through other combinations of new unit and existing unit standards.[127,128] Since in the early years few new units are expected, for simplicity we model these reductions starting in 2019 to account for the six-year time lag for developing performance standards for existing units.

3. Middle-of-the-Road Scenario for Manufacturing

According to NEMS support documentation for AEO2012, industrial boilers account for only 28 percent of manufacturing heat and power energy consumption, excluding byproduct fuels.[129] In the middle-of-the-road scenario, we therefore assume that EPA devises performance standards that account for the entire industrial facility and purchased electricity, instead of merely capturing boiler efficiency opportunities. This more holistic approach would capture efficiencies in the entire industrial process, thereby improving the rate of emissions per unit of output. This would require a slightly more expansive approach to performance standards than EPA has implemented in the past. However, it is worth noting that a similar approach was discussed by the Climate Change Working Group of the Clean Air Act Advisory Committee.[130] Such standards could take the form of output-based emissions rates, or (in the case of existing units) through a flexible compliance program for industry that rewards improvements in emissions per unit of output.

TABLE A-1.12 Performance Standards to Reduce Industry Emissions

	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Fossil-fuel Combustion in Manufacturing and Cement Kilns	Emissions reductions consistent with a 10 percent improvement in efficiency beyond base case levels starting in 2019.	Emissions reductions consistent with harnessing all cost-effective energy efficiency across the entire manufacturing facility. Emissions standards also drive reductions in process emissions from cement kilns.	Emissions reductions consistent with harnessing all cost-effective energy efficiency across the entire manufacturing facility; all new units must meet emissions rate equivalent to natural gas combustion. Emissions standards also drive reductions in process emissions from cement kilns.
Refineries	Emissions reductions consistent with a 1 percent improvement in efficiency.	Emissions reductions consistent with a 5 percent improvement in efficiency.	Emissions reductions consistent with a 10 percent improvement in efficiency.

In order to gauge the additional reductions achievable through process efficiency improvements beyond those included in AEO2012, we relied on a study commissioned by the Department of Energy (DOE), *Scenarios for the Clean Energy Future* (CEF).[131] The CEF study examines the effect of a suite of voluntary policies on reducing industrial emissions. In the CEF, two different policy implementation scenarios are analyzed: a moderate and advanced scenario. The CEF advanced scenario included voluntary sector agreements between government and industry and a suite of complementary policies, including expanded research and development and a domestic carbon dioxide emissions trading system with prices around $19 per ton of carbon dioxide.[132] This valuation of the impact of carbon dioxide emissions could be integrated into the development of sector-appropriate standards, whether they are in the form of source-specific emissions rates, or a more flexible compliance program.

The CEF study, which was completed in November 2000, was based on AEO1999. In *Real Prospects for Energy Efficiency in the United States,*[133] the National Academy of Sciences concluded that the percentage of reductions found in the CEF can be applied to more recent releases of the AEO. This was because "new energy efficiency opportunities arise each year as infrastructure and equipment ages, and as new and improved technologies are introduced into the marketplace."[134] For the middle-of-the-road scenario, we assumed that reductions commence in 2019 due to the time lag for establishing standards on existing units through section 111(d). We then assumed that industrial efficiency ramps up in a linear manner so that in 2025 it achieves the same percent improvement, relative to business-as-usual projections, as was found in the CEF study for 2010. We assumed that the relative energy efficiency benefits modeled in the CEF study for 2020 would be achieved in 2035. We also assume a linear rate of change between the reductions modeled in 2025 and 2035.

The built-in time lags are intended to provide the sector time to turn over stock and adopt improved efficiency measures at existing facilities. The precise amount of time needed to achieve these changes is uncertain, as the CEF analysis did not provide annual results, but instead presented findings at two separate intervals. For this scenario, we did not need to independently calculate unit turnover, as it is already built into the CEF reduction scenario. However, the CEF generally assumed a slightly higher unit retirement rate than is incorporated into the AEO, based on their own assessment of the retirement rates commonly observed across industrial classes. This level of efficiency and technology improvement leads to GHG emissions reductions of 16 mmtCO_2 in 2020 and 76 mmtCO_2 in 2035 from onsite combustion above what is projected in the base case. It also leads to reductions in purchased electricity of 28 TWh (3 percent) in 2020 and 168 TWh (21 percent) in 2035 compared to the base case.

4. Go-Getter Scenario for Manufacturing

In the go-getter scenario, we again assume that EPA captures efficiencies across the entire industrial process by establishing equipment efficiency standards, sector-wide benchmark standards, or some other flexible compliance program for industry. This is modeled using the CEF improvements in the same manner as the middle-of-the-road scenario. In the go-getter scenario, we also assume that EPA establishes emissions standards for all new combustion sources (not just boilers) equivalent to natural gas combustion. This could be accomplished through co-firing of biomass, use of natural gas, carbon capture and sequestration, or built into the reduction schedule of a flexible compliance program. Combined, these standards lead to reductions of 30 mmtCO_2e in 2020 and 97 mmtCO_2e in 2035 compared to the base case projections in the same years. Similar to the middle-of-the-road scenario, purchases of electricity are reduced by 28 TWh in 2020 and 168 TWh in 2035 compared to the base case.

5. Uncertainties for Manufacturing

The CEF's considerations of cost, unit turnover, and its direct comparison to projected efficiency improvements built into the AEO make it a particularly valuable study for incorporation into the model. Since this study was published, other analyses have been completed, but they do not provide these same features. Nevertheless, some of them warrant consideration for comparative purposes. Of note are the series of "bandwidth" studies sponsored by the Department of Energy's Industrial Technologies Program. These studies assess the amount of energy that can be saved from a particular industrial process and compare current average energy use to state-of-the-art practices and the practical minimum energy use. Since each of the bandwidth

studies was conducted independently, there are some inconsistencies. The studies examine state of the art/best practice for each sector, which they generally define as the least energy-intensive option in current use. They also examine what they call the practical minimum, which varies somewhat between the energy required "assuming application of reasonable technologies such as heat recovery, batch preheating, etc,"[135] and the "energy required for a typical plant after deployment of new process technologies developed through applied research and development."[136]

Table A-1.13 compares the sector-specific findings of the bandwidth studies with energy savings modeled under this report's middle-of-the-road and go-getter scenarios. For instance, under our scenarios efficiency improvements from the paper and glass sectors are well below those that would be achieved if they employed the best practices identified in their respective bandwidth studies. Meanwhile, we predict that the GHG emissions reductions from the bulk chemical sector are between the energy savings identified from best practices and those identified with the practical minimum. Projected energy reductions from the iron and steel sector exceed the bandwidth's practical minimum by 3 percent[137] (the practical minimum is not expected to be technically feasible without additional research and development), raising questions about the feasibility of achieving the level of improvement modeled for the iron and steel industry in the CEF. However, in *Real Prospects for Energy Efficiency in the United States*, the National Academy of Sciences concludes that significant opportunities exist to reduce energy use in the iron and steel sector, pointing to a McKinsey and Company study that found 22 percent energy savings were obtainable by 2020 compared to 2007 levels, which is much greater than the 3 percent improvement the bandwidth study found for current best practices.[138] Furthermore, an American Iron and Steel Institute study, *Saving One Barrel of Oil per Ton*,[139] sets an industry-wide goal of reducing energy-use per ton of steel production by 39 percent in 2025 compared to 2003 levels. Due to this lack of consensus in the available literature in terms of potential efficiency improvements and a common baseline, we did not adjust the iron and steel numbers from those found in the CEF.

TABLE A-13 Energy Savings and Energy-Related Carbon Dioxide Intensity Improvements in the Manufacturing Sector (percent)

	ENERGY SAVINGS WITH BEST PRACTICE (BANDWIDTH)	ENERGY SAVINGS WITH PRACTICAL MINIMUM (BANDWIDTH)	TOTAL ENERGY SAVINGS IN 2035 WHEN COMBINE SAVINGS FROM CEF AND AEO2012	MODELED CO_2 INTENSITY IMPROVEMENT 2035 VS. 2012 (TONS CO_2 FROM COMBUSTION/VALUE OF SHIPMENT)			
				Base Case	Lackluster (10 percent efficiency gain all boilers)	Middle-of-the-Road (CEF)	Go-Getter (CEF + natural gas emissions rate for new units)
Food Products	NA	NA	33	20	26	37	40
Paper	26	39	11	19	25	38	42
Bulk Chemical	18	71	38	27	33	37	38
Glass	35	52	21	11	12	18	19
Cement	NA	NA	31	9	9	32	46
Iron & Steel	3	31	34	33	33	37	45
Aluminum	NA	NA	48	25	28	47	51

Note: The bandwidth study determined baseline energy consumption for paper manufacturing using 2002 Manufacturing Energy Consumption Survey (MECS) data, plus data collected for the report. The bandwidth study for glass was based on data collected through surveys collected for the report prior to publication in 2007. The bandwidth study for steel was based on energy-use data from 2000. The bandwidth study for bulk chemicals was based on energy data collected in 2004 for the report.[140]

Source: Steel Industry Energy Bandwidth Study. Energetics, Inc., U.S. Department of Energy, October 2004; Chemical Bandwidth Study Exergy Analysis: A Powerful Tool for Identifying Process Inefficiencies in the U.S. Chemical Industry. Dickson Ozokwelu, Joseph Porcelli, and Peter Akinjiola, U.S. Department of Energy, December 2006; Industrial Glass Bandwidth Analysis, David Rue, James Servaites, and Warren Wolf, U.S. Department of Energy, December 2006; Pulp and Paper Industry Energy Bandwidth Study, Jacobs Institute of Paper Science and Technology, American Institute of Chemical Engineers, August 2006.

There is considerable uncertainty in industrial unit turnover. Greater equipment turnover could lead to more significant reductions depending on the pace of new technology development and actual standards that are set for new units. Lower turnover would lead to fewer reductions.

There is also considerable uncertainty about the long-term production forecast for each manufacturing subsector. Increased production beyond what is modeled in the AEO2012 could increase emissions, but may also signal improved economics for domestic industry that would allow for greater investments in efficiency technologies and deeper cuts in GHG emissions.

Furthermore, this study relies heavily on the CEF to estimate the emissions reductions achievable if plant-wide efficiency opportunities were incorporated into GHG performance standards. The CEF study considers cost, unit turnover, and directly compares efficiency gains to those built into the AEO. More current assessments would be necessary before regulatory standards could be established for these sectors. New assessments would likely produce different estimates for each manufacturing sector than what we modeled here. Nevertheless, we believe that this analysis provides a sense of the range of reductions achievable through federal authority given the assessments currently available.

6. Modeling Notes for Manufacturing

Changes in purchases of electricity are accounted for in the electricity demand module. Because we relied on EIA's AEO2012 $25 carbon tax scenario for the go-getter power sector generation projections, we had to make adjustments to industrial efficiency savings. This is because the $25 carbon tax scenario includes industrial efficiency savings beyond those modeled in the AEO2012 reference case. Therefore, we incorporated only the benefits that occur beyond those included in the $25 carbon tax scenario, amounting to roughly 45 TWh of additional electricity savings in 2035.

Changes in natural gas consumption are accounted for in the natural gas demand module that adjusts upstream natural gas emissions to reflect downstream consumption patterns.

AEO2012 does not separate out new and older units in intermediary or final outputs for the industrial sector module. Therefore, we had to estimate unit turnover in order to account for the new unit standards in the go-getter scenario. Since the scenario is based on the CEF study, we employed the retirement rates found in the CEF, which are generally higher than those used in the AEO2012. In this analysis, modeling of new unit development is somewhat simplified and can lead to the overdeployment of new units if production rapidly changes for a very brief period of time. To prevent that from occurring, we smoothed the production curves upon which turnover was based. The model did not build out new units if it projected that sector production would result in a surplus supply within seven years of new unit construction. Seven years was chosen because it parallels the AEO2012 assumption that new units are not eligible to retire within the first seven years of construction.

B. CEMENT KILNS

1. Base Case for Cement Kilns

Base case emissions for energy-related CO_2 emissions are discussed above in Section VI.A. In 2010 CO_2 emissions from energy consumption accounted for 46 percent of total CO_2 from cement plants, while the remaining CO_2 emissions were the result of chemical processes (limestone calcination) associated with cement production.[141] In the analysis, we relied on ADAGE for the base case projections of non-energy CO_2 emissions. However, ADAGE does not include a separate line item for cement process emissions, but instead folds them into a broader category that includes process emissions from all energy-intensive manufacturing. Therefore, we developed our own projections. We determined the percentage of industrial process CO_2 emissions attributable to cement production in 2010 using EPA's *2012 Inventory of Greenhouse Gas Emissions and Sinks*,[142] and multiplied this by AEO2012 projections. We then multiplied 2010 emissions by the percent change in cement output for all subsequent years, as obtained from Table 30 of AEO2012, "Cement and Lime Industry Energy Consumption." Using this approach, we estimate that process emissions will increase from 36 mmtCO_2 in 2010 to 42.5 mmtCO_2 in 2035 under the base case. This methodology is viable because AEO2012 does not increase the use of blended cements. Even though section 108 of the Energy

Policy Act of 2005 requires federally funded projects to increase the recovered mineral fraction in cement (e.g., fly ash or blast furnace slag), AEO2012 does not include this requirement because the proportion of mineral component is not specified in the legislation or subsequent regulations.[143]

2. Lackluster Scenario for Cement Kilns

In the ANPR, EPA concluded that the range of effectiveness of individual efficiency measures for existing cement plants was less than 1 percent to 10 percent.[144] EPA also notes that benchmarking and other studies have demonstrated that the most efficient new plants can use 40 percent less energy than older plants using wet kilns. However, AEO2012 assumes that no new wet kilns are built and that all new cement plants are dry kilns,[145] making this comparison less relevant for purposes of this analysis. Therefore, for the lackluster scenario, we assume that EPA establishes performance standards for GHGs for new and existing boilers at cement plants that achieve a 10 percent reduction in emissions beyond business-as-usual projections, which is consistent with the manufacturing lackluster scenario above. Facilities could meet these standards through efficiency improvements or fuel switching.

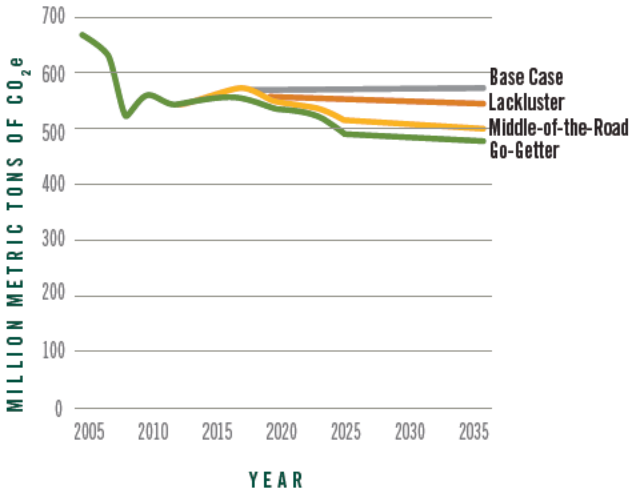
3. Middle-of-the-Road and Go-Getter Scenarios for Cement Kilns

According to AEO2012, boilers are projected to only account for 3 percent of total energy consumption at cement plants in 2012. Therefore, in the middle-of-the-road and go-getter scenarios, we assume that EPA requires facilities to capture emissions reduction opportunities in the entire industrial process that reduce emissions from onsite combustion and purchased electricity. This could be accomplished through output-based emission rate standards or through a more flexible compliance mechanism. In the go-getter scenario, we also assume that EPA establishes emissions standards for all combustion sources in new cement kilns (not just boilers) through New Source Performance Standards, and that those standards require an emissions rate equal to the emissions rate of natural gas combustion. This could be accomplished through co-firing of biomass, fuel switching, carbon capture and sequestration, or built into the reduction schedule of a flexible compliance program. We modeled the middle-of-the-road and go-getter scenarios for cement kilns using the same methodology that we employed for the manufacturing sector middle-of-the-road and go-getter scenarios. The only difference between the cement scenarios and the other manufacturing scenarios is that we also consider reductions in process emissions from the cement sector in our middle-of-the-road and go-getter scenarios. We assume that this is primarily accomplished through greater use of blended cements. Alternatively, cement kilns could comply through the employment of carbon capture and storage. Applying CEF reduction percentages based on more widespread use of blended cements leads to reductions in CO_2 process emissions of 2 percent in 2020 and 13 percent in 2035. CO_2 emissions reductions are detailed in Figure A-1.22 in the middle-of-the-road and go-getter scenarios

4. Uncertainties for Cement Kilns

The uncertainties detailed in the manufacturing sector also apply to the cement sector. We note, however, that there is also considerable uncertainty about the long-term production forecast for cement. Increased production beyond that modeled in AEO2012 could increase emissions, but may also signal improved economics for domestic industry that would allow for greater investments in efficiency technologies and deeper cuts in GHG emissions.

FIGURE A-1.17 Carbon Dioxide Emissions from Industrial Fossil Fuel Combustion and Processes



C. PETROLEUM REFINERIES

1. Base Case for Petroleum Refineries

Base case emissions start with the AEO2012 reference case, which predicts that CO_2 emissions from combustion at refineries will increase from 268 mmtCO_2 in 2012 to 323 mmtCO_2 in 2035. However, the AEO2012 reference case does not include the EPA and NHTSA extension of the national GHG emissions and CAFE standards for model year 2017 through 2025 light-duty vehicles, finalized in August 2012.[146] These standards are included in the base case, and thus we adjusted the base case projections for refineries to account for this reduced demand for refinery products. To calculate the refinery emissions reductions from decreased refinery product demand, we used the simplifying assumption of treating all refinery outputs as though their production required the same relative energy input. This resulted in comparable emissions per unit of production. We also assumed that imports and domestic production would decline at a similar rate, and thus a 10 percent reduction in demand would result in a 10 percent reduction in emissions at refineries located in the United States.

Using the above approach, we estimate that the existing standards will reduce refinery output by 5.2 percent by 2025 and 10.7 percent by 2035 in the base case. These projections are comparable to the AEO side case that considered the proposed vehicle standards.

Our base case assumptions for the projected relative contribution of each refinery product for years 2009–2035 comes from AEO2012.[147] The relative reduction in each refinery product was based on transportation scenario outputs and the relative contribution from each transportation sector in 2010, as reported in EPA's 2012 *Inventory of Greenhouse Gas Emissions and Sinks*.[148]

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Petroleum Refineries

In December 2010, U.S. EPA announced they would establish GHG performance standards for new and existing refineries using their authority under section 111 of the Clean Air Act. As part of this announcement they established a timeline to propose standards by December 2011 and finalize those standards by November 2012.[149] EPA has not met these deadlines, and has not yet issued proposed standards.

Therefore, in all scenarios, we assume that emissions from refineries are reduced by the establishment of performance standards for new and existing units. In the Advanced Notice of Proposed Rulemaking, EPA concludes that benchmarking data suggests that most existing refineries could economically improve energy efficiency by 10–20 percent, and that new refineries could be designed to be at least 20 percent more efficient than existing refineries.[150] One recent study, Energy Bandwidth for Petroleum Refining Processes, published in 2006 by industry experts for the DOE Industrial Technologies Program (ITP), reviewed five major industrial processes that account for roughly 70 percent of energy use in the refining sector. This study concluded that total energy savings of more than 35 percent are achievable using existing "best practices and state-of-the-art technologies under real-world conditions" for these five major processes, and that "plant-wide refinery energy savings potential is usually found to be around 30 percent."[151]

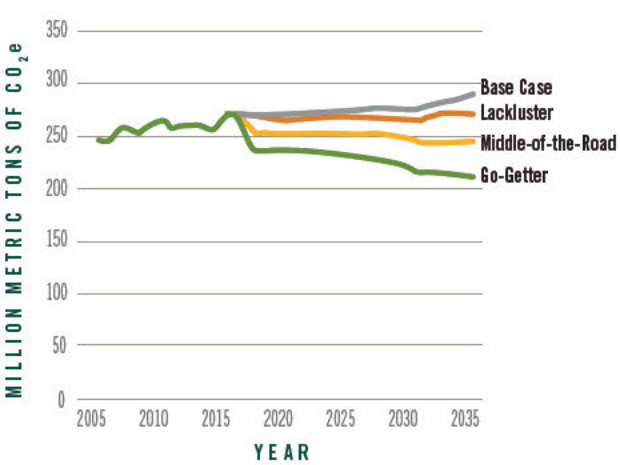
Also, according to a study by the National Academy of Sciences, *Real Prospects for Energy Efficiency in the United States*, identifying plant-wide energy savings of approximately 30 percent would be typical. However, the study also concludes that these gains will be offset by the use of increasingly heavier crude slates in the coming years, resulting in an overall increase in energy consumption per unit of refined product. To some extent these trends are being mitigated by recent production increases of light sweet crude oil from domestic shale plays.[152] The specific efficiency improvements built into the refinery module of AEO2012 are confidential, making it impossible to examine the specific efficiency improvements built into its projections. According to the AEO2012 table *Refining Industry Energy Consumption*, the total energy consumption per unit of refinery input remains relatively constant from 2010 through 2030. If crude slates become increasingly heavy, it may be challenging to get additional emissions reductions beyond those already included in AEO2012.

Given the lack of access to the data underlying AEO2012 projections and the limited inferences that can be drawn from available data, we take a conservative approach to modeling the refinery sector. All three of the reduction scenarios are derived from the lower range of estimates provided for existing

units (i.e., 10 percent) by EPA in the ANPR. For the go-getter scenario, we assumed EPA would require existing units to reduce emissions 10 percent below future projected levels beginning in 2018 through GHG performance standards. For the middle-of-the-road scenario, we assumed that EPA would require existing units to reduce emissions 5 percent below future projected levels, and for the lackluster scenario, we assumed that EPA would require existing units to reduce emissions 1 percent below future projected levels. While we assume that EPA would establish standards for new and existing units, we only modeled reductions for existing sources. This is because AEO2012 does not predict significant deployment of new refineries after 2012,[153] and new development could be offset by reductions in demand caused by the transportation scenarios.

In addition, we examine GHG emissions reductions that result from decreased refinery operation. This is caused by further reductions in petroleum demand due to additional emissions standards for vehicles and industry, energy efficiency standards for home appliances, GHG performance standards for industry, and operational changes for aircraft. The model predicts a 4.8, 9.8, and 17.1 percent decrease in petroleum demand by 2035 compared to base case demand projections under the federal action-only scenarios (and even more when layering in state action). These demand reductions are thus major drivers of emissions reductions across the scenarios.

FIGURE A-1.23 Carbon Dioxide Emissions from Refineries



3. Uncertainties for Refineries Scenarios

The impact of changes in crude slates is uncertain. It is also not entirely clear what efficiency improvements have been built into the AEO2012 base case for refineries. Little unit turnover is projected and this could change, making the emissions reductions projections too low. Under the scenarios we considered, which were intentionally conservative, the primary source of emissions reductions in 2035 was reductions in demand, and not NSPS for refineries. Thus, actual refinery emissions will vary mostly based on actual fuel economy standards, fuel content standards, and changes in vehicle miles traveled.

VII. Appliance and Equipment Efficiency Standards (Heating)

A. MODELING APPROACH FOR APPLIANCE AND EQUIPMENT STANDARDS (HEATING)

Here we focus on opportunities to reduce GHG emissions by increasing the efficiency of appliances that use fossil fuel for purposes such as home heating, cooking, and water heating. We note that there are even greater opportunities to reduce direct combustion of fossil fuels in residential and commercial buildings through improved performance of the building envelope. However, building code policies directly affecting new and existing buildings have historically been controlled by U.S. states and municipalities. These policies are explored in the state scenarios.

Natural gas consumption accounts for the vast majority of onsite fuel consumption for residential and commercial buildings. According to AEO2012, natural gas is expected to account for about 78 to 80 percent of total onsite fuel consumption for residential and commercial buildings from 2012 through 2035. The next largest contributor is distillate fuel, which is only expected to account for about 6 to 9 percent of onsite fuel consumption. Due to this significant disparity, the energy savings primarily affect natural gas consumption.

B. LACKLUSTER, MIDDLE-OF-THE-ROAD, AND GO-GETTER SCENARIOS FOR APPLIANCE AND EQUIPMENT STANDARDS (HEATING)

We base our assumptions about the reductions achievable through increased federal standards for residential and commercial appliances that combust fossil fuels on the *Efficiency Boom* study, discussed in Section III.B. The Efficiency Boom analysis examines efficiency opportunities for the following residential appliances: boilers, clothes washers, dishwashers, and faucets, as well as commercial clothes washers, warm-air furnaces, pre-rinse spray valves, and unit heaters. The study concludes that standards for those sources could reduce gas demand by 126 TBtu in 2025 and 235 TBtu in 2035. For purposes of this analysis, we assumed that standards commence in 2015, and result in a constant increase in savings between 2015 and 2025, and from 2025 through 2035. The net result of the standards is a reduction in CO_2 emissions of 6.7 mmtCO_2 in 2025 and 12.5 mmtCO_2 in 2035.

Opportunities for improving efficiency are also detailed in the AEO2011 expanded standards side case, which found 110 TBtu of savings in 2025 and 230 TBtu of savings in 2035. We rely exclusively on *Efficiency Boom,* however, as it lists specific product standards upon which future actions can be easily compared. No such list is provided for the EIA side case.

Endnotes

1. *Draft Global Non-CO2 Emissions Projections Report: 1990–2030.* Office of Atmospheric Programs, Climate Change Division, U.S. Environmental Protection Agency, EPA 430-D-11-003, August 2011. Accessible at: <http://www.epa.gov/climatechange/EPAactivities/economics/nonco2projections.html>.

2. To download data annex, see: <http://www.epa.gov/climatechange/economics/economicanalyses.html>.

3. *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas.* James Bradbury, Michael Obeiter, Laura Draucker, Wen Wang, and Amanda Stevens. World Resources Institute, Working Paper, forthcoming.

4. *Draft Global Non-CO2 Emissions Projections Report: 1990–2030.* Office of Atmospheric Programs, Climate Change Division, U.S. Environmental Protection Agency, EPA 430-D-11-003, August 2011. Accessible at: <http://www.epa.gov/climatechange/EPAactivities/economics/nonco2projections.html>.

5. To download data annex, see: <http://www.epa.gov/climatechange/economics/economicanalyses.html>.

6. *RTI Applied Dynamic Analysis of the Global Economy (ADAGE) Model.* RTI International-Scientific Research Development Institute. Accessible at: <http://rti.org/page.cfm?objectid=DDC06637-7973-4B0F-AC46B3C69E09ADA9>.

7. *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas.* James Bradbury, Michael Obeiter, Laura Draucker, Wen Wang, and Amanda Stevens.World Resources Institute, Working Paper, forthcoming.

8. For more information, see: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

9. *Life Cycle Carbon Footprint of Shale Gas: Review of Evidence and Implications.* Christopher Weber and Christopher Clavin. Environ Sci Technol,2012,doi:10.1021/es300375n.Available at: <http://pubs.acs.org/doi/abs/10.1021/es300375n> (with supplemental document).

10. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010.* U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

11. *Annual Energy Review,* Table 5.1b Petroleum Overview, Selected Years, 1949–2011. U.S. Energy Information Administration. Accessible at: <www.eia.gov/totalenergy/data/annual/pdf/sec5_7.pdf>.

12. *Annual Energy Outlook 2012.* U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/>.

13. *Benefits of Addressing HFCs under the Montreal Protocol.* Office of Atmospheric Programs, U.S. Environmental Protection Agency, June 2012. Accessible at: <http://www.epa.gov/ozone/downloads/Benefits%20of%20Addressing%20HFCs%20Under%20the%20Montreal%20Protocol,%20June%202012.pdf>.

14. *VISION 2012 AEO Base Case.* Argonne National Laboratory. Accessible at: <http://www.transportation.anl.gov/modeling_simulation/VISION/>.

15. *Annual Energy Outlook 2012.* U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/>.

16. This emissions level is lower compared to past AEO projections. The previous year's projections, AEO2011, estimated that 2035 emissions from the power sector would be over 8 percent higher (2.5 billion metric tons) than current projections. This is part of a larger trend of declining projections in the AEO going back to 2005. The change in outlook is due to a variety of factors, such as an assumed slow growth in electricity demand, growing use of renewable technologies and fuels, improved efficiency, and increased use of natural gas.

17. Note that AEO2012 includes the impact of AB32 on power sector emissions only.

18. In its initial announcement, EPA committed to issuing these proposed regulations by July 26, 2011 and finalizing the standards and guidelines by May 26, 2012. EPA has not kept to this timeline. For more information, see: <http://www.epa.gov/carbonpollutionstandards/settlement.html>.

19. In setting NSPS, EPA prescribes emissions limitations based on the "best demonstrated technology" (BDT) for new and modified existing source categories it designates. EPA must consider technological feasibility, cost, lead time, and energy and non-air environmental impacts.

20. EPA is conducting a review of the role biomass may play in meeting regulatory requirements for GHGs. No final determinations have emerged from that review. For more information, see: <http://www.epa.gov/NSR/ghgdocs/McCarthytoMartella.pdf>.

21. *The Power to Reduce CO2 Emissions, The Full Portfolio.* 2009 Technical Report, Electric Power Research Institute, Research Update, Oct. 2009.

22. *New "Flexible" Power Plant from GE Breaks Efficiency Record; Nearly $1.2 Billion in Orders.* GE, September 25, 2012. Accessed December 10, 2012. Accessible at: <http://www.gereports.com/new-flexible-power-plant-from-ge-breaks-efficiency-record/>.

23. *Regulating Greenhouse Gas Emissions Under the Clean Air Act.* 73 Register §147 (2008). Accessible at: <http://www.epa.gov/climatechange/emissions/downloads/ANPRPreamble5.pdf>.

24. I*mproving the Efficiency of Coal-Fired Power Plants for Near Term Greenhouse Gas Emissions Reductions.* Phil DiPetro and Katrina Krulla. National Energy Technology Laboratory, Office of Systems, Analyses and Planning, DOE/NETL-2010/1411, April 16, 2010. Accessible at: <http://www.netl.doe.gov/energy-analyses/pubs/ImpCFPPGHGRdctns_0410.pdf; http://www.netl.doe.gov/energy-analyses/pubs/NETL%20Power%20Plant%20Efficiency%20Workshop%20Report%20Final.pdf>. Analyses Show Benefits of Improving Unit Heat Rate as Part of a Carbon Mitigation Strategy. Lehigh Energy Update, Vol. 28, No. 1, February 2010. Accessible at: <http://www.lehigh.edu/~inenr/leu/leu_65.pdf>. Opportunities to Improve the Efficiency of Existing Coal-fired Power Plants. J. Eisenhauer and R. Scheer. National Energy Technology Laboratory, July 15, 2009. *Regulating Greenhouse Gases from Coal Power Plants under the Clean Air Act.* Joshua Linn, Erin Mastrangelo, and Dallas Burtraw. Resources for the Future, January 2012 (revised February 2012). Accessible at: <http://www.rff.org/documents/RFF-DP-11-43-REV.pdf>.

25. For comparative purposes, we note that the National Energy Technology Laboratory (NETL) has set a vision of improving the generation-weighted average efficiency from 32.5 percent to 36 percent based on improvements to existing units, retirement of lower efficiency units, and increased generation from higher efficiency units. This would improve the average heat rate of existing coal units by 10 percent. Researchers at Lehigh University also found that a 10 percent improvement in the heat rate at existing coal-fired units can be achieved through several technological upgrades. Resources for the Future found that after controlling for a variety of technical features across the boiler fleet—such as design, size, and pollution control equipment—a 5 percent reduction in the fleet-wide emissions rate may be technically feasible.

26. Personal communication with Laura Martin, Energy Information Administration, June 27, 2012.

27. *Retail Electricity Price Savings from Compliance Flexibility in GHG Standards for Stationary Sources.* Dallas Burtraw, Matt Woerman, and Anthony Paul. Energy Policy 42: 67–77. RFF Discussion Paper, 11-30, 2012.

28. *Regulating Greenhouse Gases from Coal Power Plants under the Clean Air Act.* Joshua Linn, Dallas Burtraw, and Erin Mastrangelo. RFF Discussion Paper 11-43,2012.

29. *The Consequences of Subcategorization in a GHG Tradable Performance Standard Policy.* Dallas Burtraw and Matt Woerman. Presentation at the annual meeting of the Association of Environmental and Resource Economists, Asheville TN, June 4, 2012.

30. *Closing the Power Plant Carbon Pollution Loophole: Smart Ways the Clean Air Act Can Clean Up America's Biggest Climate Polluters.* Daniel Lashof, Starla Yeh, David Doniger, Sheryl Carter, and Laurie Johnson. Natural Resources Defense Council, December 2012. Accessible at: <http://www.nrdc.org/air/pollution-standards/files/pollution-standards-report.pdf>.

31. AEO2012 predicts that natural gas combined cycle units will remain at 40 to 48 percent capacity through 2035.

32. Note that the Clean Air Act does not permit trading or averaging when complying with performance standards for new sources.

33. *Annual Energy Outlook 2012*. U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/>.

34. *The Efficiency Boom: Cashing In on the Savings from Appliance Standards*. Amanda Lowenberger, Joanna Mauer, Andrew deLaski, Marianne DiMascio, Jennifer Amann, and Steven Nadel. American Council for an Energy-Efficient Economy, Appliance Standards Awareness Project, ASAP-8/ACEEE-A123, March 2012. Accessible at: <http://www.aceee.org/sites/default/files/publications/researchreports/a123.pdf>.

35. 42 U.S.C. Sections 6291 to 6309.

36. See, e.g., 42 U.S.C. Section 6292(b).

37. *The Efficiency Boom: Cashing In on the Savings from Appliance Standards*. Amanda Lowenberger, Joanna Mauer, Andrew deLaski, Marianne DiMascio, Jennifer Amann, and Steven Nadel. American Council for an Energy-Efficient Economy, Appliance Standards Awareness Project, ASAP-8/ACEEE-A123, March 2012. Accessible at: <http://www.aceee.org/sites/default/files/publications/researchreports/a123.pdf>.

38. IEE is an affiliate of the Edison Electric Institute.

39. *Assessment of Electricity Savings in the U.S. Achievable through New Appliance/Equipment Efficiency Standards and Building Efficiency Codes (2010–2025)*. Institute for Electric Efficiency, May 2011. Accessible at: <http://www.edisonfoundation.net/iee/Documents/IEE_CodesandStandardsAssessment_2010-2025_UPDATE.pdf>.

40. Even though the study utilized AEO2011, we believe the study's findings can be applied to our base case, which relies on AEO2012, as conversations with EIA staff indicated that there were no substantive differences in equipment standards between the AEO2011 and AEO2012 reference case.

41. *2010 ISO New England Electric Generator Air Emissions Report*. System Planning Department, ISO New England, Inc., March 2012. Accessible at: <http://www.iso-ne.com/genrtion_resrcs/reports/emission/final_2010_emissions_report_v2.pdf>.

42. *2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards*. U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, 2011. Accessible at: <http://www.gpo.gov/fdsys/pkg/FR-2011-12-01/pdf/2011-30358.pdf>.

43. This follows a rulemaking in May 2010 that required model year 2016 vehicles to meet an emissions standard of 250 grams of carbon dioxide-equivalent emissions per mile, which is equivalent to a fuel economy standard of 35.5 mpg if the automobile industry were to meet those standards solely through fuel economy improvements. The accompanying NHTSA standard was set at 34.1 mpg. At the time, NHTSA considered only drive train improvements and did not consider air conditioning leakage or efficiency improvements for purposes of establishing CAFE standards.

44. *VISION 2012 AEO Base Case*. Argonne National Laboratory. Accessible at: <http://www.transportation.anl.gov/modeling_simulation/VISION/>.

45. While the VISION model relies on EIA's *Annual Energy Outlook* (AEO) projections as much as possible, there are some differences and so VISION's base case does not match EIA's AEO reference case results.

46. *2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards*. U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, 2011. Accessible at: <http://www.gpo.gov/fdsys/pkg/FR-2011-12-01/pdf/2011-30358.pdf>.

47. Interim Joint Technical Assessment Report: Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2017–2025. Office of Transportation and Air Quality, U.S. Environmental Protection Agency, Office of International Policy, Fuel Economy, and Consumer Programs; National Highway Traffic Safety Administration, U.S. Department of Transportation; California Air Resources Board, September 2010. Accessible at: <http://www.epa.gov/otaq/climate/regulations/ldv-ghg-tar.pdf>.

48. CAFE standards do not include benefits from HFC emissions reductions. EPA projected that these benefits would result in credits amounting to 14.3 grams CO_2 per mile in 2025. We deduct these credits when converting from the EPA CO_2 standards to the equivalent CAFE standard.

49. This level of EV penetration will likely require significant infrastructure development and advances in battery technology, both of which would benefit from additional policy interventions.

50. *Analysis of the Transportation Sector: Greenhouse Gas and Oil Reduction Scenarios*. U.S. Environmental Protection Agency, March 2010. Accessible at: <http://www.epa.gov/oms/climate/GHGtransportation-analysis03-18-2010.pdf>.

51. *Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles*. U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, 2011. Accessible at: <http://www.gpo.gov/fdsys/pkg/FR-2011-09-15/pdf/2011-20740.pdf>.

52. *Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles*. U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, 2011. Accessible at: <http://www.gpo.gov/fdsys/pkg/FR-2011-09-15/pdf/2011-20740.pdf>.

53. *Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles*. U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, 2011. Accessible at: <http://www.gpo.gov/fdsys/pkg/FR-2011-09-15/pdf/2011-20740.pdf>.

54. Class 2b vehicles designed as passenger vehicles (medium-duty passenger vehicles, MDPVs) are covered by the light-duty GHG and fuel economy standards and not addressed in this rule.

55. Both EPA and NHTSA also provide manufacturers with optional alternative implementation schedules, but for purposes of our analysis we assume that all manufacturers comply with EPA's standards under the primary implementation schedule.

56. The Energy Independence and Security Act of 2007 (EISA) requires at least three years of "regulatory stability" whereby fuel efficiency standards for medium- and heavy-duty vehicles remain fixed.

57. The rate of improvement in the standards for our lackluster and middle-of-the-road scenarios was calculated as the annual improvement rate between model year 2013 vehicles and the model year 2018 vehicle standard across the medium- and heavy-duty fleet for each of our scenarios.

58. Average fleet-wide fuel economy was weighted using the projected sales for each vehicle category in VISION.

59. *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles*. Committee to Assess Fuel Economy Technologies for Medium- and Heavy-Duty Vehicles, Board on Energy and Environmental Systems Division on Engineering and Physical Sciences, Transportation Research Board, Washington, DC, National Academies, 2010.

60. The major technologies that the National Academies study found necessary to achieve the highest level of reductions are hybridization, advanced diesel engines, and aerodynamics. Other technologies that could help reduce fuel consumption include low-rolling-resistance tires, improved transmissions, idle-reduction technologies, and weight reduction. While the study included energy reductions resulting from driver management and coaching for combination trucks, we did not include these savings in our analysis because EPA has not mandated such operational improvements to date in these standards.

61. In President Obama's May 2010 memorandum, he directed EPA and NHTSA to begin working on a joint rulemaking to establish fuel efficiency and greenhouse gas emissions standards for medium- and heavy-duty vehicles beginning with model year 2014. The memorandum noted that preliminary estimates indicate that large tractor trailers can reduce greenhouse gas emissions by as much as 20 percent and increase their fuel efficiency as much as 25 percent.

62. *Presidential Memorandum Regarding Fuel Efficiency Standards*. May 21, 2010. Accessible at: <http://www.whitehouse.gov/the-press-office/presidential-memorandum-regarding-fuel-efficiency-standards>.

63. *VISION 2012, New Auto Fuel Economy Ratio to Base ICE* (using gasoline equivalent gallons). Argonne National Laboratory. Accessible at: <http://www.transportation.anl.gov/modeling_simulation/VISION/>.

64. *Final Rulemaking to Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles: Regulatory Impact Analysis.* Table 6-11: Estimated Fleet-Wide Fuel Efficiency by Model Year for Alternative 3 [gallons/100 miles]. U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, August 2011. Accessible at: <http://www.epa.gov/oms/climate/documents/420r11901.pdf>.

65. *EPA Analysis of the Transportation Sector.* U.S. Environmental Protection Agency, March 2010.

66. *EPA Analysis of the Transportation Sector.* U.S. Environmental Protection Agency, March 2010.

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68. *EPA Analysis of the Transportation Sector.* U.S. Environmental Protection Agency, March 2010.

69. *Doc 9963 Report of the Independent Experts on the Medium and Long Term Goals for Aviation Fuel Burn Reduction from Technology.* ENGLISH ISBN 978-92-9231-765-2 Order No. 9963,2010.

70. *Factsheet: Technology Roadmap for Environmental Improvement.* International Air Transport Association, June 2012. Accessible at: <http://www.iata.org/pressroom/facts_figures/fact_sheets/Pages/technology.aspx>.

71. *U.S. Aviation Greenhouse Gas Emissions Reduction Plan.* Federal Aviation Administration, June 2012. Accessible at: <http://www.faa.gov/about/office_org/headquarters_offices/apl/environ_policy_guidance/policy/media/Aviation_Greenhouse_Gas_Emissions_Reduction_Plan.pdf>.

72. *Next Gen Implementation Plan.* Federal Aviation Administration, 2012. Accessible at: <http://www.faa.gov/nextgen/implementation/media/NextGen_Implementation_Plan_2012.pdf>.

73. *Reducing emissions from the aviation sector.* European Commission. For more information, see: <http://ec.europa.eu/clima/policies/transport/aviation/index_en.htm>.

74. It is expected that EPA's most recent rulemakings for light-, medium-, and heavy-duty vehicles will result in emissions savings from reduced HFC leakage. For light-duty vehicles, EPA is offering a credit for manufacturers that choose to reduce HFC leakage from air conditioning equipment, and projects that these benefits would result in credits amounting to 14.3 grams CO_2 per mile in 2025. EPA set a separate standard that requires a reduction in the amount of HFC leakage from AC systems in heavy-duty pickup trucks and vans as well as class 7 and 8 tractors, based on the refrigerant capacity of the installed AC system. Since these regulations have been finalized, we account for these savings in our adjusted base case emission projections for HFCs.

75. *Draft Global Non-CO2 Emissions Projections Report: 1990-2030.* Office of Atmospheric Programs, Climate Change Division, U.S. Environmental Protection Agency, EPA 430-D-11-003, August 2011. Accessible at: <http://www.epa.gov/climatechange/EPAactivities/economics/nonco2projections.html>.

76. *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas.* James Bradbury, Michael Obeiter, Laura Draucker, Wen Wang, and Amanda Stevens. World Resources Institute, Working Paper, forthcoming.

77. *Life Cycle Carbon Footprint of Shale Gas: Review of Evidence and Implications.* Christopher Weber and Christopher Clavin. Environ Sci Technol,2012,doi:10.1021/es300375n.Available at: <http://pubs.acs.org/doi/abs/10.1021/es300375n> (with supplemental document).

78. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010.* U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

79. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010.* U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

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81. *Annual Energy Outlook 2012.* U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/>.

82. *Benefits of Addressing HFCs under the Montreal Protocol.* Office of Atmospheric Programs, U.S. Environmental Protection Agency, June 2012. Accessible at: <http://www.epa.gov/ozone/downloads/Benefits%20of%20Addressing%20HFCs%20Under%20the%20Montreal%20Protocol,%20June%202012.pdf>.

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87. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010.* U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

88. *Life Cycle Carbon Footprint of Shale Gas: Review of Evidence and Implications.* Weber, Christopher and Christopher Clavin,Environ Sci Technol,2012,doi:10.1021/es300375n. Available at: http://pubs.acs.org/doi/abs/10.1021/es300375n (with supplemental document).

89. For more information, see: http://www.epa.gov/airquality/oilandgas/actions.html.

90. For more information, see: http://www.epa.gov/airquality/oilandgas/pdfs/20120417finalrule.pdf.

91. *How The EPA's New Oil and Gas Standards Will Reduce Greenhouse Gas Emissions.* Michael Obeiter, World Resources Institute Insights Blog, May 9, 2012. Accessible at: http://insights.wri.org/news/2012/05/how-epas-new-oil-and-gas-standards-will-reduce-greenhouse-gas-emissions.

92. Specifically, the regulations require that high-bleed pneumatic controllers, employed during the processing stage of the natural gas lifecycle to maintain gas pressure, need to meet a new leakage rate of six cubic feet of gas per hour. This results in small reductions in methane emissions, according to emissions data from the EPA GHG inventory. More significant reductions will come from compressors used in gas production and processing, as they are a much larger sources of emissions and they will need to reduce VOC emissions by 95 percent. The new rule should reduce methane emissions from compressors by a similar amount, and can be achieved by converting wet seal compressors to dry seals. Additionally, a new performance standard for storage tanks at well sites will primarily address VOC emissions, with limited GHG co-benefits, as storage tanks are not a major source of GHG emissions, according to the GHG inventory.

93. While leak monitoring and repair can apply to the entire transmission life-cycle stage, it is less cost-effective outside of compressor stations since there are hundreds of thousands of miles of pipeline.

94. The payback period for these technologies assumes natural gas prices from the AEO2012 reference case, which range from $4.59/Mcf in 2019 to $7.58/Mcf in 2035.

95. *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas.* James Bradbury, Michael Obeiter, Laura Draucker, Wen Wang, and Amanda Stevens. World Resources Institute, Working Paper, forthcoming.

96. *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas.* James Bradbury, Michael Obeiter, Laura Draucker, Wen Wang, and Amanda Stevens. World Resources Institute, Working Paper, forthcoming.

97. *Leaking Profits: The U.S. Oil and Gas Industry Can Reduce Pollution, Conserve Resources, and Make Money by Preventing Methane Waste.* Natural Resource Defense Council, March 2012. Accessible at: <http://www.nrdc.org/energy/files/Leaking-Profits-Report.pdf>.

98. These conclusions are based on unpublished analysis conducted for this report by the authors of *Clearing the Air on Shale Gas Emissions.*

99. *Annual Energy Review.* Figure 6.0: Natural Gas Flow 2011. U.S. Energy Information Administration, September 2012. Accessible at: <http://www.eia.gov/totalenergy/data/annual/pdf/sec6_3.pdf>.

100. The relative difference largely depends on the actual impact of plunger lifts.

101. Specifically, we predict that demand for natural gas will decrease by 7 percent and 10 percent in 2035 in our lackluster and middle-of-the-road scenarios, respectively. Meanwhile, we predict that demand for natural gas will increase by 12 percent in our go-getter scenario. Across all of the scenarios, power plant standards and residential and commercial appliance and equipment standards were the primary drivers of changes in natural gas demand.

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104. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010.* U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

105. *Draft Global Non-CO2 Emissions Projections Report: 1990–2030.* Office of Atmospheric Programs, Climate Change Division, U.S. Environmental Protection Agency, EPA 430-D-11-003, August 2011. Accessible at: <http://www.epa.gov/climatechange/EPAactivities/economics/nonco2projections.html>.

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107. *Benefits of Addressing HFCs under the Montreal Protocol.* Office of Atmospheric Programs, U.S. Environmental Protection Agency, June 2012. Accessible at: <http://www.epa.gov/ozone/downloads/Benefits%20of%20Addressing%20HFCs%20Under%20the%20Montreal%20Protocol,%20June%202012.pdf>.

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109. *Final Rulemaking to Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles: Regulatory Impact Analysis.* Table 6-11: Estimated Fleet-Wide Fuel Efficiency by Model Year for Alternative 3 [gallons/100 miles]. U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, U.S. Department of Transportation, August 2011. Accessible at: <http://www.epa.gov/oms/climate/documents/420r11901.pdf>.

110. 40 CFR Part 82, Subpart A

111. *Benefits of Addressing HFCs under the Montreal Protocol.* Office of Atmospheric Programs, U.S. Environmental Protection Agency, June 2012. Accessible at: <http://www.epa.gov/ozone/downloads/Benefits%20of%20Addressing%20HFCs%20Under%20the%20Montreal%20Protocol,%20June%202012.pdf>.

112. *Benefits of Addressing HFCs under the Montreal Protocol.* Office of Atmospheric Programs, U.S. Environmental Protection Agency, June 2012. Accessible at: <http://www.epa.gov/ozone/downloads/Benefits%20of%20Addressing%20HFCs%20Under%20the%20Montreal%20Protocol,%20June%202012.pdf>.

113. These calculations assume that emissions from the five main end uses for HFCs were equivalent to the midpoint of their emissions range, as described in EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010.* For each of the five main end uses, reported annual emissions rates are as follows: refrigeration and air conditioning (1–28 percent), aerosols (100 percent), foams (100 percent), solvents (90 percent), and fire protection (5–8 percent). Note that if average emissions are more consistent with the lower range of the reported emissions rates for the five major end uses, then total U.S. GHG emissions in 2020 will be 15 percent below 2005 levels. If average emissions are consistent with the upper-bound emissions rate, then total U.S. GHG emissions in 2020 will be 19 percent below 2005 levels.

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119. *Global Mitigation of Non-CO2 Greenhouse Gases.* Micke Gallaher, Deborah Ottinger, Dave Godwin, and Benjamin DeAngelo, Robert Beach, Jochen Harnisch, Sina Wartmann, William Salas, Changsheng Li, Stephen Del Grosso, and Timothy Sulser. U.S. Environmental Protection Agency, EPA Technical Report, June 2005. Accessible at: <http://www.ars.usda.gov/research/publications/publications.htm?seq_no_115=197768>.

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122. *Assumptions to the AEO2012.* U.S. Energy Information Administration, June 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/assumptions/pdf/0554(2012).pdf>.

123. AEO2012 is built using the National Energy Modeling System (NEMS). NEMS assumes that gas and oil burners meet the standards set by the Energy Policy Act of 1992, which requires gas burners to have heat rates of 1.25 (80 percent efficiency) and oil burners have heat rates of 1.22 (82 percent efficiency). AEO2012 assumes that cogeneration units experience a steady increase in their efficiency through 2035.

124. *Regulating Greenhouse Gases from Coal Power Plants under the Clean Air Act.* Joshua Linn, Erin Mastrangelo, and Dallas Burtraw. Resources for the Future, January 2012 (revised February 2012). Accessible at: <http://www.rff.org/documents/RFF-DP-11-43-REV.pdf>.

125. For the iron and steel sector we assumed that boiler efficiency gains only reduce combustion of main fuel sources (natural gas, residual oil, steam coal, etc.), and not intermediary fuels that are the byproduct of direct combustion in coke ovens and blast furnaces.

126. Refineries were modeled separately. Therefore, for purposes of this analysis, we consider the following categories to be included in the manufacturing sector: food and kindred projects, paper and allied products, bulk chemicals, glass and glass products, cement, iron and steel, aluminum, fabricated metal products, machinery, computer and electronic products, transportation equipment, electrical equipment, appliances and components, wood products, and plastic and rubber products. The remaining manufacturing facilities are grouped into a single subcategory, called balance of manufacturing.

127. EPA finalized new standards for emissions of air toxics from industrial boilers (Boiler MACT) in December 2012.Those standards require boiler tune-ups, which according to EPA have been shown to improve efficiency between 1 and 5 percent. Those standards will lower the marginal improvement from the GHG standards we model. However, we note that the upper range of the efficiency improvements identified by EPA fall well short of those modeled in the lackluster scenario, suggesting that GHG emissions standards could drive additional reductions from industrial boilers.

128. *Regulatory Impact Results for the Reconsideration Proposal for National Emission Standards for Hazardous Air Pollutants for Industrial, Commercial, and Institutional Boilers and Process Heaters at Major Sources.* U.S. Environmental Protection Agency, December 1, 2011. Accessible at: <http://www.epa.gov/ttn/atw/boiler/boilersriaproposalrecon111201.pdf>.

129. *Model Documentation Report: Industrial Sector Demand Module of the National Energy Modeling System, DOE/EIA-M064(2011).* U.S. Energy Information Administration, Office of Integrated Analysis and Forecasting, May 2011. Accessible at: <http://www.eia.gov/FTPROOT/modeldoc/m064(2011).pdf>.

130. See the reports of the Climate Change Working Group at: <http://www.epa.gov/air/caaac/climatechangewg.html>.

131. *Scenarios for a Clean Energy Future.* Interlaboratory Working Group and Lawrence Berkeley National Laboratory, Oak Ridge, TN, Berkeley, CA, ORNL/CON-476 and LBNL-44029, November 2000.

132. We converted the study's listed price ($50 per ton of carbon) into a carbon dioxide price and 2011 dollars using the consumer price index. For more information, see Consumer Price Index, All Urban Consumers, at: <ftp://ftp.bls.gov/pub/special.requests/cpi/cpiai.txt>.

133. *Real Prospects for Energy Efficiency in the United States.* Panel on Energy Efficiency Technologies, Washington, D.C., National Academy Press, 2009. *The Untapped Energy Efficiency Opportunity in the U.S. Industrial S*ector: Details of Research, 2008. McKinsey and Company, 2008.

134. Note that the CEF projects sector-specific fuel-use patterns that were developed before the recent boom in shale gas extraction and consumption.

135. *Industrial Glass Bandwidth Analysis.* David Rue, James Servaites, and Warren Wolf. U.S. Department of Energy, December 2006. Accessible at: <http://www1.eere.energy.gov/manufacturing/industries_technologies/glass/pdfs/industrial_bandwidth.pdf>.

136. *Chemical Bandwidth Study Exergy Analysis: A Powerful Tool for Identifying Process Inefficiencies in the U.S. Chemical Industry.* Dickson Ozokwelu, Joseph Porcelli, and Peter Akinjiola. U.S. Department of Energy, December 2006. Accessible at: <http://www1.eere.energy.gov/industry/chemicals/pdfs/chemical_bandwidth_report.pdf>.

137. This comparison is based on the middle-of-the-road scenario, which only includes efficiency improvements. The go-getter scenario includes fuel switching, leading to greater emissions reductions.

138. *Real Prospects for Energy Efficiency in the United States.* Panel on Energy Efficiency Technologies, Washington, D.C., National Academy Press, 2009. *The Untapped Energy Efficiency Opportunity in the U.S.* Industrial Sector: Details of Research, 2008. McKinsey and Company, 2008.

139. *Saving One Barrel of Oil per Ton.* American Iron and Steel Institute, October 2005.

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141. Energy-CO_2 emissions from *Annual Energy Outlook 2012.* U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/>. Process CO_2 emissions from *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010.* U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

142. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010.* U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

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144. For more information, see: <http://www.epa.gov/climatechange/Downloads/anpr/ANPRFactSheet.pdf>.

145. *Model Documentation Report: Industrial Sector Demand Module of the National Energy Modeling System, DOE/EIA-M064(2011).* U.S. Energy Information Administration, Office of Integrated Analysis and Forecasting, May 2011. Accessible at: <http://www.eia.gov/FTPROOT/modeldoc/m064(2011).pdf>.

146. *2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards.* U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, 2011. Accessible at: <http://www.gpo.gov/fdsys/pkg/FR-2011-12-01/pdf/2011-30358.pdf>.

147. *Annual Energy Outlook 2012.* U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/>.

148. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010.* U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

149. For more information, see: <http://www.epa.gov/airquality/cps/pdfs/refineryghgsettlement.pdf>.

150. *Regulating Greenhouse Gases from Coal Power Plants under the Clean Air Act.* Joshua Linn, Erin Mastrangelo, and Dallas Burtraw. Resources for the Future, January 2012 (revised February 2012). Accessible at: <http://www.rff.org/documents/RFF-DP-11-43-REV.pdf>.

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152. Personal communication, U.S. Energy Information Administration, October 29, 2012.

153. *Annual Energy Outlook 2012.* Table 59: Domestic Refinery Distillation Base Capacity and Expansion. U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/>.

Appendix II: State Methods

I. State Action

This analysis seeks to understand the impact state actions can have on U.S. greenhouse gas emissions. It has two components: the first considers the impact of states taking action in the absence of federal action; the second considers the impact of states taking action in the presence of varying levels of federal action. In both components we examine the implication of states implementing the same types of policies modeled for the federal government, as well as more traditional state-level actions in the transportation, energy efficiency, and renewables areas.

This approach is based on the observation that the Constitution grants states broad authority to regulate their energy sources and emissions. Thus, states have the ability to implement many of the same policies as federal agencies. We also note that states are more likely to pursue these options when federal action falls short.

State-level actions generally complement federal authorities in transportation, energy efficiency, and renewable energy. Regarding transportation, the state scenarios consider measures to encourage low-carbon fuels and reduce vehicle miles traveled to complement federal vehicle efficiency measures. In the energy efficiency area, actions modeled include reduced energy consumption through end-use energy efficiency for electricity and natural gas, improved building performance, and increased deployment of combined heat and power. For renewables, the analysis adds new and additional renewable energy deployment across a certain number of states.

Unlike the federal analysis, many of the state actions modeled would require new legislation at the state level. Also unlike the federal scenario, the categorization of state action—whether "lackluster," "middle-of-the-road," or "go-getter"—is partially a function of how many states adopt the actions modeled. Thus a lackluster state trajectory does not necessarily mean that individual states have failed to take ambitious action. Instead, it can represent a scenario where a limited number of states have taken action and the result is that the combination of state actions has affected the national trajectory in a lackluster manner.

In the state scenarios, we do not identify specific states that take action. Rather, we identify percentages of the relevant sector that are subject to a new or expanded action, thus accounting for a variety of possible combinations of states and policies that can result in a similar level of GHG benefits. For example, to model the middle-of-the-road scenario for low-carbon fuels, we assume that states that account for 25 percent of energy consumption from transportation fuels reduce the carbon intensity of fuels by 1 percent per year beginning in 2015. This scenario, however, is not meant to be limited to this specific set of assumptions. Other combinations of numbers of states and levels of stringency could achieve this same "middle-of-the-road" result. For example, the same level of reductions could be achieved if states that accounted for 12.5 percent of energy consumption from transportation fuels reduced the carbon intensity of fuels by 2 percent per year. In this way, we capture a variety of possible combinations of policy ambition and state adoption levels under the same scenario.

II. Transportation

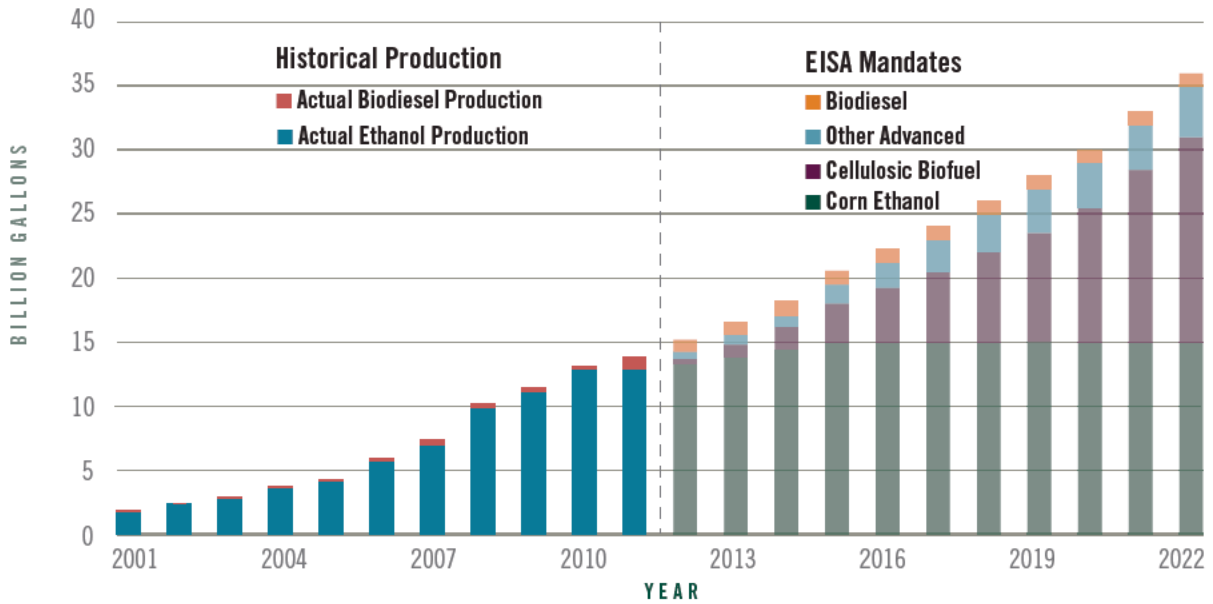
A. DIVERSIFICATION OF FUEL MIX REDUCES THE AVERAGE CARBON CONTENT OF FUELS

1. Base Case for Diversification of Fuel Mix

As described in Appendix I (Sections VII.A and VII.B), we developed our base case assumptions for light-, medium-, and heavy- duty vehicles from Argonne National Laboratory's "VISION 2012 AEO base case," which is calibrated to the *Annual Energy Outlook 2012.* However, we updated the base case to reflect new standards for light-duty vehicles sold through the 2025 model year.

The Energy Independence and Security Act of 2007 (EISA 2007) increases the volume of renewable fuel required to be blended into transportation fuel sold in the U.S. from nine billion gallons in 2008 to thirty-six billion gallons in 2022 (See Figure A-2.1). The law requires that the vast majority of the increase from current production levels come from cellulosic biofuel and other advanced biofuels. EISA 2007 requires EPA to annually estimate projected biofuel capacity for the following year, and if necessary adjust the production

FIGURE A-2.1 Biofuel Production Required by the Energy Independence and Security Act of 2007



Sources: Figure created using data from U.S. EIA's Annual Energy Review 2011 and U.S. EIA's Annual Energy Outlook 2012.

mandates downward. In each of the past three years, EPA determined it was not possible to meet the annual cellulosic biofuel target and adjusted the target downward compared to the level mandated in the initial rule.[1,2,3] Based on this recent history, and their own assessment of financial and technological barriers, the AEO 2012 assumes that the advanced biofuel targets will not be met until 2033.[4]

To qualify for credit under EISA 2007, transportation fuels sold in the U.S. must meet specified life-cycle emissions thresholds, which are lower than the life-cycle GHG emissions of conventional gasoline or diesel.[5] The statute requires EPA to account for the direct and indirect life-cycle emissions implications of qualifying biofuel production, considering all stages of fuel and feedstock production and distribution, including those emissions associated with direct and indirect land-use change. EPA has found that there are always life-cycle emissions associated with the production of biofuels. In contrast, AEO assumes that all biofuels are carbon neutral. When quantifying GHG emissions associated with the combustion of fuels, AEO assumes that biofuel emissions are offset by carbon sequestration that occurs during growth of the feedstock and does not consider emissions from land use and land-use change.[6] We did not adjust AEO's treatment of biofuel emissions in developing our base case.

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Diversification of Fuel Mix

Enhanced fuel mix diversity can reduce the average carbon intensity of fuels, thereby reducing GHG emissions associated with transportation. Fuel-mix diversification can be promoted by programs that promote alternative fuel production and/or consumption, or through the development of fueling station infrastructure.

Seven states have already set minimum requirements on the amount of renewable fuel that must be blended into gasoline, diesel, or both. However, these programs do not specify what types of renewable fuels must be used, thus allowing for the use of a wide range of biofuel feedstock, with uncertain net emissions implications. Louisiana and Pennsylvania have blend mandates for ethanol and diesel that will be triggered once state production reaches specified levels.[8]

To date, twenty-eight states offer biofuel tax incentives for ethanol, biodiesel, or both.[9] Idaho, North Dakota, South Dakota, and Wisconsin are among several states that offer tax incentives for development of biofuel infrastructure.[10] In addition, Louisiana, Minnesota, Nebraska, North Dakota, and Virginia have already begun to offer programs supporting research and development of advanced biofuels.[11] Rhode Island is

TABLE A-2.1 Low-carbon Transportation Fuel Scenarios

ACTION	POLICIES AND PROGRAMS DRIVING ACTION	SCENARIOS		
		Lackluster	Middle-of-the-Road	Go-Getter
Diversity in fuel mix resulting in lower average carbon content of fuels	• Low-carbon fuel standard • Clean fuel standard • Advanced biofuels standard • Infrastructure incentives	States that account for 15 percent of energy consumption from transportation fuels reduce carbon intensity of fuels by 1 percent per year beginning in 2015 through 2035.	States that account for 25 percent of energy consumption from transportation fuels reduce carbon intensity of fuels by 1 percent per year beginning in 2015 through 2035.	States that account for 35 percent of energy consumption from transportation fuels reduce carbon intensity of fuels by 1 percent per year beginning in 2015 through 2035.

actively researching and developing plans to expand advanced biofuel production.

Life-cycle GHG emissions intensity can vary considerably depending on the fuel type, sources, and production methods. In the Renewable Fuel Standard Regulatory Program Analysis completed in February 2010, EPA found that advanced biofuels can reduce life-cycle GHG emissions 40 to 90 percent below conventional gasoline, whereas corn ethanol from typical new facilities can only reduce life-cycle GHG emissions between 0 and 40 percent below conventional gasoline.[12,13]

In order to guarantee a reduction in the carbon intensity of fuels, some states have begun to pursue a clean fuel standard or a low-carbon fuel standard. The first such standard was issued by the California Air Resources Board in 2009. It requires the carbon intensity of fuels sold in California to be reduced 10 percent by 2020.[14] Initiatives under way in the Pacific Northwest and Northeast and Mid-Atlantic are evaluating the implications of implementing similar types of standards.[15]

In our scenarios we assume that states pursue a range of actions such as those described above, and that those policies further reduce the average carbon intensity of transportation fuels by 1 percent per year between 2015 and 2035. This rate is generally consistent with targets being considered in the Northeast, Washington, and Oregon, as well as the targets required under California's Low Carbon Fuel Standard.[16] If a similar target was adopted nationwide, this would reduce the carbon intensity of fuels an additional 6 percent in 2020 and 21 percent in 2035. In the lackluster scenario, we assume this annual reduction is achieved by states accounting for 15 percent of energy consumption from transportation fuels. In the middle-of-the-road and go-getter scenarios, we assume that these policies are pursued by states accounting for 25 percent and 35 percent of fuel consumption, respectively. We assume these state actions affect both gasoline and diesel consumption.

Table A-2.2 is intended to help put these numbers into context. It shows that California alone accounts for 10 percent of U.S. on-road fuel consumption, and that the Northeast and Pacific Northwest account for 17 percent and 3 percent of on-road fuel consumption, respectively. Meanwhile, the top five biofuel producing states (IA, NE, IL, MN, and IN) account for 10 percent of on-road fuel consumption.

TABLE A-2.2 Motor Fuel Consumption, 2010

	PERCENT OF TOTAL U.S. MOTOR FUEL CONSUMPTION
California	10
Northeast (New England, Mid-Atlantic, DE, MD)	17
Pacific Northwest	3
Top 5 Biofuel Producers (IA, NE, IL, MN, IN)	10

Source: State Energy Data System, U.S. EIA, 2012.

The 2007 EISA established a national renewable fuel standard that requires increasing renewable fuel production through 2022, with required production levels in later years to be established by the EPA in a future rulemaking. In the scenarios that we consider, biofuel production does not meet or exceed

those standards through 2022. Under all of the state scenarios, biofuel consumption continues to rise until 2035, and over time even the lackluster scenario could lead to biofuel production levels in excess of the 2022 standards sometime before 2035. Note that the precise date the EISA's 2022 standards are exceeded and the total level of biofuel consumption will depend on assumptions about federal agency actions and the impact of fuel economy standards on biofuel consumption. The EISA 2022 standard represents 22 percent of total fuel consumed by light-, medium-, and heavy-duty vehicles in 2022 under our base case.

3. Modeling Notes for Diversification of Fuel Mix

In our model we assume that all of the GHG reductions from fuel diversification are the result of increased biofuel consumption and are not due to state policies and programs promoting use of PHEVs, EVs, and natural gas vehicles. Deployment of PHEVs, EVs, and natural gas vehicles provide credit for manufacturers to meet their national emissions and CAFE standards. This means that increased deployment of these vehicles in one state can help a manufacturer meet the standards and therefore will not necessarily result in nationwide emission reductions.[17] It is true that the current CAFE standards contain an incentive for biofuel vehicles. However, no such credit is provided under EPA's GHG emissions standards, and thus increased consumption of biofuels is expected to lead to additional reductions in GHG emissions.

Biofuels present a modeling challenge due to the uncertainty about the GHG benefits they provide. EPA's *Renewable Fuel Standard Regulatory Program Analysis* finds that in some cases corn ethanol consumption could be worse than traditional gasoline consumption—for instance, if the ethanol is produced in a dry mill fueled by coal.[18]

It is beyond the scope of our analysis to directly model emissions from the fuel production process. Instead, we avoid modeling these impacts by considering only those state policies that are directly or indirectly responsive to the life-cycle impacts of fuel production (e.g., clean fuel standard, advanced biofuel standard).

We assume that the same states that pursue fuel diversification policies also pursue VMT reduction policies. This results in a conservative estimate of the benefits of these policies, since the relative impact of each policy will be less in the presence of the other policy than it would on its own.

4. Uncertainties for Diversification of Fuel Mix

California's LCFS is currently being challenged in two separate lawsuits brought by ethanol producers, refineries, and truckers.[19] One of the rulings prevented California from enforcing the rule, but this injunction was lifted in April 2012 pending a decision on California's appeal. A three-judge panel of the Ninth Circuit Court of Appeals heard oral arguments in this case in October 2012.

For purposes of this analysis, we assume that state policies drive changes in the fuel mix beyond what is required nationally. If, however, state and federal policies are designed in a way that allows increased state consumption or production to count toward the federal fuel standards, then benefits of those policies would decrease.

B. VMT REDUCTION

1. Base Case for VMT Reduction

In these scenarios we only consider reductions in vehicle miles traveled (VMT) from light-duty vehicles. We use the same baseline for gasoline and diesel consumption for light-duty vehicles as our base case for diversity in fuel mix. The AEO2012 projects VMT to increase from 2,660 billion miles in 2010 to 3,583 billion miles in 2035. This is a slower rate of growth than has been projected in previous AEOs, which can be attributed to rising fuel costs and the effects of the economic recession.[20]

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for VMT Reduction

A variety of growth and land-use strategies can reduce VMT and contribute to GHG emissions savings.[21] These include smart-growth strategies, such as targeting growth near public transportation, favoring infill, limiting sprawl, mixed-use development, and provision of affordable housing options. Growth strategies can be complemented by a variety of other tools to reduce VMT, including improving and expanding public transportation options, bike and pedestrian pathways, and car sharing, as well as through speed limit restrictions, intercity tolls, and strategies to limit driving within urban centers (such as parking restrictions).[22]

States play an important role in encouraging the development of smart-growth and related strategies. They can adopt VMT or GHG reduction targets, direct funding for smart growth, and work with regional

TABLE A-2.3 Vehicle Miles Traveled (VMT) Scenarios

ACTION	POLICIES AND PROGRAMS DRIVING ACTION	SCENARIOS		
		Lackluster	Middle-of-the-Road	Go-Getter
Vehicle miles traveled (VMT) reduction	• Smart growth • Improved public transit • Pedestrian and biking infrastructure • Improved traffic systems operation	States that account for 15 percent of GHG emissions from light-duty vehicles annually reduce VMT 0.5 percent below base case projections beginning in 2016	States that account for 25 percent of GHG emissions from light-duty vehicles annually reduce VMT 0.5 percent below base case projections beginning in 2016	States that account for 35 percent of GHG emissions from light-duty vehicles annually reduce VMT 1 percent below base case projections beginning in 2016

planning organizations to implement strategies that will achieve reduction goals.

Several states are in the process of implementing or developing smart-growth programs and policies. In Maryland, the Greenhouse Gas Reduction Act of 2009 required the Maryland Department of the Environment to develop a plan to reduce GHG emissions 25 percent below 2006 levels by 2020 and to allocate reduction targets to lead agencies by economic sector.[23] The Maryland Department of Transportation then developed a plan to meet its allocated goal by adopting VMT reduction strategies such as improved public transportation, bike and pedestrian infrastructure, and travel demand management. According to analysis by the Maryland Department of Transportation, plans that are already currently funded are expected to reduce VMT by roughly 5 percent by 2020 compared to business-as-usual projections, or just over 0.5 percent per year between 2012 and 2020.[24]

California is pursuing a similar strategy with its Sustainable Communities and Climate Protection Act of 2008. This law directs state agencies to set GHG emissions targets from smart growth and other VMT policies and to work with metropolitan planning organizations (MPOs) to implement strategies expected to help achieve these targets.[25] California's Air Resources Board worked with MPOs to develop regionally appropriate targets. In the MPOs with the greatest population densities, this process resulted in per capita GHG emissions reduction targets of 7 to 8 percent below 2005 levels by 2020 and 13 to 16 percent below 2005 levels by 2035. In lower density MPOs, this process resulted in targets around 5 percent below 2005 levels by 2020 and 10 percent below 2005 levels by 2035. In rural areas, targets are lower, and in some cases VMT growth will be allowed until after 2020. The state lacks the authority to require MPOs to adopt these targets or to require the jurisdictions therein to implement VMT strategies. The MPOs, however, have been able to get jurisdictions to participate by prioritizing transportation funding and streamlining administrative requirements for those jurisdictions implementing VMT reduction plans.[26]

Other states are moving forward as well. In Oregon, legislation directed the state Department of Transportation to set GHG reduction goals consistent with a statewide target of 10 percent below 1990 levels by 2020, and to work with MPOs to enact strategies to meet those goals.[27] Similar legislation in Washington established specific VMT reduction targets of 35 percent below 1990 levels by 2035, although later reevaluation of the target suggested 7 to 10 percent was more realistic.[28] Other states—including New York and Massachusetts—are developing smart-growth and VMT reduction strategies as part of broader climate initiatives.[29]

In our lackluster and middle-of-the-road scenarios, we assume that states implement policies and programs that reduce their VMT an additional 0.5 percent below business-as-usual projections per year beginning in 2016, leading to a 10 percent reduction below business-as-usual projections in 2035.[30] This is on the conservative end of the range found in current state programs. We assume that states accounting for 15 percent and 25 percent of GHG emissions from light-duty vehicles adopt programs or policies that lead to these annual savings in the lackluster and middle-of-the-road scenarios, respectively. In the go-getter

scenario, we assume that states reduce their VMT 1 percent below business-as-usual projections per year beginning in 2016, leading to a 20 percent reduction in 2035.

We assume that such programs or policies are pursued by states accounting for 35 percent of GHG emissions from light-duty vehicles.

A VMT reduction of 1 percent per year is consistent with existing plans in California, Oregon, and New York. An analysis by the Urban Land Institute and Cambridge Systematics that looks at a similar set of policies finds that widespread adoption of land use and public transportation strategies results in GHG reductions of about 17 percent below baseline in 2030.[31] By comparison, if all states pursued go-getter-level ambition, reductions in 2030 would be 15 percent below baseline.

Note that the six states identified as already pursuing mandatory and voluntary policies above account for 22 percent of VMT. None of these state programs are directly included in the AEO2012 reference case. Additional state VMT profiles are provided in Table A-2.4.

TABLE A-2.4 Top 15 States According to Light-Duty Vehicle Miles Traveled (VMT), 2010

STATE	VMT (billions)	PERCENT OF TOTAL U.S. VMT
California*	323	11
Texas	234	8
Florida	196	7
New York*	131	4
Ohio	112	4
Georgia	112	4
Illinois	106	4
North Carolina	102	3
Pennsylvania	100	3
Michigan	98	3
Virginia	82	3
Indiana	76	3
New Jersey	73	3
Missouri	71	2
Tennessee	70	2
Washington*	57	2
Maryland*	56	2
Massachusetts*	54	2
Oregon*	33	1

Source: Bureau of Transportation Statistics, State Transportation Statistics, Table 5-3.
Note: Asterisks indicate states with VMT reduction plans. States shaded gray are not in the top 15 of light-duty VMT but are listed here for reference because they have existing reduction plans.

III. Energy Efficiency

A. ELECTRICITY SAVINGS

I. Base Case for Electricity Savings

Reducing electricity demand through improved end-use efficiency avoids the need to burn fossil fuel to generate electricity, thus reducing GHG emissions. A variety of state policies and programs already drive efficiency improvements, including energy efficiency resource standards, programs funded by system benefit charges, and least-cost procurement.[32] In addition, most states participating in the Northeastern and Mid-Atlantic Regional Greenhouse Gas Initiative (RGGI) also use auction revenue to fund electric efficiency programs.[33]

As described in detail in Appendix I, Sections III.A and IV.A, we utilized U.S. Energy Information Administration's (EIA) data for electricity demand in our base case. AEO2012 does not explicitly model state energy efficiency programs. However, programs in existence in 2011 and earlier are generally thought to be captured through recent regional electricity demand trends. Efficiency savings from new programs or existing programs that increase their incremental targets are generally expected to be additional to those modeled in the AEO reference case.[34]

Because AEO2012 does not model state-specific projections, we had to develop electricity demand projections for each U.S. state and the District of Columbia. This was done using historical electricity demand data for each state from EIA's State Energy Data System[35] and regional annual electricity demand growth rates from the AEO2012 reference case.

TABLE A-2.5 Electricity Savings Scenarios

ACTION	POLICIES AND PROGRAMS DRIVING ACTION	SCENARIOS		
		Lackluster	Middle-of-the-Road	Go-Getter
Electricity savings from states with EE targets	• Energy efficiency resource standards • System benefit charge funds or other funds • Least-cost procurement requirements	States responsible for 75 percent of electricity consumption that have existing annual energy efficiency targets below 1.5 percent achieve annual efficiency savings of 1.5 percent per year beginning in 2015 through 2035.	States responsible for 75 percent of electricity consumption that have existing annual energy efficiency targets below 2 percent achieve annual efficiency savings of 2 percent per year beginning in 2015 through 2035.	States responsible for 75 percent of electricity consumption that have an existing annual energy efficiency target below 2.5 percent achieve annual efficiency savings of 2.5 percent per year beginning in 2015 through 2035.
Electricity savings from states without EE targets		States responsible for 25 percent of electricity consumption achieve efficiency savings of 1 percent per year beginning in 2015 through 2035.	States responsible for 25 percent of electricity consumption achieve efficiency savings of 1.5 percent per year beginning in 2015 through 2035.	States responsible for 50 percent of electricity consumption achieve efficiency savings of 1.5 percent per year beginning in 2015 through 2035.

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Electricity Savings

Twenty-four states covering 60 percent of electricity demand currently have energy savings targets, which range from 0.3 to 2.4 percent savings per year.[36] An ACEEE analysis of twenty states with energy efficiency resource standards (EERS) in place in 2009 and 2010 found that states are generally on track toward meeting their efficiency goals.[37,38]

Under each scenario, we assume that some states without existing energy efficiency targets adopt policies and programs that lead to electricity savings beginning in 2015 (see FigureA-2.2). In the lackluster scenario, we assume that states accounting for 25 percent of electricity consumption not covered by an energy efficiency target achieve savings of 1 percent per year. In our middle-of-the-road scenario, we assume that states accounting for 25 percent of electricity consumption not covered by an energy efficiency target achieve savings of 1.5 percent per year. In our go-getter scenario, we assume that states accounting for 50 percent of electricity consumption not covered by an energy efficiency target adopt policies and programs that lead to electricity savings of 1.5 percent per year.

Under each scenario, we also assume that some states with existing energy efficiency targets adopt policies and programs that lead to additional electricity savings above these targets beginning in 2015. In our lackluster scenario, we assume that 75 percent of states with energy efficiency targets below 1.5 percent achieve electricity savings of 1.5 percent per year. In the middle-of-the-road scenario, we assume that 75 percent of states with energy efficiency targets below 2 percent achieve electricity savings of 2 percent per year. In the go-getter scenario, we assume that 75 percent of states with an energy efficiency target below 2.5 percent achieve electricity savings of 2.5 percent per year.

For additional context for these scenarios, see Table A-2.6, which provides a list of the top electricity consumers by state.

3. Modeling Notes for Electricity Savings

For purposes of our analysis we only examined the incremental benefit of new targets. A list of existing state targets was obtained from ACEEE's *2012 State Energy Efficiency Scorecard*.[39]

Typically, energy efficiency targets do not apply to all electricity sales within a state. In some states, targets apply only to investor-owned utilities (IOUs), in others

FIGURE A-2.2 Existing State Energy Efficiency Resource Standards and Scenario Assumptions (percent)

Source: Figure created using data from American Council for an Energy-Efficiency Economy's The 2012 State Energy Efficiency Scorecard, October 2012.
Note: We do not assume all the states pictured reach the scenario targets. Rather, we assume that only some states will take action. See Table A-2.5 for details. Texas had an electricity efficiency standard at the time of publication, but was treated as a state without a target for modeling purposes because its target is relatively low (about 0.2 percent of demand). This approach results in a more conservative estimate of total electricity savings than if Texas were treated as a state with an existing target.

targets apply only to utilities with large numbers of customers, while other states apply targets to varying combinations of IOUs, municipal utilities, and cooperatives.[40] On average, 13 percent of sales are not included by existing targets. To account for this, we adjusted the electricity savings by the percent of electricity sales covered. In the case of states with existing targets, we applied historical coverage percentages estimated by ACEEE (2012).[41] For those states without existing targets, we assumed that the percent of electricity sales covered was equal to the average percentage covered in states with existing targets.

We summed the incremental electricity savings for all states and incorporated the total savings into our electric demand module, which calculates the resulting greenhouse gas benefits (see Appendix I, Section V for more information).

For purposes of this analysis we assumed that these energy efficiency gains would be incremental to the other policies considered in our state and federal scenarios. Thus we assume that these benefits are in addition to savings from improved building codes and increased deployment of combined heat and power systems. We note that some states count combined heat and power (CHP) toward their energy efficiency standards,[42] and some states may allow other policies and programs to count under their energy efficiency goals. However, we believe our approach helps readers to more clearly identify the potential gains from any particular set of actions than would otherwise be possible.

B. NATURAL GAS EFFICIENCY

1. Base Case for Natural Gas Efficiency

Efficiency improvements in residential, commercial, and industrial systems provide GHG benefits by reducing demand for fossil fuels. As described in greater detail below, a number of states have efficiency programs in place that specifically target natural gas consumption.[43]

Our base case relies on U.S. Energy Information Administration's (EIA) data for natural gas demand. AEO2012 does not explicitly model state energy efficiency programs. However, programs in existence in 2011 and earlier are generally thought to be captured through recent regional natural gas demand trends.[44] Because AEO2012 does not model state-specific projections, we had to develop natural gas demand projections for each U.S. state and the District of Columbia. This was done using historical natural gas demand data for each state from EIA's State Energy Data System[45] and regional annual natural gas demand growth rates from the AEO2012 reference case.

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Natural Gas Efficiency

Eleven states covering 34 percent of natural gas demand currently have natural gas savings targets, most of which range from 0.5 to 1.5 percent savings of total natural gas demand per year (see Figure A-2.3).[46] 1 Under each scenario, we assume that some states

TABLE A-2.6 Largest Electricity Consumers, 2010

COVERED BY AN ELECTRIC EFFICIENCY STANDARD			UNCOVERED BY AN ELECTRIC EFFICIENCY STANDARD		
State	Demand (trillion Btu)	Percent of covered sales	State	Demand (trillion Btu)	Percent of uncovered sales
CA	882	14	TX	1223	19
OH	526	8	FL	789	12
PA	508	8	GA	480	8
IL	494	8	VA	388	6
NY	493	8	TN	353	6
NC	465	7	KY	319	5
IN	362	6	AL	310	5
MI	354	5	MO	294	5
WA	308	5	LA	290	5
AZ	249	4	SC	281	4
WI	235	4	NJ	270	4
MN	231	4	OK	197	3
MD	223	3	MS	170	3
MA	195	3	KS	138	2
CO	181	3	WV	109	2

Source: State Energy Data System, U.S. EIA, 2012.

TABLE A-2.7 Natural Gas Efficiency Scenarios

ACTION	POLICIES AND PROGRAMS DRIVING ACTION	SCENARIOS		
		Lackluster	Middle-of-the-Road	Go-Getter
Natural gas savings from states with EE targets	• Energy efficiency resource standards • System benefit charge funds or other funds	States responsible for 25 percent of natural gas consumption that have energy efficiency targets below 1 percent achieve savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 50 percent of natural gas consumption that have energy efficiency targets below 1 percent achieve savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 75 percent of natural gas consumption that have energy efficiency targets below 1.5 percent achieve savings of 1.5 percent of total demand per year from 2015 to 2035.
Natural gas savings from states without EE targets		States responsible for 10 percent of natural gas consumption achieve natural gas savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 25 percent of natural gas consumption achieve natural gas savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 50 percent of natural gas consumption achieve natural gas savings of 1.5 percent of total demand per year from 2015 to 2035.

without existing energy efficiency targets adopt policies and programs that lead to savings in natural gas demand beginning in 2015. In the lackluster scenario, we assume that states accounting for 10 percent of natural gas consumption not covered by an energy efficiency target achieve savings of 1 percent per year. In our middle-of-the-road scenario, we assume that states accounting for 25 percent of natural gas consumption not covered by an energy efficiency target achieve savings of 1 percent per year. In our go-getter scenario, we assume that states accounting for 50 percent of natural gas consumption not covered by an energy efficiency target adopt policies and programs that lead to savings of 1.5 percent per year.

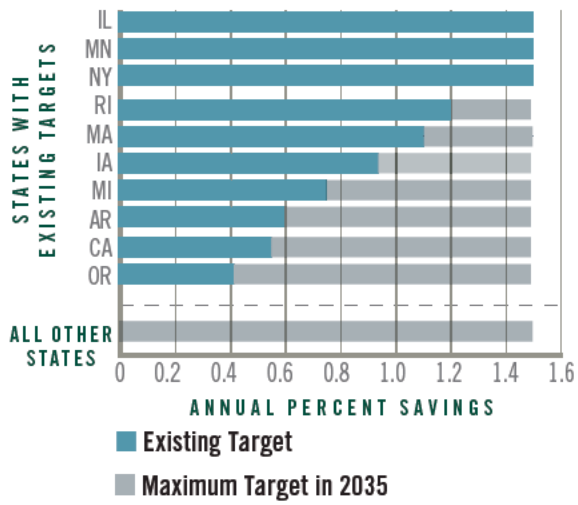
Under each scenario, we also assume that some states with existing energy efficiency targets adopt policies and programs that lead to additional natural gas savings above these targets beginning in 2015. In our lackluster scenario, we assume that 25 percent of states with energy efficiency targets below 1 percent achieve savings of 1 percent beginning in 2015. In the middle-of-the-road scenario, we assume that 50 percent of states with energy efficiency targets below 1 percent achieve savings of 1 percent. In the go-getter Scenario, we assume that 75 percent of states with an energy efficiency target below 1.5 percent achieve savings of 1.5 percent.

For additional context for these scenarios, see Table A-2.8, which provides a list of the top natural gas consumers by state.

3. Modeling Notes for Natural Gas Efficiency

While AEO2012 does not explicitly model state energy efficiency programs, programs in existence in 2011 and earlier are generally thought to be captured through recent regional natural gas demand trends. Efficiency savings from new programs or existing programs that increase their incremental targets are generally expected to be additional to those modeled in the AEO reference case.Therefore, we only modeled incremental benefits from new targets. We obtained the list of existing state targets from ACEEE's *2012 State Energy Efficiency Scorecard.*[48]

FIGURE A-2.3 Existing Natural Gas Efficiency Targets and Scenario Assumptions



Source: Figure created using data from American Council for an Energy-Efficiency Economy's *The 2012 State Energy Efficiency Scorecard,* October 2012.
Note: We do not assume all the states pictured reach the scenario targets. Rather we assume that only some states will take action. See Table A-2.7 for details. Wisconsin and Colorado had natural gas savings targets at the time of publication, but were treated as states without targets in order to generate more conservative modeling results. Wisconsin's targets were defunded in 2011. Colorado sets annual targets commensurate with funding levels and these targets have been historically low (approximately 0.1 percent of demand).

Typically, natural gas targets apply to all commercial, residential, and industrial sales within a state.[49] However, in our middle-of-the-road and go-getter scenarios, we already account for industrial efficiency gains through industrial standards. To avoid double counting of these benefits, we do not include natural gas savings from the industrial sector in either of these two scenarios. Rather, we apply the efficiency gains described in these scenarios to commercial and residential sales only, and assume that the programs will affect virtually all of those sales. The lackluster scenario for industrial policies only targets boiler efficiency improvements, and results in considerably less efficiency gains. Therefore we assume it would be possible to achieve additional efficiency improvements at industrial sources through natural gas efficiency programs in our lackluster scenario. We assume that the targets will affect nearly 100 percent of sales in the applicable customer class (i.e., residential, commercial, and in some cases industrial).

TABLE A-2.8 Largest Consumers of Natural Gas in Commercial, Residential, and Industrial Sectors, 2010

COVERED BY A NATURAL GAS EFFICIENCY TARGET			NOT COVERED BY A NATURAL GAS EFFICIENCY TARGET		
	Demand (trillion Btu)	Percent of sales covered by a target		Demand (trillion Btu)	Percent of sales not covered by a target
California	1546	31	Texas	2000	18
Illinois	869	17	Louisiana	1143	10
New York	772	15	Ohio	733	7
Michigan	618	12	Pennsylvania	587	5
Minnesota	375	8	Indiana	495	5
Iowa	256	5	New Jersey	460	4
Massachusetts	248	5	Colorado	397	3
Arkansas	167	3	Oklahoma	367	3
Oregon	125	3	Georgia	352	3
Rhode Island	36	1	Wisconsin	330	3

Source: State Energy Data System, U.S. EIA, 2012.

Note: Although Colorado and Wisconsin have natural gas savings targets in place, we treat them as though they do not have targets in order to generate more conservative modeling results. Wisconsin's targets were defunded in 2011. Colorado sets annual targets commensurate with funding levels and these targets have been historically low (approximately 0.1 percent of demand).

C. REDUCED ENERGY CONSUMPTION IN BUILDINGS

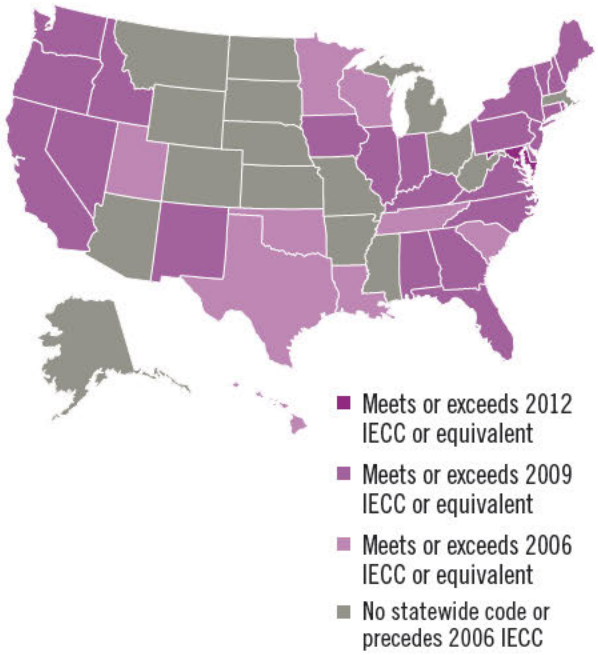
1. Base Case for Reduced Energy Consumption in Buildings

Our base case relies on the AEO2012 reference case. AEO2012 estimated that residential and commercial buildings accounted for 40 percent of total U.S. energy consumption and 73 percent of U.S. electricity use in 2010. These percentages rise to 41 percent of total U.S. energy consumption and 78 percent of U.S. electricity consumption in 2035. The majority of GHG emissions associated with buildings are the result of electricity use, which accounts for 78 percent of emissions in the commercial sector, and 74 percent of emissions in the residential sector. AEO2012 projects that even though population will increase 25 percent by 2035, energy use from buildings will only increase by 9 percent due to improvements in appliance and building shell efficiency.

Building codes provide a vehicle for establishing minimum efficiency standards for new buildings and major renovations. Building codes have historically been controlled by U.S. states and municipalities. As a result, the stringency of commercial and residential building codes they have adopted varies considerably (see Figures A-2.4 and A-2.5). It is also worth noting that the benefit of building codes varies to some extent from state to state depending on enforcement.[50]

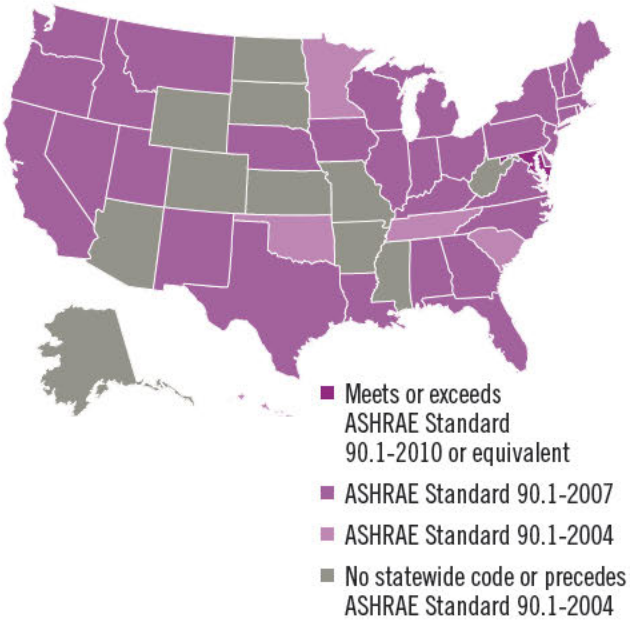
The American Recovery and Reinvestment Act of 2009 attempted to raise the level of standards across the United States by making state funding for the State Energy Program contingent upon states adopting the IECC 2009 codes for new residential buildings and ASHRAE 90.1-2007 for new commercial buildings. However, a number of states have not yet adopted these new codes. AEO2012 assumes that all states will adopt these new codes by 2017. The AEO2012 reference case does not model explicit adoption of additional building codes, although other economic and policy drivers (such as appliance standards) may lead to additional efficiency improvements.

FIGURE A-2.4 Residential Building Codes



Note: Building Code Maps adapted from the Online Code and Advocacy Network (OCEAN) (http://energycodesocean.org/code-status as of November 9, 2012).

FIGURE A-2.5 Commercial Building Codes



Note: Building Code Maps adapted from the Online Code and Advocacy Network (OCEAN) (http://energycodesocean.org/code-status as of November 9, 2012).

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Reduced Energy Consumption in Buildings

In our lackluster scenario, we assume that 10 percent of the electricity consumed by the building sector is covered by more ambitious building codes. In our middle-of-the-road and go-getter scenarios, we assume that 30 and 50 percent of the electricity consumed by the building sector is covered by more ambitious building codes.

Those building codes and the assumed electric energy savings achievable through their adoption are based on the Institute for Electric Efficiency's (IEE's) *Assessment of Electricity Savings in the U.S. Achievable through New Appliance/Equipment Efficiency Standards and Building Efficiency Codes (2010-2025).*[51] This paper quantifies reductions associated with "moderate" and "aggressive" scenarios of new building code adoption. Those scenarios are as follows:

- Residential buildings: The moderate scenario assumes that IECC 2012 goes into effect in 2015, followed by IECC 2015 in 2019, with savings of 25 percent and 45 percent compared to IECC 2006. The aggressive scenario uses the same assumptions as the moderate case until 2024, when it is assumed that a new code, with energy savings of 60 percent, goes into effect.

- Commercial buildings: The moderate scenario assumes the 2007 ASHRAE standards go into effect in 2013, followed by the 2010 ASHRAE in 2015, and 2013 ASHRAE in 2018, with savings of 15 percent, 20 percent, and 40 percent compared to the 2004 ASHRAE standards. The aggressive scenario uses the same assumptions until 2024, when it is assumed that a new ASHRAE standard with savings of 50 percent goes into effect.

Since IEE does not consider natural gas savings, we use the natural gas savings projected from building codes in the AEO2011 expanded standards and codes case. This equates to 210 trillion Btu of energy savings in 2025 (1 percent of total building consumption) and 450 trillion Btu of energy savings (2 percent of consumption) in 2035. The building code adoption

TABLE A-2.9 Building Code Scenarios

ACTION	POLICIES AND PROGRAMS DRIVING ACTION	SCENARIOS		
		Lackluster	Middle-of-the-Road	Go-Getter
Reduced energy consumption in buildings	• Commercial and residential building codes • Financial incentives	States that account for 10 percent of energy consumption in residential and commercial buildings phase in increasingly ambitious building codes through 2035. Generally, residential codes increase from IECC2009 to IECC2015 and commercial codes increase from 2004 ASHRAE 90.1 to 2013 ASHRAE 90.1.	States that account for 30 percent of energy consumption in residential and commercial buildings phase in increasingly ambitious building codes through 2035.	States that account for 50 percent of energy consumption in residential and commercial buildings phase in increasingly ambitious building codes through 2035.

schedule and associated energy savings in our analysis are considerably more ambitious than the AEO2011 expanded standards[52] and codes side case, driving roughly double the level of electricity savings.[53] This suggests that actual natural gas savings associated with adoption of the building code improvements assumed in our scenario would likely be considerably larger than we estimate here. We assume that there is minimal overlap between the natural gas savings due to improved building codes and energy efficiency programs for natural gas. This is because building codes affect new buildings and major renovations, while efficiency programs typically affect only existing buildings.

3. Modeling Notes for Reduced Energy Consumption in Buildings

The IEE report only provides electricity savings for 2025. We therefore estimated savings by assuming a linear rate of growth from 2015 through 2025. For years 2026–35, we extrapolated the national annual electricity savings by applying an assumed incremental benefit, based on the results of the moderate and aggressive scenarios of the IEE paper.[54]

We calculated electricity savings for each scenario by discounting the annual totals according to the percentage of states adopting the IEE building code schedule as described in Table A-2.9. We incorporated the total savings into our electric demand module, which incorporates changes in electricity demand resulting from a variety of federal regulations and state actions (see Appendix I, Section V, for more information).

D. INCREASED COMMERCIAL AND INDUSTRIAL COMBINED HEAT AND POWER (CHP) CAPACITY

1. Base Case for Increased Commercial and Industrial Combined Heat and Power (CHP)

Conventional electricity generation wastes one-half to two-thirds of the embodied energy of fuel, by releasing it as unused heat.[55] Combined heat and power (CHP) systems put that wasted heat energy to work, by simultaneously generating electricity and steam in a single system. This allows for considerable energy savings, thus reducing GHG emissions.[56]

Our base case relies on total electricity demand and energy CO_2 emissions projections from the AEO2012 reference case. AEO2012 projects 13 GW of new CHP capacity by 2020 and 36 GW of new capacity by 2035. This represents a growth of 144 percent from the 25 GW of CHP projected to be installed in 2012.

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Increased Commercial and Industrial Combined Heat and Power (CHP)

Annual additions of CHP have slowed since 2006 in part because of market uncertainty and the financial crisis, among other factors. However, there is emerging recognition of the environmental and economic benefits of CHP at the federal and state levels.[57] For instance, a recent executive order set an ambitious (but non-binding) national goal to deploy 40 GW of new CHP capacity by the end 2020.[58] The Department of Energy is currently working with states to realize this goal.

TABLE A-2.10 Combined Heat and Power (CHP) Scenarios

ACTION	POLICIES AND PROGRAMS DRIVING ACTION	SCENARIOS		
		Lackluster	Middle-of-the-Road	Go-Getter
Increased installation of industrial and commercial combined heat and power (CHP) systems	• Financial incentives, such as tax credits, loans, and loan guarantees • Standard interconnection rules • Reduced stand-by rates • Net metering policies • Output-based emissions regulations	State action results in deployment of an additional 10 GW of new CHP by 2025.	State action results in deployment of an additional 20 GW of new CHP by 2025.	State action results in deployment of an additional 40 GW of new CHP by 2025. When coupled with the new CHP modeled in AEO2012 (13 GW by 2020), this results in CHP deployment consistent with the Executive Order target of 40 GW of new CHP by 2020.

State policies and programs that can facilitate CHP deployment include standard interconnection rules, reduced stand-by rates, net metering policies, friendly air quality regulations such as output-based emissions regulations, feed-in tariffs, and technical assistance programs. Financial incentives—including tax credits, loans, and loan guarantees—can help ease financial uncertainty and encourage investment in CHP. These programs and incentives tend to be most effective, however, when paired with mechanisms that help overcome grid access issues such as developing interconnection standards for CHP.[59]

In a number of states, regulatory policies have not yet been revised to support distributed generation. High standby rates, which power consumers must pay in order to remain connected to the grid when they are not drawing power, offset otherwise positive economics for CHP systems. Net-metering policies that allow CHP operators to sell excess generation back to the grid can be very helpful, but are not yet widespread. In addition, utility acceptance of CHP interconnection varies widely across the states.

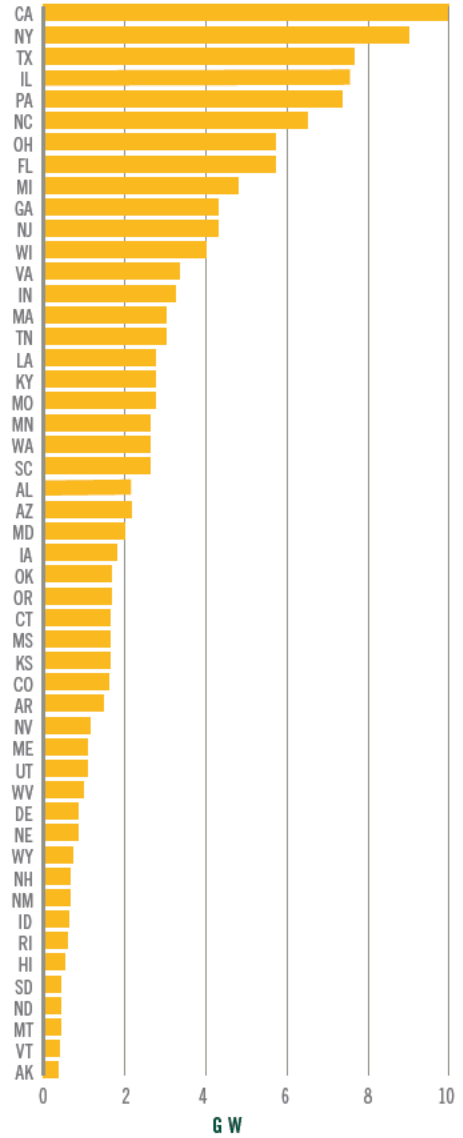
ICF International's *Effect of a 30 Percent Tax Credit on the Economic Potential for Combined Heat and Power* provides the most robust state-level assessment of the technical potential for CHP for all 50 states, and thus serves as the basis for all three of our scenarios. In generating these estimates, ICF limits CHP system size to the site's average electric demand, thus avoiding the need to deal with the challenges of selling electricity onto the grid.

In our lackluster, middle-of-the-road, and go-getter scenarios, we assume that state action results in deployment of an additional 10, 20, and 40 GW of new CHP by 2025. This is roughly 7.5, 15, and 30 percent of the technical potential identified by ICF. Such improvements could be achieved if states accounting for 15, 30, and 60 percent of total technical potential adopted policies that led them to develop new CHP units (above and beyond those modeled in AEO2012) that represent half of their technical potential. In the lackluster and middle-of-the-road scenarios, we assume that policies are implemented in 2015 and that CHP deployment phases in linearly through 2025. Thereafter it plateaus, so that no additional CHP is deployed between 2026 and 2035. In the go-getter scenario, we assume that this ramp-up occurs more rapidly so that 27 of the 40 GW are built by 2020. When coupled with the 13 GW of new CHP already predicted to be built in AEO2012, this enables the U.S. to meet the 40 GW target established by the August 2012 executive order. Figure A-2.6 shows technical potential by state, and is intended to help provide some context for these assumptions.

3. Modeling Notes for Increased Commercial and Industrial Combined Heat and Power (CHP)

We assume that all of the new CHP detailed in the scenarios above is in addition to what is modeled in the AEO2012 reference case. We note that even in our go-getter scenario we build 40 GW of additional CHP. When coupled with the 36 GW of new capacity AEO2012 predicts in 2035, this equates to 58 percent of the technical potential identified by ICF. However, we note that the AEO currently falls far short of recent ICF estimates of existing CHP capacity, estimating

FIGURE A-2.6 Combined Heat and Power Technical Potential



Source: *Effect of a 30 Percent Tax Credit on the Economic Potential for Combined Heat and Power,* ICF International, October 2010.

only 30 GW of capacity in 2011, compared to the 82 GW of CHP capacity estimated in the ICF study.[60]

CHP leads to electricity savings by providing on-site electric generation and displacing electricity that would otherwise be obtained from the grid. The impact of displacing that electricity is calculated by our electricity demand module, described in detail in Appendix I, Section V. Consistent with the ICF study, we assume that CHP units that produce cooling, heating, and power use half of their thermal output to displace electricity production for cooling and half to displace onsite fuel consumption.

CHP deployment tends to result in increased on-site fuel consumption. We estimate both the electricity savings and net increase in onsite fuel consumption using the documented assumptions and findings from ICF International's *Effect of a 30 Percent Tax Credit on the Economic Potential for Combined Heat and Power.*[61] We assume that all new CHP units and retired or refurbished units use 100 percent natural gas.[62] While a few industries are expected to increase use of coal and coal-to-liquid fuel, this will likely be offset by the greater amount of biomass, waste heat, and renewables used in other key industries.[63]

IV. Increased Generation from Renewable Sources

A. BASE CASE FOR INCREASED GENERATION FROM RENEWABLE SOURCES

Increased renewable generation can result from a variety of state programs, such as renewable portfolio standards, alternative energy standards, feed-in or other special tariffs, and other types of financial incentives. Renewable portfolio standards (RPS) specify a percentage of electricity generation (or sales) that must be met by renewable or other alternative sources. Such standards are in place in twenty-nine states and the District of Columbia, which together account for approximately 64 percent of electricity demand.

RPSs have successfully driven renewable development in those states that have adopted them. Analysis by Lawrence Berkeley National Laboratory found that all but three states were within 90 percent of their targets in 2009 and 2010.[64] Most states—including those without RPSs—encourage renewable development through tax incentives, grants and loans, and technical assistance programs.[65]

Our electricity demand projections rely on EIA's AEO2012, which includes all existing mandatory renewable electricity targets. AEO2012 projects that 340 TWh of new renewable electric generation will be built between 2009 and 2035, with an average growth rate of 2 percent in renewables per year, so that renewables account for approximately 14 percent of generation in 2020.

TABLE A-2.11 Renewable Uptake Scenarios

ACTION	POLICIES AND PROGRAMS DRIVING ACTIONS	SCENARIOS		
		Lackluster	Middle-of-the-Road	Go-Getter
Increased renewables from states with renewables targets	• Renewable portfolio standards • Alternative energy standards • Feed-in tariffs • Financial incentives	States responsible for 25 percent of electricity consumption increase their renewable generation by 1 percent annually after the last year for which a standard is set.	States responsible for 50 percent of electricity consumption increase their renewable generation by 1 percent annually after the last year for which a standard is set.	States responsible for 75 percent of electricity consumption increase their renewable generation by 1 percent annually after the last year for which a standard is set.
Increased renewables from states without renewables targets		States responsible for 10 percent of electricity consumption increase their renewable generation 0.5 percent annually beginning in 2015.	States responsible for 25 percent of electricity consumption increase their renewable generation 0.5 percent annually beginning in 2015.	States responsible for 50 percent of electricity consumption increase their renewable generation 0.5 percent annually beginning in 2015.

B. LACKLUSTER, MIDDLE-OF-THE-ROAD, AND GO-GETTER SCENARIOS FOR INCREASED GENERATION FROM RENEWABLE SOURCES

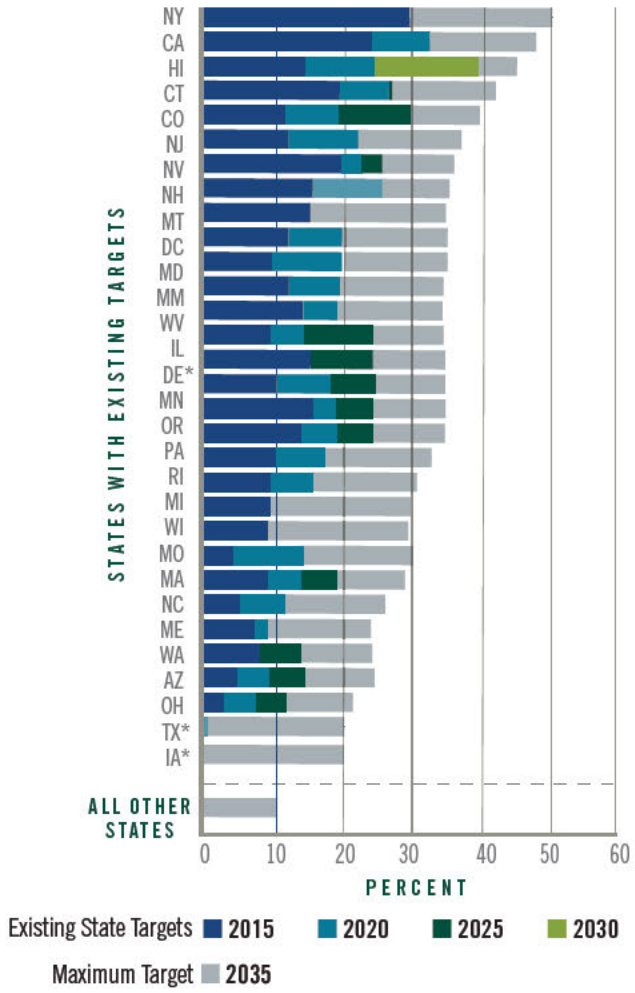
Under each scenario, we assume that some states with existing renewable standards increase these targets by 1 percent per year beginning the year after the target is reached. We choose a 1 percent annual gain because it represents the most common annual gain required by mature state programs (see Figure A-2.7).

Under each scenario, we also assume that some states without existing renewable targets increase renewable generation by 0.5 percent annually beginning in 2015. This is one-half the rate of change we model for states that already have renewable standards in place. In the lackluster scenario, we assume that this improvement occurs in states that account for 10 percent of electricity consumption in the cohort of states without existing renewable standards. In the middle-of-the-

TABLE A-2.12 Largest Electricity Consumers, 2010

COVERED BY A RENEWABLE TARGET			NOT COVERED BY A RENEWABLE TARGET		
State	Demand (trillion Btu)	Percent of sales covered by a target	State	Demand (trillion Btu)	Percent of sales covered by a target
TX	1223	15	FL	789	17
CA	882	11	GA	480	10
OH	526	6	VA	388	8
PA	508	6	IN	362	8
IL	494	6	TN	353	8
NY	493	6	KY	319	7
NC	465	6	AL	310	7
MI	354	4	LA	290	6
WA	308	4	SC	281	6
MO	294	4	OK	197	4

FIGURE A-2.7 Existing State Renewable Targets and Scenario Assumptions



Source: Figure created using data from the Database of State Incentives for Renewables and Efficiency (DSIRE), downloaded September 2012.
Note: Solid bars represent existing renewable targets and hashed bars represent the maximum new renewable energy that could be deployed in any particular state in 2035 if they increase their renewables at the designated rate (i.e., 1 percent or 0.5 percent). As discussed above, we do not assume that each state experiences this level of incremental renewable generation, but instead assume that a fraction of the states achieve this level of incremental renewable generation. Further note that Texas and Iowa have absolute rather than percent targets. Texas' 5,880 MW by 2015 target is calculated as an approximate percentage of electricity demand for ease of display. Iowa's 105 MW target is not displayed here because the target date (2000) is earlier than what is considered here.

road and go-getter scenarios, we assume that increases to 25 percent and 50 percent, respectively. Note that the same level of benefit achieved by states without a current standard can be achieved if half the number of states pursues the same level of ambition as we assume in states that already have renewable standards (i.e., increase renewable generation by 1 percent per year). For context, see Table A-2.12, which provides a list of the top electricity consumers.

To confirm that the assumptions in our scenarios are technically achievable, we compared the maximum (undiscounted) renewables penetration for each state with its technical potential as calculated by the National Renewable Energy Laboratory (NREL). In most states, the maximum level of renewables penetration does not exceed 2 percent of the state's technical potential.

C. MODELING NOTES FOR INCREASED GENERATION FROM RENEWABLE SOURCES

AEO aggregates renewable electricity targets by North American Electric Reliability Corporation region, and does not provide individual state targets.[67] Therefore, we estimated incremental renewable generation state-by-state due to their renewable standards, using our estimated electricity demand baseline for each state (see Section II.C. of Appendix II above for details),[68] and annual RPS targets by state for the years 2005–35 from the DSIRE Renewables Database.[69]

Since our scenarios do not choose what states take action, when modeling we assumed each state took action, but discounted the incremental renewable gains by the assumed implementation level. In some states, renewable targets can be met in part through energy efficiency improvements. Due to the significant energy efficiency increases across all three of our scenarios, we assumed that those energy efficiency limits would be met, thereby reducing the level of renewable energy obtained due to programs in those states.

Most existing renewable targets, and those established in our scenarios, are tied to demand (e.g., Colorado requires that 30 percent of electricity sales will be met with renewables by 2020). Therefore, estimates of the GHG benefits from renewable programs must take into account the impacts of reduced electricity consumption from energy efficiency programs. Incremental renewable generation for each of our scenarios was calculated by comparing the total projected new renewable generation to the original renewable uptake projected under our base case scenario. The greenhouse gas benefits from the new renewable development were calculated using our electric demand module. For more information see Appendix I, Section V.

V. States Implement Policies Modeled for Federal Action

States have broad authority to regulate energy sources and emissions within their boundaries. States may therefore implement many of the same policies that we ascribe to the federal government in the federal analysis, with some exceptions. In this approach we assume that states pursue the same "lackluster," "middle-of-the-road," and "go-getter" policies that are considered in the federal scenarios. Consistent with our other state policies, we do not assume, however, that all states pursue such action. Instead, we assume that these policies are pursued by states accounting for 10, 25, and 50 percent of GHG emissions from those sources. These approaches include state action for all sectors discussed in the federal action section, except for those policies that are ill-suited for state implementation. We deemed policies that eliminate HFCs, regulate off-highway vehicles, adopt appliance and equipment efficiency standards where federal standards already exist, or regulate aviation to be ill-suited to state implementation because they are preempted by federal law. It is important to note that one implication of modeling state-level ambition off of federal ambition for these sectors is that the state scenarios provide the greatest incremental benefit when they are coupled with a less ambitious federal policy.

Endnotes

1. *Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program; Final Rule.* Federal Register, Vol. 75, No. 58, Part II, March 26, 2010.

2. *Regulation of Fuels and Fuel Additives: 2011 Renewable Fuel Standards; Final Rule.* Federal Register, Vol. 75, No. 236, Part II, December 9, 2010.

3. *Regulation of Fuels and Fuel Additives: 2012 Renewable Fuel Standards; Final Rule.* Federal Register, Vol. 77, No. 5, Part V, January 9, 2012.

4. *Annual Energy Outlook 2012.* U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/archive/aeo12/index.cfm>.

5. Thresholds for specific fuel types are as follows: 20 percent for corn ethanol, 50 percent for biomass-based diesel or advanced biofuel, and 60 percent for cellulosic biofuel.

6. *Assumptions to the AEO2012.* U.S. Energy Information Administration, June 25 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/assumptions/pdf/0554(2012).pdf>.

7. To date, these states are Florida, Hawaii, Minnesota, Missouri, Oregon, New Mexico, and Washington. Massachusetts suspended its biodiesel blend mandate and implemented a voluntary program.

8. U.S. Department of Energy Alternative Fuels Data Center. Accessible at: <http://www.afdc.energy.gov>.

9. To date, these states are Alabama, Florida, Georgia, Hawaii, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Montana, New Mexico, New York, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Rhode Island, South Dakota, Virginia, Washington, and Wisconsin. For the most recent information on state biofuels policies, see U.S. Department of Energy Alternative Fuels Data Center at <http://www.afdc.energy.gov>.

10. *Advanced Transportation Fuels Advisory Group Recommendations and Supporting Fact Sheets, Midwestern Governors Association.* For more information, see: <http://www.midwesterngovernors.org/fuels.htm>.

11. *Overview of State Biofuel Policies, Incentives, and Opportunities.* Association of State Energy Research and Technology Transfer Institutions, July 2012.

12. *Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis.* EPA (EPA-420-R-10-006), February 2010.

13. These estimates are based on 100-year global warming potential estimates as published in the IPCC Fourth Assessment Report.

14. *Low Carbon Fuel Standard 2011 Program Review Report.* Advisory Panel, December 2011. For more information, see: <http://www.arb.ca.gov/fuels/lcfs/lcfs.htm>.

15. For more information on these plans, see the following resources:
Washington: <http://www.ecy.wa.gov/climatechange/fuelstandards.htm>.
Oregon: <http://www.deq.state.or.us/aq/committees/advcomLowCarbonFuel.htm>.
Mid-Atlantic/Northeast: <http://www.nescaum.org/topics/clean-fuels-standard>.
Introducing a Low Carbon Fuel Standard in the Northeast: Technical and Policy Considerations. Northeast States Center for a Clean Air Future, July 2009.

16. California's Low Carbon Fuel Standard and similar fuel standards under consideration in other states are not included in the AEO2012 reference case.

17. State programs to promote these vehicles are still valuable. In fact, a case can be made that widespread deployment of PHEVs and EVs, in particular, is essential to meet our long-term emissions trajectory, and that states have an integral role to play in deploying the infrastructure needed to make this possible.

18. *Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis.* EPA (EPA-420-R-10-006), February 2010.

19. For more information, see: <http://www.arb.ca.gov/fuels/lcfs/lcfs.htm>. The California LCFS was ruled unconstitutional by a federal district court judge in *Rocky Mountain Farmer's Union v. Goldstene*, 719 F. Supp.2d 1170 (E. Dist. Cal. 2010), and the case is currently on appeal with the Federal Circuit Court of Appeals for the 9th Circuit. The appeal was heard on oral arguments and on deliberation by the three-judge panel when one of the judges died. Parties to the case are awaiting reassignment of the case to a new third judge. Timing of an ultimate decision is unknown but expected at the end of 2013 or early 2014.

20. *Annual Energy Outlook 2012.* U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/archive/aeo12/index.cfm>.

21. For example, see:
Growing Cooler: The Evidence on Urban Development and Climate Change. Urban Land Institute, Washington, DC, 2009.
Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions. Urban Land Institute, Washington, DC, 2009.

22. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions.* Urban Land Institute, Washington, DC, 2009.

23. *Greenhouse Gas Reduction Act of 2009 (HB 315).* For more information, see: <http://www.mde.state.md.us/assets/document/Air/ClimateChange/GreenHouse_Gas_Reduction_Act_Bill_2009_Summary.pdf>.

24. *Maryland Climate Action Plan, Maryland Department of Transportation Draft Implementation Plan.* Maryland Department of Transportation, April 2011.

25. Sustainable Communities and Protection Act of 2008 (SB 375). For more information, see: <http://www.arb.ca.gov/cc/sb375/sb375.htm>.

26. For more details, see: <http://www.arb.ca.gov/cc/sb375/sb375.htm>.

27. *Draft Oregon Statewide Transportation Strategy.* Oregon Department of Transportation, May 2012.

28. *Sustainable Communities and Climate Protection Act of 2008 (SB 375).* Statutes of 2008. For more information, see: <http://www.arb.ca.gov/cc/sb375/sb375.htm>.

29. *Climate Action Plan Interim Report.* New York State Climate Action Council, November 2010. *Massachusetts Clean Energy and Climate Plan for 2020.* Executive Office of Energy and Environmental Affairs, December 2010.

30. We start the VMT policies one year later than the other policies we consider because of the extra time typically needed to implement local planning policies and programs.

31. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions.* Prepared by Cambridge Systematics for the Urban Land Institute, July 2009.

32. *The 2012 State Energy Efficiency Scorecard.* American Council for an Energy-Efficiency Economy (ACEEE), Report Number E12C, October 2012.

33. As of December 31, 2010, about $400 million—52 percent of RGGI auction revenue—had been used to support energy efficiency programs in the ten states participating at the time.

34. Personal communication with Erin Boedecker, EIA, December 2012.

35. *U.S. Energy Information Administration's State Energy Data System, 2012.* Accessible at: <http://www.eia.gov/state/seds/>.

36. *The 2012 State Energy Efficiency Scorecard.* American Council for an Energy-Efficiency Economy (ACEEE), Report Number E12C, October 2012.

37. *Energy Efficiency Resource Standards: A Progress Report on State Experience.* American Council for an Energy-Efficiency Economy (ACEEE), Report Number U112, June 2011.

38. Specifically, they found that thirteen states had reached or exceeded their goals, three achieved over 90 percent of their goals, and three had reached 80 percent or less of their goals. They found, however, that several of the states that missed their goals have programs that are still ramping up, and predict that those programs will deliver greater savings in the coming years.

39. *The 2012 State Energy Efficiency Scorecard.* American Council for an Energy-Efficiency Economy (ACEEE), Report Number E12C, October 2012.

40. In Colorado, Arkansas, California, Ohio, New Mexico, Nevada, and Texas, targets apply only to investor-owned utilities (IOUs) and not to municipal utilities or cooperatives. Illinois and Pennsylvania set targets only on utilities with large numbers of customers. Arizona, Massachusetts, Rhode Island, Indiana, and Washington set targets on some combination of IOUs, municipal utilities, and cooperatives, but not on all utilities. Hawaii, Maryland, Minnesota, New York, Vermont, Iowa, Michigan, Oregon, Wisconsin, and North Carolina have targets covering all sales.

41. Estimated percent coverage in existing states obtained from *The 2012 State Energy Efficiency Scorecard*, American Council for an Energy-Efficiency Economy (ACEE), Report Number E12C, October 2012.

42. At present, these states include Connecticut, Ohio, Texas, Massachusetts, North Carolina, Pennsylvania, Maine, Washington, Vermont, Arizona, Hawaii, and Nevada.

43. *The 2012 State Energy Efficiency Scorecard*. American Council for an Energy-Efficiency Economy (ACEEE), Report Number E12C, October 2012.

44. Personal communication with Erin Boedecker, EIA, December 2012.

45. *U.S. Energy Information Administration's State Energy Data System, 2012.* Accessible at: <http://www.eia.gov/state/seds/>.

46. *The 2012 State Energy Efficiency Scorecard*. American Council for an Energy-Efficiency Economy (ACEEE), Report Number E12C, October 2012.

47. Personal communication with Erin Boedecker, EIA, December 2012.

48. *The 2012 State Energy Efficiency Scorecard.* American Council for an Energy-Efficiency Economy (ACEEE), Report Number E12C, October 2012.

49. *Energy Efficiency Resource Standards: State and Utility Strategies for Higher Energy Savings*. ACEEE Report Number U113, June 2011.

50. *The 2012 State Energy Efficiency Scorecard*. American Council for an Energy-Efficiency Economy (ACEEE), Report Number E12C, October 2012.

51. *Assessment of Electricity Savings in the U.S. Achievable through New Appliance/Equipment Efficiency Standards and Building Efficiency Codes (2010-2025).* IEE Whitepaper, May 2011.

52. The AEO expanded standards and codes side case assumes that the AEO added three rounds of codes: a 30 percent improvement over IECC 2006 in the residential sector and a 30 percent improvement over ASHRAE 90.1-2004 in the commercial sector by 2020, then two subsequent incremental 5 percent increases in 2023 and 2026.

53. *Annual Energy Outlook 2011.* EIA, June 2011.

54. The only difference between the aggressive and moderate scenarios in the IEE paper is that the aggressive scenario adds a new code in 2024. Therefore, we assumed that the rate of change is identical in both scenarios until 2023 and the incremental difference between the two occurs in years 2024–25. We extrapolate using the sum of the incremental benefit from this code and the incremental benefit from the moderate scenario since benefits of the new code will continue to accrue through 2035.

55. *Efficiency Benefits*. Combined Heat and Power Partnership, U.S. EPA. Accessible at: <http://www.epa.gov/chp/basic/efficiency.html>.

56. *Combined Heat and Power: Markets and Challenges.* ICF International, June 2012.

57. *Combined Heat and Power: Markets and Challenges.* ICF International, June 2012.

58. Executive Order: "Accelerating Investment in Industrial Energy Efficiency." August 30, 2012. Accessible at: <http://www.whitehouse.gov/the-press-office/2012/08/30/executive-order-accelerating-investment-industrial-energy-efficiency>.

59. *Challenges Facing Combined Heat and Power Today: A State-by-State Assessment.* ACEEE Report Number IE111, September 2011.

60. ICF uses a more comprehensive data collection system compared to EIA. For example, EIA does not collect data for systems less than 1 MW in size. For medium and large sites, there may be underreporting where surveys are not sent to sites with CHP installations.

61. *Effect of a 30 Percent Tax Credit on the Economic Potential for Combined Heat and Power.* ICF International, October 2010.

62. *Effect of a 30 Percent Tax Credit on the Economic Potential for Combined Heat and Power.* ICF International, October 2010.

63. *Annual Energy Outlook 2012.* U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/archive/aeo12/index.cfm>.

64. *The State of the States: Update on the Implementation of U.S. Renewable Portfolio Standards.* Ryan Wiser and Galen Barbose, Lawrence Berkeley National Laboratory, 2011 National Summit on RPS, October 26, 2011.

65. For a summary of state incentives for renewable energy, see: <http://www.dsireusa.org/summarytables/finre.cfm>.

66. NREL defines technical potential as "the achievable energy generation of a particular technology given system performance, topographic limitations, environmental, and land-use constraints." For more details see: *U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis.* NREL Technical Report NREL/TP-6A20-51946, July 2012.

67. *Assumptions to the AEO2012.* U.S. Energy Information Administration, June 25 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/assumptions/pdf/0554(2012).pdf>.

68. For those states with absolute targets rather than percent targets (Iowa, New Jersey, and Texas), we assume the absolute targets are met and add the amount of renewable generation into our electricity demand module.

69. Database of State Incentives for Renewables and Efficiency (DSIRE), RPS Database downloaded from dsireusa.org in September 2012.

Acknowledgments

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WORLD
RESOURCES
INSTITUTE

10 G Street, NE (Suite 800)
Washington, DC 20002
USA
Tel: (1 202) 729 76 00
Fax: (1 202) 729 76 10
www.wri.org

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WRI REPORT

Can The U.S. Get There From Here?

Using Existing Federal Laws and State Action to Reduce Greenhouse Gas Emissions

NICHOLAS M. BIANCO
FRANZ T. LITZ
KRISTIN IGUSKY MEEK
REBECCA GASPER

About the Authors

Nicholas Bianco leads WRI's efforts with U.S. states and U.S. federal agencies as they work together and in parallel to develop programs to reduce greenhouse gas emissions. His areas of research include the role of states in future federal climate programs; the regulation of greenhouse gas emissions via existing regulatory authorities; market-based pollution control programs; and stacking of payments for ecosystem services (e.g., greenhouse gas offsets). Nicholas previously worked with the Massachusetts Department of Environmental Protection on climate change and air quality programs. While there, he worked on several market-based air quality and climate change programs, including the Regional Greenhouse Gas Initiative (RGGI), a regional carbon dioxide cap-and-trade program for the power sector. Contact: nbianco@wri.org.

Kristin Meek is an Associate in the Climate and Energy Program at the World Resources Institute. She supports WRI's efforts with U.S. states and U.S. federal agencies as they work together and in parallel to develop programs to reduce greenhouse gas emissions. Prior to joining WRI, Kristin worked with SAIC's climate change services team, where she focused on a wide range of GHG management projects for federal government agencies, local governments, and private sector entities. Projects included supporting the U.S. Energy Information Administration's national inventory of greenhouse gases, EPA's Greenhouse Gas Reporting Program and Climate Leaders Program, researching issues related to new and existing carbon offset project types, and developing community-level GHG inventories for cities and counties across the country. Contact: kmeek@wri.org.

Rebecca Gasper is a Research Assistant in WRI's Climate and Energy Program. She supports WRI's efforts with U.S. states and U.S. federal agencies as they work together and in parallel to develop programs to reduce greenhouse gas emissions. Before joining WRI, Rebecca worked at the Center for Integrative Research (CIER) at the University of Maryland. She worked primarily on climate change mitigation and adaptation at the regional and international levels. She also has experience supporting state efforts to develop water quality markets. Contact: rgasper@wri.org.

Franz Litz is the Executive Director of the Pace Energy & Climate Center, a legal and policy think tank, and Professor of Energy and Climate Change Law in Pace Law School's top-ranked environmental law program. Franz leads his Center's work at the state, regional, national, and international levels on climate change, energy efficiency, renewable energy, transportation, and community energy. Franz is an expert on the federal Clean Air Act, state-level climate and energy policies, and emissions trading. Franz actively convenes officials from U.S. states and Canadian provinces cooperating on energy and climate change policy issues. He also frequently brings stakeholders from diverse viewpoints together to engage policy makers on difficult energy and climate policy issues. Before assuming his leadership role at the Pace Energy & Climate Center in 2011, Franz was a senior fellow at the World Resources Institute in Washington, DC. He led WRI's state and regional climate change initiatives, as well as WRI's engagement with the U.S. EPA. Contact: flitz@law.pace.edu.

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Summary for Policymakers

I. Introduction

CLIMATE CHANGE IMPACTS IN THE UNITED States are increasingly evident and come with steep economic and social costs. The frequency and intensity of extreme weather events has increased in recent years, bringing record-breaking heat, heavy precipitation, coastal flooding, severe droughts, and damaging wildfires.[1] According to the National Oceanic and Atmospheric Administration (NOAA), weather-related damages in the United States were $60 billion in 2011, and are expected to be significantly greater in 2012.[2]

The mounting costs convey an unmistakable urgency to address climate change by reducing greenhouse gas emissions (GHGs). This report examines pathways for GHG reductions in the United States through actions taken at the federal and state levels without the need for new legislation from the U.S. Congress.

This report answers a number of key questions:

- What are current U.S. GHG emissions? Without further action to reduce emissions, what are they projected to be in 2020 and 2035?
- What legal and policy tools exist under current federal law to achieve emissions reductions? What additional actions can states pursue to contribute to emissions reductions?
- Which legal and policy tools at the state and federal levels offer the greatest potential for achieving emissions reductions in the near- and mid-term?
- Can the U.S. meet its international commitment to reduce emissions 17 percent below 2005 levels by 2020 without new federal legislation?
- Can the U.S. put itself on a trajectory to meet or exceed its long-term commitment of reducing emissions by more than 80 percent below 2005 levels by 2050, without new legislation from Congress?

The answers to these questions are set out in detail in the body of this report. Two significant findings stand out. First, it is clear the U.S. is not currently on track to meet its 2020 reduction pledge, however, this target is achievable through implementation of strong new federal measures to reduce emissions using existing legal authorities. Second, the mid-century goal of reducing emissions by 80 percent or more appears unattainable using existing authorities. New legislation will eventually be needed.

BOX 1 Key Conclusions and Recommendations

1. Without new action by the U.S. Administration, greenhouse gas (GHG) emissions will increase over time. The U.S. will fail to make the deep emissions reductions needed in coming decades, and will not meet its international commitment to reduce GHG emissions by 17 percent below 2005 levels by 2020.
2. The U.S. EPA should immediately pursue "go-getter" emissions reductions from power plants and natural gas systems using its authority under the Clean Air Act. These two sectors represent two of the top opportunities for substantial GHG reductions between now and 2035.
3. The U.S. Administration should pursue hydrofluorocarbon (HFC) reductions through both the Montreal Protocol process and under its independent Clean Air Act authority. Eliminating HFCs represents the biggest opportunity for GHG emissions reductions behind power plants.
4. U.S. states should complement federal actions to reduce emissions through state energy efficiency, renewables, transportation, and other actions. States can augment federal reductions.
5. New federal legislation will eventually be needed, because even go-getter action by federal and state governments will probably fail to achieve the more than 80 percent GHG emissions reductions necessary to fend off the most deleterious impacts of climate change.

Potential reductions in the United Stated were assessed in a 2010 WRI Report entitled *Reducing Greenhouse Gas Emissions in the United States Using Existing Federal Authorities and State Action.*[3] This updated report revisits these questions, taking into account the latest GHG emissions information and recent actions taken at the federal and state levels. Since the publication of the last report, notable factors influencing U.S. GHG emissions include:

- Reduced global economic growth, including slower growth of economic output in the United States;
- Increased fuel switching from coal to natural gas in the generation of electricity; and
- Reduced demand for transportation fuel, partly as a result of higher petroleum prices, lower miles traveled, and more efficient vehicles.

These factors and others, including the issuance of new motor vehicle emissions and fuel efficiency standards for cars and trucks, will reduce greenhouse gas emissions. However, even with these factors, we project that total U.S. emissions will experience relatively modest growth over the coming decades.

At the 2009 Conference of the Parties of the United Nations Framework Convention on Climate Change in Copenhagen, Denmark, President Obama made a commitment to reduce U.S. greenhouse gas emissions in the range of 17 percent below 2005 levels by 2020. Despite the inability of Congress to pass comprehensive climate change legislation, the Administration has re-committed to the Copenhagen pledge and taken some steps to reduce emissions using authority under existing laws.[4] While the Administration has reaffirmed its commitment to this target, it has not yet matched that commitment with adequate action. Though significant progress has been made in some areas since our 2010 analysis, most notably with the vehicle rules, key opportunities, such as reductions from power plants, remain untapped. The fact that the U.S. remains far from the "go-getter" emissions trajectory laid out in our 2010 report reinforces the urgency for taking strong action now.

Although the U.S. emissions reduction commitment for 2020 represents an important step toward reducing GHG emissions, much greater reductions are necessary. According to the Intergovernmental Panel on Climate Change, industrialized countries need to collectively reduce emissions between 25 and 40 percent below 1990 levels by 2020 and 80 to 95 percent below 1990 levels by 2050 in order to keep global average temperatures from increasing more than 2 degrees Celsius above preindustrial levels. This report evaluates the potential for meeting the 17 percent commitment and the deeper longer-term reduction pathway necessary to avoid the worst impacts of climate change.

BOX 2 Ambition Matters

Within the bounds of what is legally and technically possible, the single most important factor influencing emissions reductions is political and policy ambition. This analysis considers three levels of ambition:

- **Lackluster.** This is low ambition and represents the results of actions of lowest cost or least optimistic technical achievement.
- **Middle-of-the-Road.** This is mid-level ambition and represents the results of actions of moderate cost and moderately optimistic technical achievement.
- **Go-Getter.** This is the highest ambition achievable without new congressional action. It represents the results of actions of higher cost or most optimistic technical achievement.

The term "go-getter" is not meant to suggest the actions are adequate to achieve U.S. reduction targets or reductions the science suggests are necessary to ward off the worst effects of climate change.

1. *America's Climate Choices: Panel on Advancing the Science of Climate Change.* National Research Council, 2010.ISBN 978-0-309-14588-6. Accessible at: <http://www.nap.edu/catalog.php?record_id=12782>.
2. *Preliminary Info on 2012 U.S. Billion-Dollar Extreme Weather/ Climate Events.* National Oceanic and Atmospheric Administration. Accessible at: <http://www.ncdc.noaa.gov/news/preliminary-info-2012-us-billion-dollar-extreme-weatherclimate-events>. (Last accessed January 15, 2013)
3. Accessible at: <http://www.wri.org/publication/reducing-ghg-emissions-using-existing-federal-authorities-and-state-action>.
4. Most recently, the U.S. delegation to the Conference of the Parties of the UN Framework Convention on Climate Change in Doha, Qatar, made it clear that the 17 percent pledge is not contingent on new legislation from Congress.

Attaining even the 17 percent reduction goal will require new and ambitious action from the U.S. Administration—ambitious action that must survive court challenges. Real progress depends on numerous actions not yet taken by the U.S. Administration—especially for stationary emissions sources like power plants, natural gas systems, and industry. U.S. states may also need to take action to fill any emissions gaps left by the federal government. Achieving the necessary mid-century reductions will almost certainly require the U.S. Congress to act to achieve the needed reductions.

Section II summarizes the report's key findings, including the range of reductions that are possible and a brief description of the analytical approach. An examination of current emissions in the United States and projected emissions without new actions follows in Section III. Section IV summarizes the sector-by-sector actions the federal government might take under existing laws. Section V summarizes potential state actions. Section VI sets out summary conclusions. Two detailed appendixes set out the assumptions and methodologies for the federal and state analyses. The picture revealed is one of significant potential greenhouse gas emissions reductions, provided there is sufficient political will to take strong action.

II. Charting a Path Forward in the U.S.: Summary of Key Findings

This report identifies significant potential for GHG emissions reductions by the U.S. Administration under current laws and through state-level actions, as well as the limitations of current tools. The reductions actually achieved will depend on the level of ambition brought to the effort by the U.S. Administration, including executive agencies such as the U.S. Environmental Protection Agency. At the state level, outcomes will depend on the number of states that choose to support renewable energy, energy efficiency, and transportation measures, and to pursue policies that the federal government opts not to pursue or that go beyond the minimum stringency set by the federal government. Key findings are set out below for federal and state actions.[5]

A. FEDERAL GHG REDUCTIONS POSSIBLE WITHOUT NEW LEGISLATION

- Only with "go-getter" ambition by the U.S. Administration can the United States achieve emissions reductions using current law that meet or exceed the Copenhagen commitment to reduce global warming pollution by at least 17 percent below 2005 levels by 2020.[6] With middle-of-the-road ambition, the United States will fall well short of its 17 percent commitment, unless supplemented by go-getter actions by the states.

- Even with go-getter ambition, long-term emissions reductions fall short of the level of reductions necessary to put the United States on pace to reach its long-term reduction goal of reducing emissions 83 percent below 2005 levels by 2050. New congressional legislation is therefore necessary to achieve reductions in line with what the international scientific community agrees is necessary by mid-century in order to stabilize global average temperatures and avert the worst impacts of climate change.

- After taking action to significantly improve motor vehicle fuel efficiency, the U.S. Administration should now apply similar ambition to reducing emissions from a wider range of sources, such as existing power plants, if it is to achieve the needed reductions.

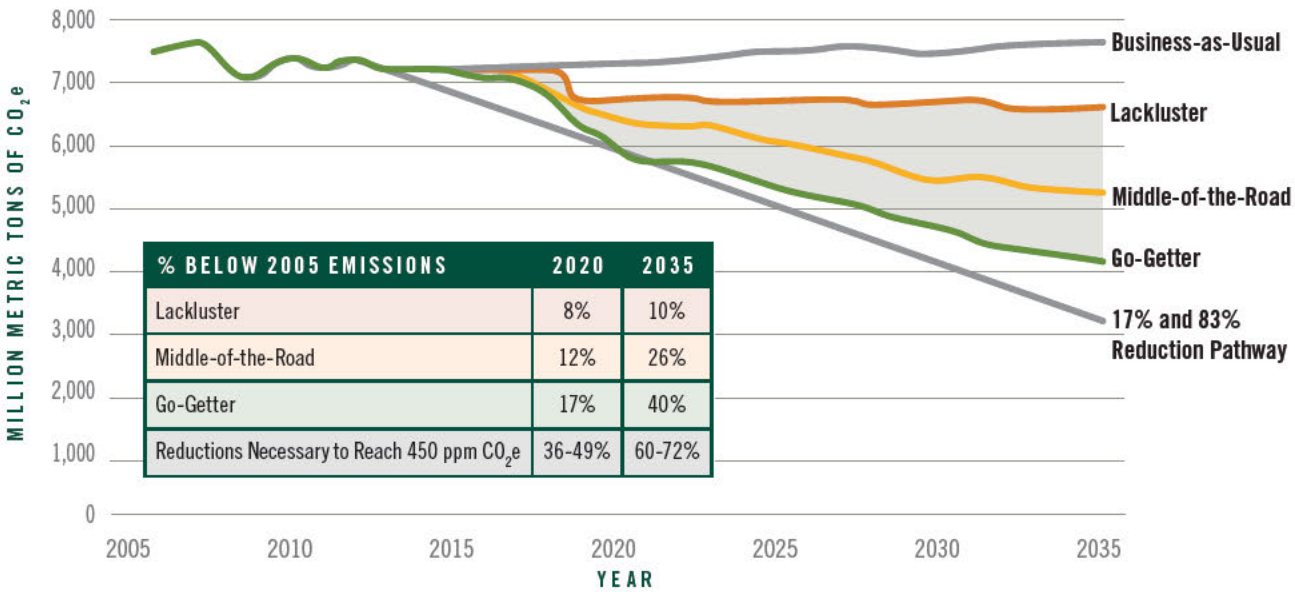
- The greatest projected emissions reduction opportunities by 2020 and beyond come from four federal policy measures. The Administration will need to pursue these opportunities if the United States is to achieve the 17 percent reduction target. Those policies are:

  - standards to reduce carbon pollution from existing power plants (48 percent of total emissions gap between business-as-usual (BAU) and 2020 target);

5. For data sources and an explanation of how expected emissions trends were compiled, please consult the appendixes. For the sake of clarity and brevity, sources are not provided in this summary.

6. The U.S. commitment in Copenhagen calls for reductions in 2020 "in the range of 17 percent [below 2005 levels], in conformity with anticipated U.S. energy and climate legislation." The U.S. submission notes that the ultimate goal of legislation pending at the time was to reduce emissions by 83 percent below 2005 levels in 2050.

FIGURE 1 Projected U.S. Emissions under Different Federal Regulatory Scenarios



% BELOW 2005 EMISSIONS	2020	2035
Lackluster	8%	10%
Middle-of-the-Road	12%	26%
Go-Getter	17%	40%
Reductions Necessary to Reach 450 ppm CO_2e	36-49%	60-72%

Note: The Intergovernmental Panel on Climate Change's (IPCC's) *Fourth Assessment Report* (2007) indicates that industrialized countries need to collectively reduce emissions between 25 and 40 percent below 1990 levels by 2020 and 80 to 95 percent below 1990 levels by 2050 to keep atmospheric concentrations of greenhouse gases from exceeding 450 parts per million of CO_2e and to keep global average temperatures from increasing more than 2 degrees Celsius above pre-industrial levels. This target does not necessarily represent any particular country's share. Due to modeling limitations, this figure depicts HFC consumption, which is generally thought to be equivalent to life-cycle emissions. For this and all other figures, we use the global warming potentials provided in IPCC's *Fourth Assessment Report*. There are some limited exceptions. See Appendix I for more details.

- requirements to phase out the use of certain hydrofluorocarbons (HFCs) (23 percent of total emissions gap between BAU and 2020 target);
- standards to reduce methane emissions from natural gas systems (11 percent of total emissions gap between BAU and 2020 target);[7] and
- actions to improve energy efficiency in the residential, commercial, and industrial sectors (8 percent of total emissions gap between BAU and 2020 target).

B. STATE ACTION COULD HELP THE U.S. MEET NEAR-TERM PLEDGE

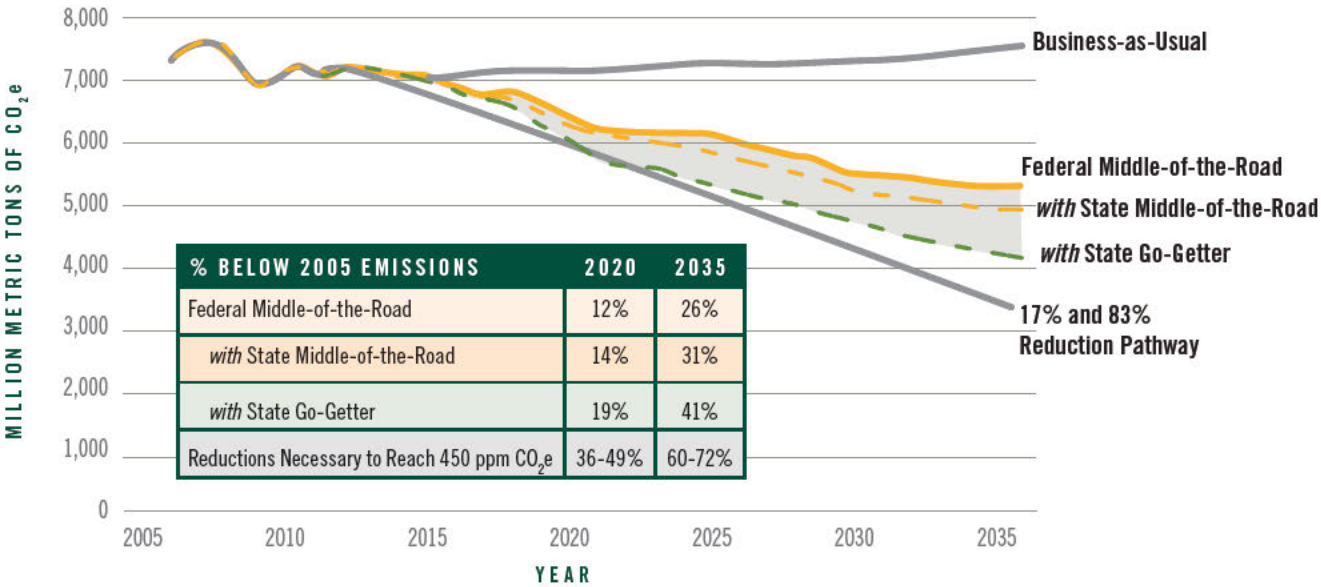
- States can be important contributors to efforts to reduce GHG emissions. If the U.S. Administration were to pursue policies with middle-of-the-road ambition, for example, states could pick up the slack and help the United States reach its goal of reducing emissions 17 percent below 2005 levels by 2020.
- If the federal government pursues a lackluster effort, even a go-getter effort by states is unlikely to achieve the U.S. Administration's 2020 reduction goal.
- Beyond 2020, go-getter state action combined with middle-of-the-road federal action falls short of putting the United States on track to make the mid-century reduction target. This suggests that strong new federal legislative action will be needed.

C. THE STUDY IN BRIEF

This updated report represents the authors' projections of the range of greenhouse gas emissions reductions possible if federal agencies and certain states implement measures to reduce GHG emissions. The report projects the range of reductions possible under current federal law based on a review of published analyses of technical feasibility. The report characterizes three emissions scenarios based on different levels of effort by federal and state actors: "lackluster," "middle-of-the-road," and "go-getter."

7. There is considerable uncertainty with regard to emissions for natural gas systems. The absolute magnitude of abatement opportunities is thus also uncertain. Nevertheless, our analysis suggests that there are important opportunities to reduce emissions from this sector. Those reductions are some of the lowest cost opportunities identified in this analysis.

FIGURE 2 Projected U.S Emissions with State Action Coupled with Middle-of-the-Road Federal Action



% BELOW 2005 EMISSIONS	2020	2035
Federal Middle-of-the-Road	12%	26%
with State Middle-of-the-Road	14%	31%
with State Go-Getter	19%	41%
Reductions Necessary to Reach 450 ppm CO_2e	36-49%	60-72%

Note: Due to modeling limitations, this figure depicts HFC consumption, which is generally thought to be equivalent to life-cycle emissions.

1. Analysis of Federal Actions

The analysis of federal actions is based on a legal assessment of the measures the U.S. Administration, including key federal agencies like EPA, may take under existing federal laws. The federal analysis assumes no new legislation is adopted. Technical studies were used to identify the range of reductions possible within a given sector or subsector. The legally and technically feasible range of reductions was then evaluated based on the level of ambition necessary to achieve a particular point in the range. Where available, we relied more heavily on studies that provided a consideration of the costs needed to achieve a particular outcome to provide a sense of the federal regulatory resolve necessary to achieve those reductions.

Where only a low level of ambition is necessary to achieve a particular technically and legally feasible outcome within a specific sector or subsector, the outcome was judged to be "lackluster." If a high level of ambition is necessary to achieve a particular reduction outcome deemed technically and legally possible, the effort necessary was deemed "go-getter" in our scenarios. "Middle-of-the-road" outcomes were those judged possible with moderate ambition and usually at the middle of the range deemed technically and legally possible.

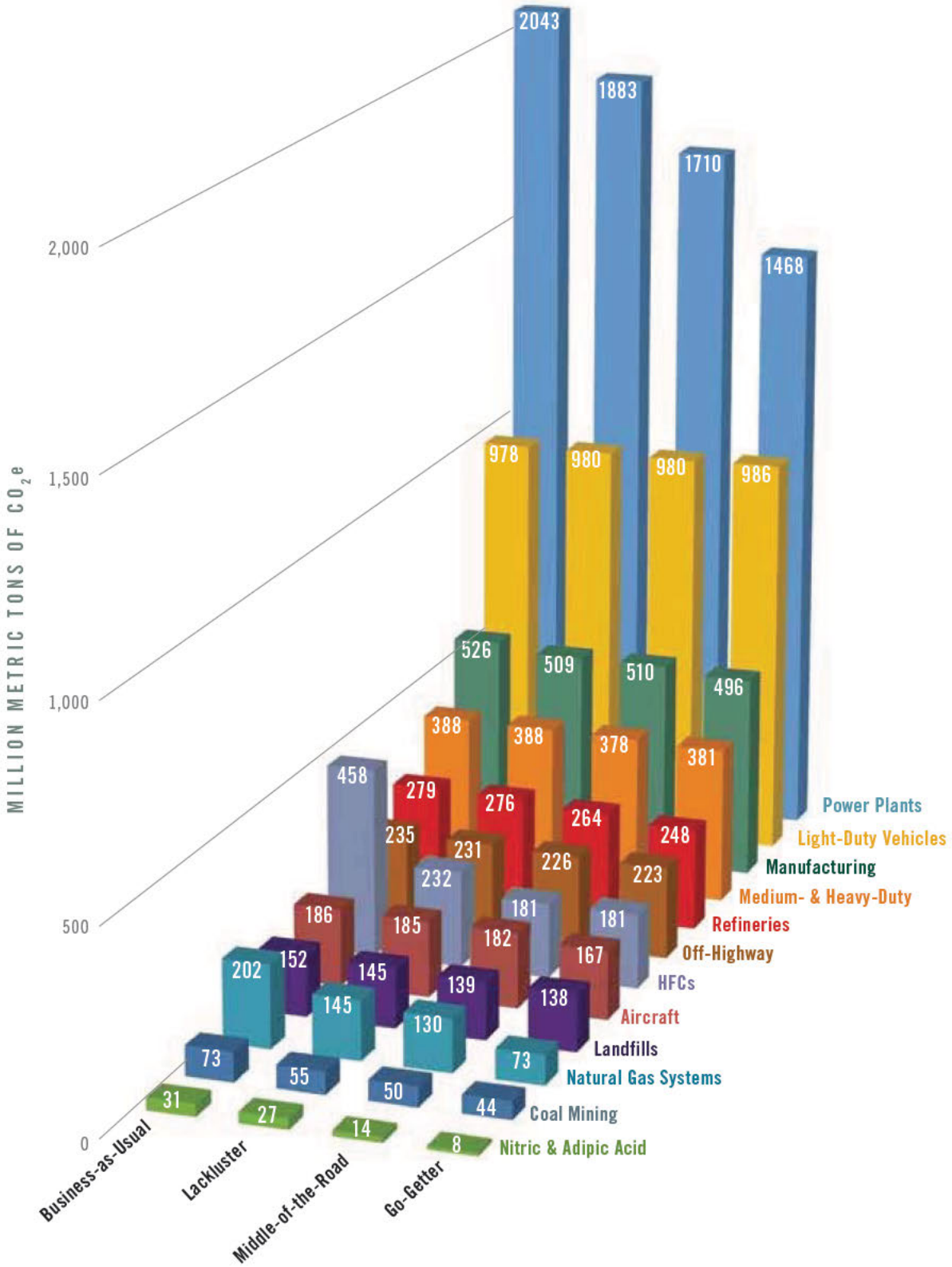
Lackluster emissions reductions from all sectors and subsectors analyzed were aggregated to determine the lackluster emissions pathway through 2035. The same approach was taken for middle-of-the-road and go-getter reductions.

2. Analysis of State Actions

The state analysis has two components: the first considers the impact of states taking action in the absence of federal action; the second considers the impact of states taking action in the presence of varying levels of federal action. In both components we examine the implication of states implementing the same types of policies modeled for the federal government, as well as complementary state-level actions in the transportation, energy efficiency, and renewables areas.

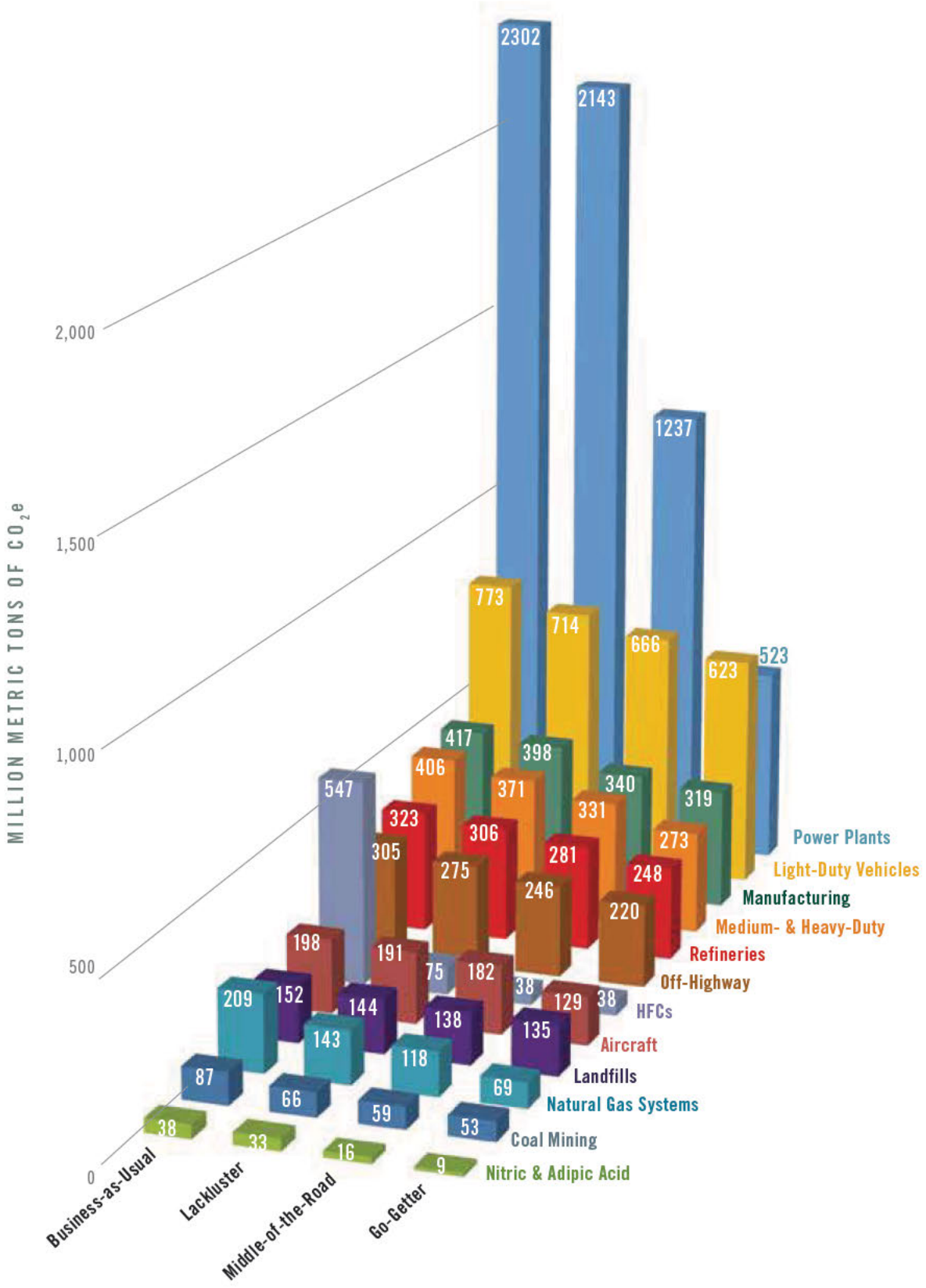
For transportation, the state scenarios consider measures to encourage low carbon fuels and reduce vehicle miles traveled. In the energy efficiency area, measures examined include increased electric end-use energy efficiency, improved building performance, and increased deployment of combined heat and power. For renewables, the analysis adds new and additional renewable energy policies across a certain number of states.

FIGURE 3 Projected U.S. Emissions in 2020 by Sector under Different Federal Regulatory Scenarios



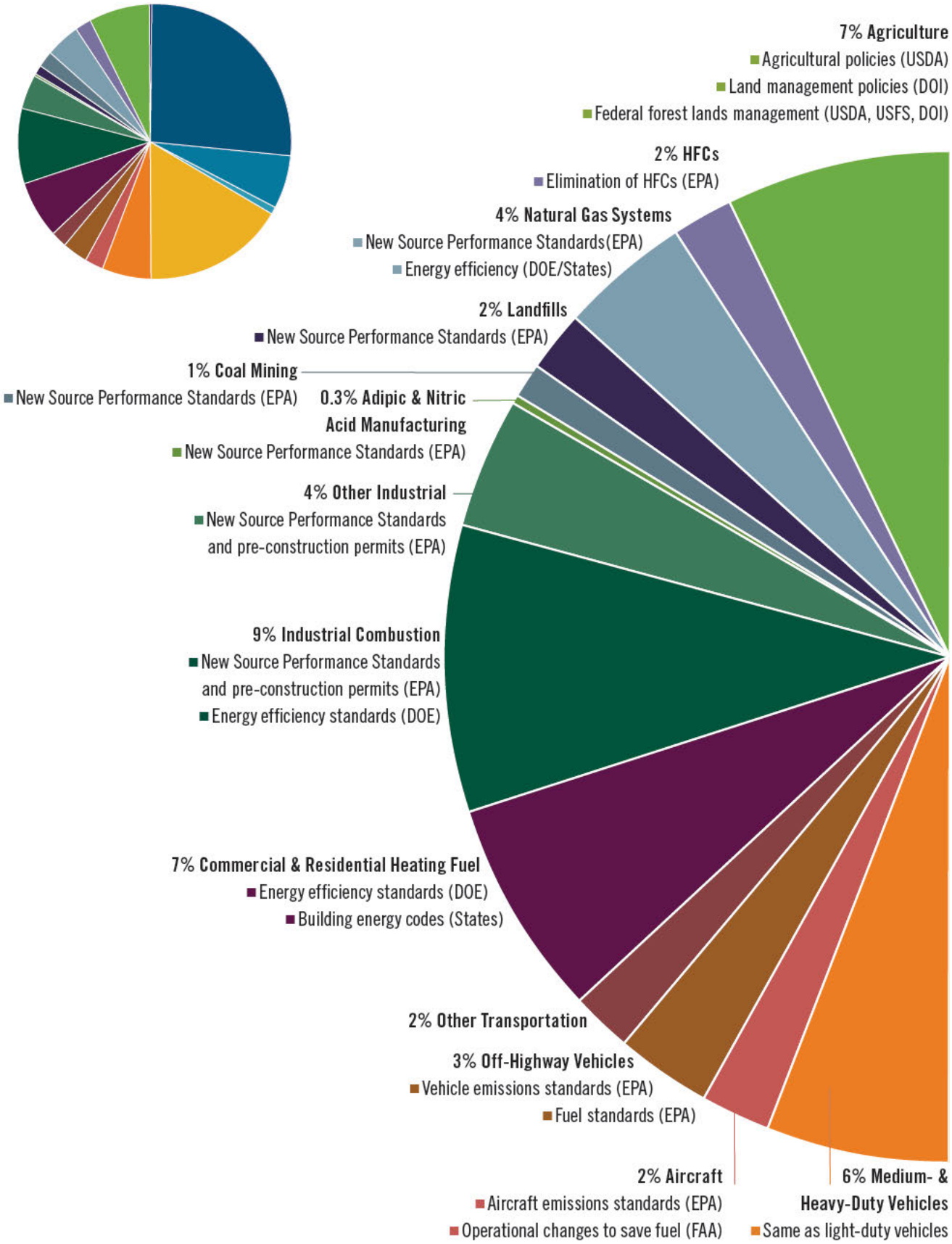
Note: Figure 3 depicts the emissions under the three federal regulatory scenarios by sector or category of sources in 2020. The bars on the left represent business-as-usual emissions. Emissions under the lackluster, middle-of-the-road, and go-getter scenarios are then shown moving from left to right of the business-as-usual emissions. Light-duty vehicle emissions initially increase in our scenarios due to assumptions about vehicle electrification and crediting rates. As shown in Figure 4, these trends reverse in later years. See Appendix I for more information. Due to modeling limitations, this figure depicts HFC consumption, which is generally thought to be equivalent to life-cycle emissions.

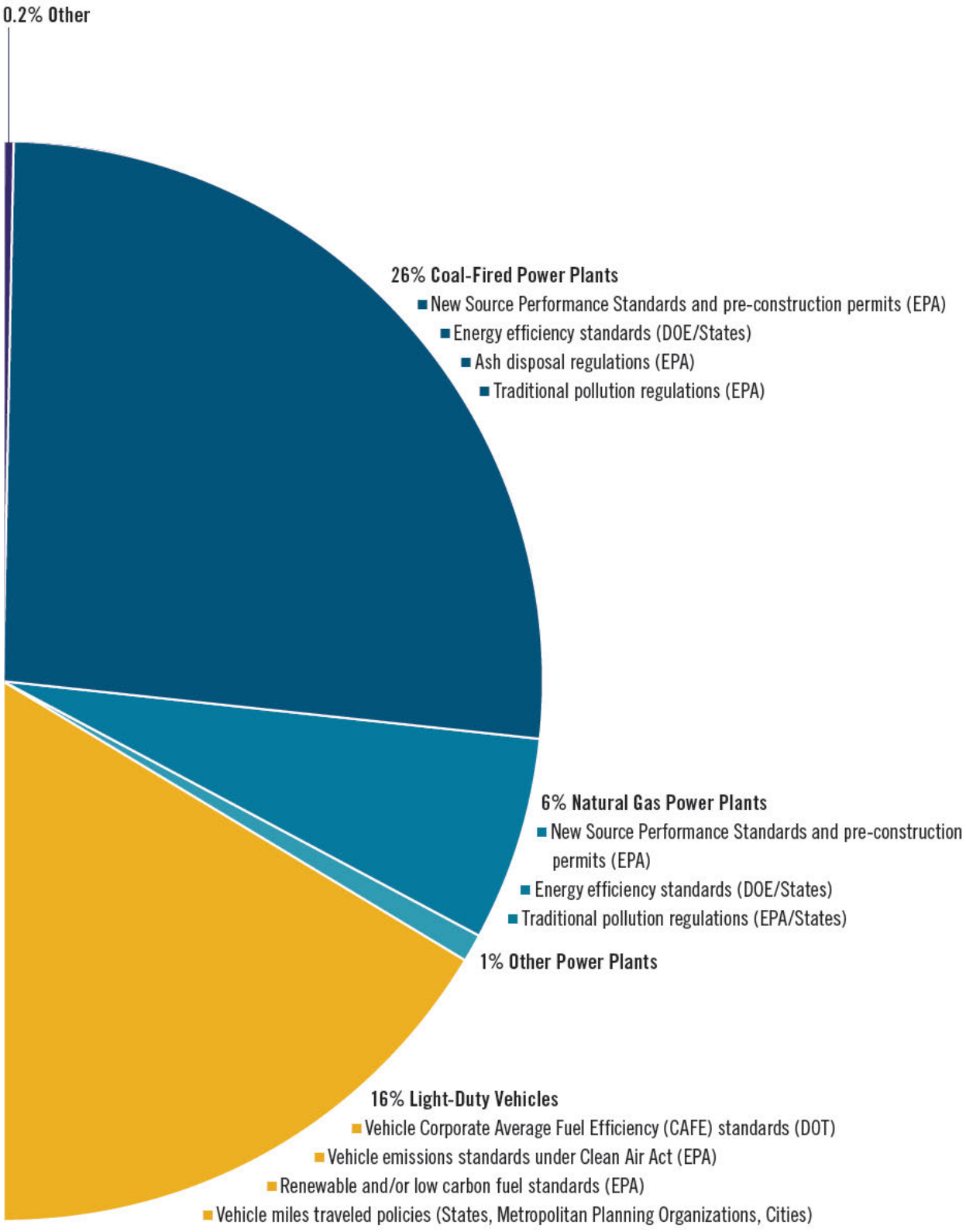
FIGURE 4 Projected U.S. Emissions in 2035 by Sector under Different Federal Regulatory Scenarios



Note: Figure 4 depicts the emissions under the three federal regulatory scenarios by sector or category of sources in 2035. The bars on the left represent the business-as-usual emissions. Emissions under the lackluster, middle-of-the-road, and go-getter scenarios are then shown moving from left to right of the business-as-usual emissions. Due to modeling limitations, this figure depicts HFC consumption, which is generally thought to be equivalent to life-cycle emissions.

FIGURE 5 U.S. Greenhouse Gas Emissions by Sector and Corresponding Federal Authorities, 2010





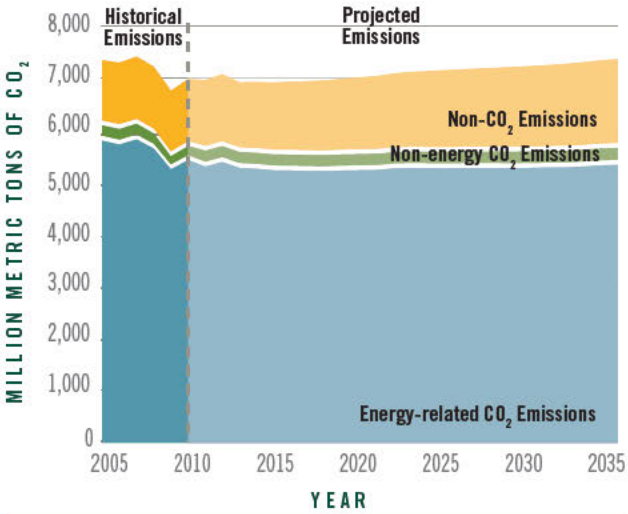
Source: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010*. U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>; *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas*. James Bradbury, Michael Obelter, Laura Draucker, Wen Wang, and Amanda Stevens. World Resources Institute, Working Paper, forthcoming.

Unlike the federal analysis, many of the state measures modeled would require new legislation at the state level. Also unlike the federal scenario, whether state action is "lackluster", "middle-of-the-road" or "go-getter" is a function of how many states adopt the measures modeled, and in some cases the ambition of the policies pursued.

3. Analysis of Federal and State Actions Together

Given that it is unlikely that federal action will occur without state action or that state action will occur without federal action, we analyzed emissions scenarios with both federal and state action. States can be expected to continue to be active in areas of traditional state purview such as energy resource planning and energy efficiency, while also compensating for weak federal action. To capture this dynamic, we modeled varying levels of action for federal and state action.

FIGURE 6 Projected U.S. Greenhouse Gas Emissions if no New State or Federal Action is Taken



Source: See sources listed under Figures 7 and 8 below.

III. The Road the U.S. is on Now: Business as Usual

The reduction pathways presented in this report are best considered in light of current U.S. emissions, along with recent and future emissions trends. A snapshot of U.S. emissions using the most recent data available is presented below, together with a summary of U.S. emissions by key sectors and recent actions to reduce them by federal agencies.

A. CURRENT U.S. EMISSIONS

In 2010 the United States emitted almost 7 billion metric tons of carbon dioxide equivalents (CO_2e), which represents a decrease of about 6 percent below 2005 levels and a 10 percent increase over 1990 levels. Fossil-fuel combustion was responsible for nearly 80 percent of U.S. emissions, with power plants accounting for about 40 percent of combustion emissions, or one-third of the total U.S. GHG inventory, according to EPA. The second largest contributor to total GHG emissions is the transportation sector, with approximately 30 percent of U.S. emissions. Non-CO_2 emissions and CO_2 emissions that result from industrial processes (as opposed to combustion) represented approximately 22 percent of U.S. total GHG emissions.

Figure 5 shows the 2010 U.S. emissions inventory by sector and subsector, together with the corresponding federal regulatory tools available to achieve reductions in the sector.

B. WHAT HAPPENS WITH NO NEW POLICIES? UNDERSTANDING CURRENT U.S. EMISSIONS TRENDS

Before discussing the reduction pathways projected for this report, it is important to describe the major emissions trends that are part of the business-as-usual projections. Business-as-usual emissions trends have shifted downward since the 2010 version of this report. While energy-related CO_2 emissions are projected to rise slowly but remain below 2010 levels through 2035, non-CO_2 emissions are projected to steadily increase over the same time period. The primary trends are noted here:

- **Current Energy-related Carbon Dioxide Emissions Down from 2005 Levels.** In 2011 carbon dioxide emissions from energy sources, which account for nearly 80 percent of U.S. GHG emissions, were 8.7 percent below 2005 levels. Nearly half of those reductions (48 percent) came from the power sector. The rest of the reductions came from transportation (28 percent), industry (18 percent), and buildings (6 percent).[8]

- **Future Energy-CO_2 Emissions Expected to be Relatively Flat.** Our projections suggest that if no future policy actions are taken, then energy-CO_2 emissions will remain approximately 10 percent

8. *Closer than You Think: Latest U.S. CO_2 Pollution Data and Forecasts Show Target Within Reach.* NRDC Issue Brief. Dan Lashof. July 2012.

below 2005 levels in 2020, and will increase slightly through 2035 to levels that are about 8 percent below 2005 levels (Figure 7).

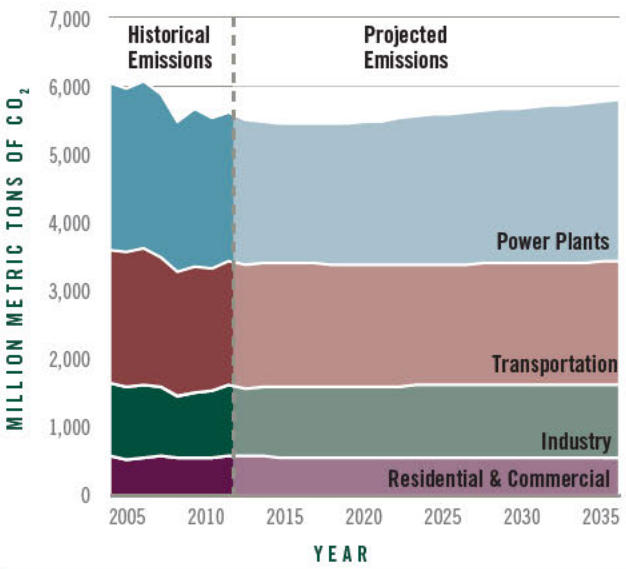
- Those trends are driven by a number of factors, including:

  - **Falling Energy Demand.** The economic slowdown experienced by the United States and other parts of the world over the period from 2008 to 2012 has led to decreased demand for goods and services and reduced energy consumption.[9] Over time, this trend is expected to reverse as economic growth picks up. In addition, the industrial sector was affected significantly by the recent economic turndown and saw a decrease in both production and emissions. This decline is projected to be temporary. Manufacturing output is expected to accelerate from 2010 through 2020, and emissions are projected to increase by 4 percent over this time.[10]

  - **Rise of Natural Gas and Renewables.** The power sector is shifting from coal-fired generation toward natural gas-fired and renewable generation. This trend is driven in part by increases in natural gas extraction, low natural gas prices, increasing coal prices, and new (non-GHG) regulations for the power sector. Increases in renewable generation are driven by state renewable standards, voluntary purchases of "green" energy, and decreasing renewable energy costs. However, gas prices are expected to slowly rise from current levels and demand for electricity is expected to rise 18 percent by 2035 from 2010 levels.[11]

  - **New Vehicle Rules.** The transportation sector is expected to become less carbon-intensive, due in large part to high petroleum prices and new federal GHG emissions and fuel efficiency standards covering light-, medium- and heavy-duty vehicles. These gains will be partially offset by continued increases in vehicle miles traveled.[12] Transportation emissions are projected to increase 1 percent below 2011 levels by 2035.

FIGURE 7 Projected U.S. Energy-Related Carbon Dioxide Emissions if no New State or Federal Action is Taken



Source: U.S. Energy Information Administration, Annual Energy Review (Years 2005-2011); U.S. Energy Information Administration, Annual Energy Outlook (Years 2012-2035)

- **Non-Energy Emissions on the Rise.** Trends for non-energy and non-CO_2 emissions, such as natural gas systems, refrigerants, and landfills, show a likely rise. In 2010, non-energy and non-CO_2 sources accounted for about 22 percent of total U.S. emissions. We project that these emissions will increase roughly 18 percent above 2005 levels by 2020 and 36 percent above 2005 levels by 2035, even after accounting for 2012 regulations that affect portions of natural gas systems and HFCs from vehicles. Those trends are driven by several factors, including:

  - **CFCs Phased Out, HFCs Phased In.** HFC emissions are increasing due to the phaseout of chlorofluorocarbons (CFCs) and other ozone-depleting substances under the Montreal Protocol, which is intended to

9. *Annual Energy Review 2012.* Figure 1.1, Primary Energy Overview (Consumption). EIA, September 2012. Accessible at: <http://www.eia.gov/totalenergy/data/annual/pdf/aer.pdf>.
10. *Annual Energy Outlook 2012 with Projections to 2035. EIA, June 2012.* Accessible at: <http://www.eia.gov/forecasts/aeo/pdf/0383(2012).pdf>.
11. *Annual Energy Outlook 2012 with Projections to 2035.* EIA, June 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/pdf/0383(2012).pdf>.
12. *Annual Energy Outlook 2012 with Projections to 2035.* EIA, June 2012.

BOX 3 Recent Federal Action 2010–12

Since the 2010 report, federal agencies have taken a number of actions that are reducing GHG emissions. The most significant actions from a GHG reduction perspective are summarized below. These are all incorporated into our new business-as-usual projections.

- **Passenger cars and light-duty trucks.** In August 2012 EPA and the National Highway Traffic Safety Administration (NHTSA) finalized new fuel economy and GHG standards for passenger cars and light-duty trucks for model years 2017–2025. These standards equate to a fleet-wide average of 54.5 mpg (101 g CO_2e/km) if they are met solely through fuel economy improvements (as opposed to reductions in HFC emissions from air conditioners). This is approximately double the fuel economy of vehicles sold in 2010. EPA estimates that the rule will save nearly 2 billion tons of CO_2e over the life of the program. This is in addition to the estimated 960 million tons of CO_2e over the life of the prior regulations for model years 2012–2016.

- **Heavy-duty vehicles.** In August 2011 EPA and NHTSA finalized the first-ever fuel efficiency and GHG emission standards for model year 2014 through 2018 medium- and heavy-duty vehicles. EPA estimates that this rule will reduce CO_2 emissions by approximately 270 million metric tons over the life of vehicles sold during the 2014–2018 model years.

- **Natural gas systems.** In April 2012 EPA finalized four regulations that will reduce emissions of volatile organic compounds, sulfur dioxide (SO_2), and air toxics from oil and natural gas systems. EPA estimates that the new standards will have the co-benefit of reducing annual methane emissions by an estimated 19–33 million metric tons of CO_2e.

- **Energy efficiency standards for new appliances.** Between 2009 and 2011, the Department of Energy established 17 new standards. According to analysis by the Appliance Standards Awareness Project and the American Council for an Energy-Efficiency Economy, these standards are expected to save 126.2 TWh in 2025 and 146.8 TWh in 2035.

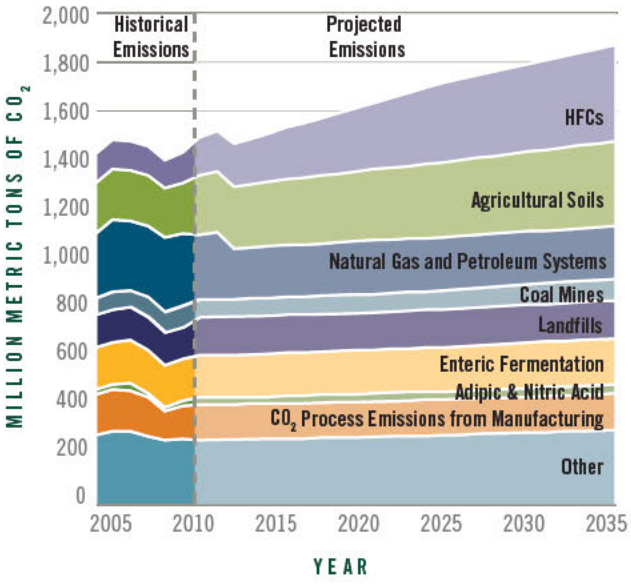
- **Non-GHG regulations for power plants.** EPA has also finalized several other non-GHG-related environmental regulations for power plants, most notably those for mercury and other air toxics. Some modeling has suggested that these rules could lead to the retirement of old, inefficient, coal-fired power plants.

protect and restore the ozone layer in the upper atmosphere, and the Clean Air Act. This trend is expected to continue as the interim substitutes, HCFCs, are also phased out as they are currently being replaced with gases that have a high global warming potential.

- **With the Natural Gas Boon, More Methane Leaks.** Extraction of natural gas in the United States has increased by over 25 percent over the period of 2005 to 2011 due to rapid development of shale gas resources.[13] Increases in natural gas extraction lead to larger fugitive methane emissions from natural gas systems. Fugitive methane emissions are expected to fall significantly, however, due to 2012 EPA regulations that reduce emissions of volatile organic

13. *Monthly Energy Review.* Table 1.2, Primary Energy Production by Source. EIA, December 2012. Accessible at: <http://www.eia.gov/totalenergy/data/monthly/pdf/sec1_5.pdf>.

FIGURE 8 Projected U.S. Non-CO_2 and Non-Energy Emissions if no New State or Federal Action is Taken



Source: U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010 (Years 2005-2010)*; U.S. Environmental Protection Agency, *Draft Global Non-CO_2 Emissions Projections Report 1990-2030 (Non-CO_2 Years 2011-2035)*; RTI, *Applied Dynamic Analysis of the Global Economy Model (Non-energy CO_2 Years 2011-2035)*; *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas.* World Resources Institute. Working Paper. James Bradbury, Michael Obelter, Laura Draucker, Wen Wang, and Amanda Stevens.

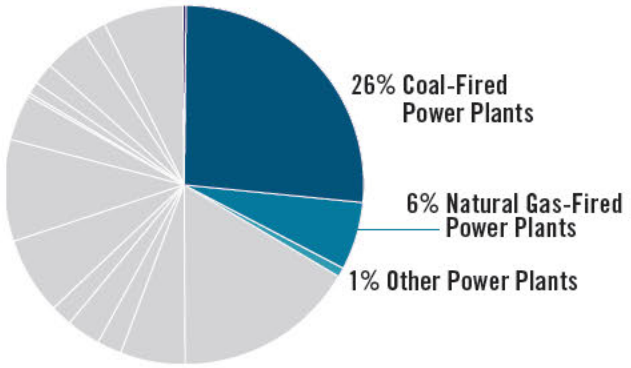
compounds, sulfur dioxide, and air toxics from natural gas systems. Actions to reduce those emissions will also reduce methane emissions (see Box 3 for more details).

IV. Understanding the Federal Reduction Pathways

A. ABOUT THE SECTOR-BY-SECTOR APPROACH

This analysis is a bottom-up assessment of the policies and regulatory tools available to the U.S. Administration, through the federal executive agencies tasked with implementing such regulations—to reduce GHG emissions. The analysis began with an examination of the makeup of U.S. emissions in 2010, followed by research and analysis into existing laws on authority to reduce emissions. We reviewed available literature to determine the range of emissions reductions technically feasible for each sector or subsector. Lastly, we considered legal authority, technical feasibility, cost and political will in constructing lackluster, middle-of-the-road, and go-getter scenarios for each sector or subsector. We briefly describe the scenarios for each sector or subsector below, beginning with the sectors that our analysis indicates offer the greatest potential for reductions. A more detailed discussion of our federal methods is provided in Appendix I.

FIGURE 9 Power Plant Emissions



As a Share of U.S. Emissions in 2010

B. ELECTRIC POWER

The electric sector is the largest single source of GHG emissions in the United States. In 2010 it made up 33 percent of total U.S. GHG emissions, and about 40 percent of all carbon pollution from the combustion of fossil fuels. This sector also represents the single biggest opportunity for emissions reductions using existing legal and regulatory tools.

1. Power plants

Carbon pollution from power plants can be reduced through the following federal regulatory authorities:

TABLE 1 Projecting New Source Performance Standards for Power Plants

	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Existing plants	Emissions reductions consistent with a 5 percent improvement in efficiency starting in 2018.	Aggregate emissions reductions across all electric generators equal to an 18 percent reduction in emissions in 2021 compared to 2012 emission levels, and a 33 percent reduction in 2035.	Aggregate emissions reduction across all electric generators equal to a 38 percent reduction in emissions in 2021 compared to 2012 emission levels, and a 74 percent reduction in 2035.
New plants	Standards initially consistent with EPA's proposal (1,000 pounds of CO_2 per megawatt-hour of output). Beginning in 2020, new unit performance improves to 570 pounds of CO_2 per megawatt-hour by 2030.	Standards initially consistent with the lackluster scenario. Beginning in 2028, new units achieve emissions rates equivalent to carbon capture and storage (CCS) with a 90 percent capture rate.	Standards initially consistent with the lackluster scenario. Beginning in 2020, new units achieve emissions rates equivalent to CCS with a 90 percent capture rate.

TABLE 2 Appliance and Equipment Efficiency Standards (Electric)

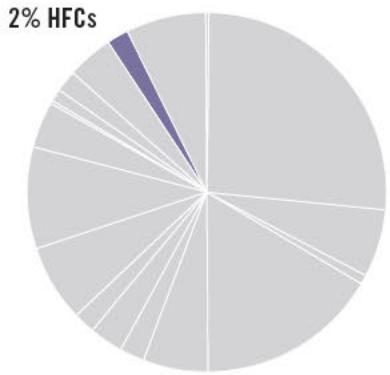
LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
192 TWh savings in 2025 from the residential and commercial sectors, plus additional savings from the industrial sector. Annual savings remain constant through 2035.	212 TWh savings in 2025 and 306 TWh savings in 2035 from the residential and commercial sectors, plus additional savings from the industrial sector.	364 TWh savings in 2025 and 525 TWh savings in 2035 from the residential and commercial sectors, plus additional savings from the industrial sector.

a. **Performance standards for new and existing sources under section 111 of the federal Clean Air Act**
Under section 111 of the Clean Air Act, EPA may prescribe emissions limitations based on the "best system of emission reduction" for new and modified existing sources within source categories EPA determines cause or contribute significantly to air pollution that may reasonably be anticipated to endanger human health or welfare.[14] To determine the "best system of emission reduction," EPA considers technological feasibility, cost, lead time, and energy and non-air environmental impacts.[15] In the spring of 2012 EPA proposed new source performance standards (NSPS) for new power plants.

In addition, for any source category EPA regulates on the federal level, EPA must also promulgate guidelines to states to use in developing requirements for existing sources under section 111(d). In regulating existing sources, states must determine the "best system of emission reduction" for existing sources while taking into account the same factors EPA uses to set limitations for new sources, and also the remaining useful life of existing sources.[16] The form of regulations imposed on existing sources is not tightly prescribed in the statute, and EPA has previously taken the position that states could implement flexible, market-based approaches in setting standards from existing sources. Table I specifies our three scenarios for new and existing power plants under section 111.

b. **Appliance and equipment efficiency standards under Department of Energy authority**
The Department of Energy (DOE) may promulgate efficiency standards for consumer appliances and non-consumer equipment under authority already granted DOE in current law. Based on available studies, the three scenarios analyzed assume progressively greater reductions through appliance and equipment standards, ranging up to 364 TWh of annual savings from residential and commercial consumers in 2025 and 525 TWh annual savings in 2035, with additional savings from industrial consumers.

FIGURE 10 HFC Emissions



As a Share of U.S. Emissions in 2010

C. HYDROFLUOROCARBONS

Hydrofluorocarbons (HFCs), used primarily for refrigeration and air conditioning, represented only 2 percent of all U.S. global warming pollution in 2010. Despite their relatively small share of the U.S. emissions picture today, our analysis finds HFCs can provide some of the greatest reductions by 2020 and through 2035. EPA has existing authority to regulate HFC consumption under Title VI of the Clean Air Act. EPA can phase down the use of HFCs under

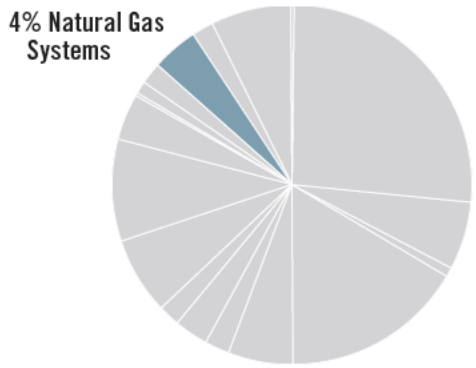
14. 42 U.S.C. §§ 7411(a)(1) & 7411(b)(1)(A).). U.S. Environmental Protection Agency. "Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act." Accessible at: <http://www.gpo.gov/fdsys/pkg/FR-2009-12-15/pdf/E9-29537.pdf>.
15. 42 U.S.C. §§ 7411(a)(1).
16. 42 U.S.C. §§ 7411(d)(1)(B).

TABLE 3 Emissions Reduction Schedule for Hydrofluorocarbons

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Consumption ramp-down occurs three years later than the schedule detailed in the joint North American Proposal.	Consumption is ramped-down in a manner consistent with the joint North American Proposal, which calls for an 85 percent reduction below 2005–2008 levels by 2033.	Consumption is ramped-down more rapidly than in the joint North American Proposal, achieving the 85 percent reduction target in 2028, five years earlier than detailed in the joint North American Proposal.

its Significant New Alternatives Program (SNAP), implementing section 612 of the Clean Air Act. The U.S. Administration has proposed an international ramp-down schedule to achieve reductions worldwide under the Montreal Protocol. Our middle-of-the-road scenarios for HFCs assume this proposed ramp-down schedule is met in the United States. The lackluster scenario assumes that the same ramp-down schedule is implemented, but on a delayed timeline, commencing in 2019 instead of 2016. Meanwhile, the go-getter scenario assumes a more ambitious reduction schedule.[17]

FIGURE 11 Emissions from Natural Gas Systems



As a Share of U.S. Emissions in 2010

D. NATURAL GAS SYSTEMS

Global warming pollution from natural gas systems accounts for approximately 4 percent of U.S. emissions. Yet like HFCs, our analysis suggests that natural gas systems may be among the top emissions reduction opportunities in the near term. Similar to power plants, EPA can regulate natural gas systems by implementing emissions performance standards for methane under section 111 of the Clean Air Act for new and existing natural gas systems. They may also be able to achieve additional GHG emissions reductions

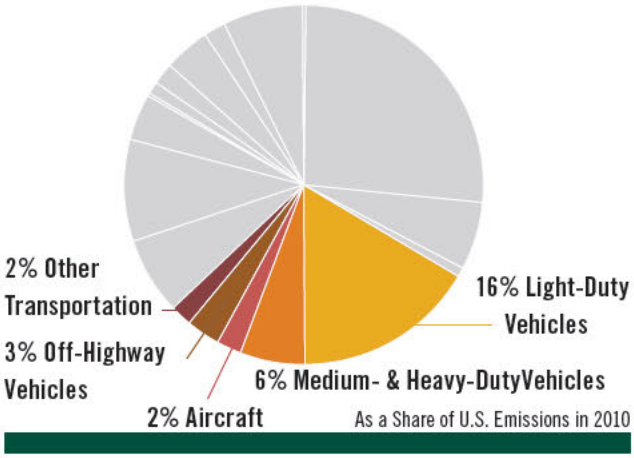
17. Due to modeling limitations, our analysis examines changes in HFC consumption. In the United States, HFC consumption is roughly equivalent to life-cycle emissions due to low rates of capture and destruction. See Appendix I for a more detailed discussion.

TABLE 4 Performance Standards to Reduce Emissions from Natural Gas Systems

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Emissions reductions of 26 percent from business-as-usual starting in 2019. Assumes implementation of plunger lift systems to reduce emissions from liquids unloading at new and existing wells, and leak monitoring and repair to reduce fugitive emissions from production, processing, and compressor stations.	Emissions reductions of 37 percent from business-as-usual starting in 2019. Assumes implementation of measures in lackluster scenario and conversion of existing high-bleed pneumatic controllers to low-bleed or no-bleed controllers to reduce emissions from production, processing, and transmission.	Emissions reductions of 67 percent from business-as-usual starting in 2019. Assumes implementation of measures in middle-of-the-road scenario, as well as desiccant dehydrators to reduce emissions during dehydration of wet gas; improved compressor maintenance to reduce emissions during processing; hot taps in maintenance of pipelines during transmission; and vapor recovery units to reduce emissions during storage.

by tightening standards for other air pollutants, such as volatile organic compounds and air toxics, as they recently did with respect to new equipment in the U.S. oil and gas sector. Through one or more of these regulatory paths, EPA could require equipment changes, upgrades, changes to operational practices, and inspection and leak prevention. Table 4 details the three scenarios analyzed. However, there is a great deal of uncertainty with regard to emissions for natural gas systems. This means that the absolute magnitude of abatement opportunities is uncertain. Nevertheless, our analysis identifies important opportunities to reduce emissions from this sector. Those reductions are some of the lowest cost opportunities identified in this analysis. See the appendix for a more detailed discussion of uncertainties and opportunities.

FIGURE 12 Transportation Emissions



E. TRANSPORT VEHICLES

Transportation is one of the largest sources of global warming pollution in the United States, accounting for 30 percent of the 2010 inventory. Improving the efficiency of motor vehicles has been a priority for the Obama Administration, which promulgated new standards to reduce emissions and raise the fuel efficiency of light-, medium- and heavy-duty vehicles. Our analysis finds that it is possible to achieve additional reductions from light-, medium-, and heavy-duty vehicles. In addition, there are opportunities to reduce emissions of global warming pollution from aircraft and off-highway vehicles.

1. Passenger vehicles

Under Title II of the Clean Air Act, EPA has the authority to regulate greenhouse gas emissions from new light-duty cars and trucks, and has done so already in two consecutive rulemakings covering vehicles sold through model year 2025. In conjunction with EPA's rulemaking, the Department of Transportation's National Highway Traffic Safety Administration (NHTSA) may promulgate corporate average fuel economy (CAFE) standards regulating the average fuel efficiency of new vehicles. Because standards have already been issued covering light-duty vehicles through model year 2025, our analysis focuses on the time period after 2025. Table 5 outlines the three scenarios, with the lackluster scenario projecting improvements at half the rate of the previous standards, middle-of-the-road projecting continuation of the same rate of improvement, and go-getter increasing the rate of improvement significantly.

2. Medium- and heavy-duty vehicles

For medium- and heavy-duty vehicles, EPA has established emissions standards and NHTSA has established fuel economy standards for model years 2014 through 2018. These standards are included in our business-as-usual emissions trajectory. Our emissions reduction scenarios pick up in model year 2020 using the same legal authority, but making different assumptions about the stringency of the next set of standards. As shown in Table 5, our lackluster scenario assumes a rate of improvement that is just half that of the current standards through 2035, middle-of-the-road projects a continuation of the current standards through 2035, and the go-getter scenario considerably increases new standards to meet the maximum level of efficiency currently thought to be technically achievable in that time frame.

3. Off-Highway engines

EPA may also regulate off-highway sources of global warming pollution under Title II of the Clean Air Act. For the lackluster, middle-of-the-road, and go-getter scenarios, respectively, the analysis assumes new standards can achieve 0.9 percent, 1.8 percent, and 2.4 percent annual improvement in the emissions rate for new equipment and engines from 2018 to 2035.

4. Aviation and aircraft

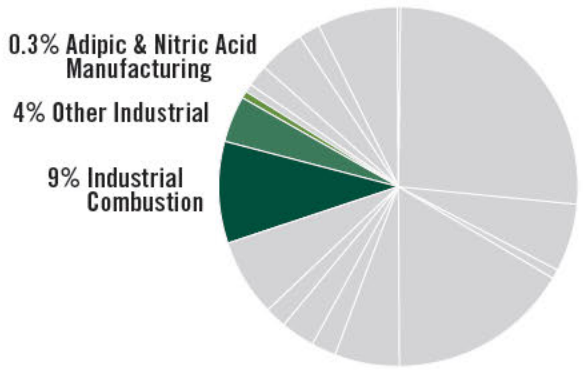
The Federal Aviation Administration (FAA) may make operational improvements in the air traffic control system that could achieve significant carbon pollution reductions over time. We draw our assumptions about operational improvements from an EPA analysis of the reductions possible and the FAA's comments on that analysis. Our scenarios, shown in Table 5, bound the range of reductions estimated by EPA and FAA.

TABLE 5 Vehicle Emissions Standards, Efficiency Standards, and Operational Improvements

	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Light-duty vehicles	Vehicle standards continue to improve from 2026–2035 at roughly half the rate of the 2017–2025 standards (2 percent per year). This results in a 131 grams per mile emissions standard and a 61 mpg CAFE standard in 2035.	Vehicle standards continue to improve from 2026–2035 at roughly the same rate as the 2017–2025 standards (4 percent per year). This results in a 104 gram per mile emissions standard and a 75 mpg CAFE standard in 2035.	Vehicle standards continue to improve from 2026–2035 at 6 percent annually. This results in a 81 grams per mile and a 92 mpg CAFE standard in 2035.
Medium- & heavy-duty vehicles	Standards continue to improve through 2035 at half the rate of the 2013–2018 standards by vehicle category—about a 1.3 percent annual improvement.	Standards continue to improve through 2035 at the same rate as the 2013–2018 standards by vehicle category—about a 2.6 percent annual improvement.	By 2020–2022, the medium- and heavy-duty fleet reduces its emissions rate by an average 26 percent and by 42 percent in 2023–2025 compared to 2010. Standards continue to improve annually by 1 percent through 2035.
Off-highway	From 2018 to 2035, a 0.9 percent annual improvement in the emissions rate for new equipment and engines.	From 2018 to 2035, a 1.8 percent annual improvement in the emissions rate for new equipment and engines.	From 2018 to 2035, a 2.4 percent annual improvement in the emissions rate for new equipment and engines.
Aviation	Through 2035, a 0.17 percent annual emissions reduction from operational improvements via FAA's NextGen Program.	Through 2035, a 0.4 percent annual emissions reduction from operational improvements via FAA's NextGen Program.	Through 2035, a 1.4 percent annual emissions reduction from operational improvements via FAA's NextGen Program, plus a 2.3 percent annual improvement in the performance of new aircraft and engines.

EPA has statutory authority under Title II of the Clean Air Act to promulgate standards to reduce emissions from new and existing aircraft engines. To date, EPA has never exercised that authority to require aircraft engine manufacturers to meet standards that the industry association has not previously adopted voluntarily. Nevertheless, our go-getter scenario, shown in Table 5, projects the emissions reductions that could be achieved if EPA were to pursue this regulatory course of action.

FIGURE 13 Industrial Emissions



As a Share of U.S. Emissions in 2010

F. INDUSTRY

Emissions from industrial facilities comprised 13 percent of U.S. global warming pollution in 2010. Fossil fuel combustion at industrial facilities accounts for 9 percent of U.S. emissions, while non-combustion industrial processes account for 4 percent of emissions. When accounting for upstream, indirect CO_2 emissions from power plants, the industrial sector is responsible for 23 percent of total U.S. GHG emissions.

EPA may regulate industrial stationary sources of emissions through performance standards under section 111 of the Clean Air Act. As with power

TABLE 6 Performance Standards to Reduce Industry Emissions

	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Fossil-fuel combustion in manufacturing and cement kilns	Emissions reductions consistent with a 10 percent improvement in combustion efficiency by boilers.	Emissions reductions consistent with harnessing all cost-effective energy efficiency across all processes and energy uses at manufacturing facilities. Emissions standards also drive reductions in process emissions from cement kilns.	Emissions reductions consistent with harnessing all cost-effective energy efficiency across the entire manufacturing facility. All new units must meet emissions rate equivalent to natural gas combustion. Emissions standards also drive reductions in process emissions from cement kilns.
Refineries	Emissions reductions consistent with a 1 percent improvement in efficiency beyond business-as-usual projections.	Emissions reductions consistent with a 5 percent improvement in efficiency beyond business-as-usual projections.	Emissions reductions consistent with a 10 percent improvement in efficiency beyond business-as-usual projections.
Nitric and adipic acid manufacturing	A 13 percent reduction in emissions.	A 56 percent reduction in emissions.	A 75 percent reduction in emissions.

plants, this is accomplished through EPA's setting of standards for new sources and issuing regulations that provide states with guidelines for covering existing sources. New source requirements typically take the form of a simple emissions rate, while regulation of existing sources can be more flexible.

1. Fossil fuel combustion in manufacturing and cement kilns

As with fossil-fuel burning power plants, reducing the GHG emissions profile of the industrial sector can be accomplished through improvements to the efficiency of boilers, fuel switching, and use of renewable energy such as biomass or geothermal, among other methods. Additional reductions are possible if regulations require a manufacturing facility to capture all cost-effective process efficiencies across an entire operation, beyond the boiler. Table 6 details the three scenarios analyzed for projecting possible reductions from the industrial sector. In addition, for the middle-of-the-road and go-getter scenarios for cement kilns, we assume emissions standards are used to drive reductions in process emissions through greater use of blended cements, and potentially carbon capture and storage, achieving reductions in process emissions of 2 percent in 2020 and 13 percent in 2035.

2. Petroleum refineries

EPA's advanced notice of proposed rulemaking, *Regulating Greenhouse Gas Emissions Under the Clean Air Act,* indicated that efficiency improvements in refineries are possible in the range of 10 to 20 percent. Some efficiency improvements are included in our business-as-usual projections, however. Therefore, in order to generate conservative estimates of emissions reductions, starting in 2018 we model lackluster, middle-of-the-road, and go-getter scenarios with reductions in annual GHG emissions of 1, 5, and 10 percent reductions beyond business-as-usual projections, respectively.

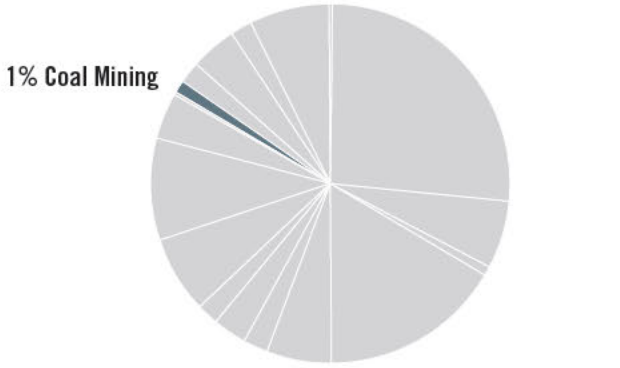
3. Nitric and adipic acid manufacturing

Nitric acid is primarily used as a feedstock for synthetic fertilizer, and also used to produce adipic acid and explosives. Adipic acid is used in the production of nylon and is a flavor enhancer in foods. The production of both compounds leads to emissions of nitrous oxide, a potent greenhouse gas. Though nitric and adipic acid manufacturing makes up less than 0.5 percent of total U.S. global warming pollution, there are opportunities to achieve dramatic reductions at low cost, making it a good target for policy.

To reduce emissions from acid manufacturing, EPA can use its authority under section 111 of the Clean Air Act to set standards for new manufacturing plants and issue guidelines to states to cover existing sources. Our

lackluster, middle-of-the-road and go-getter scenarios project reductions of annual GHG emissions of 13 percent, 56 percent, and 75 percent, respectively, compared to the business-as-usual projections.

FIGURE 14 Coal Mine Emissions

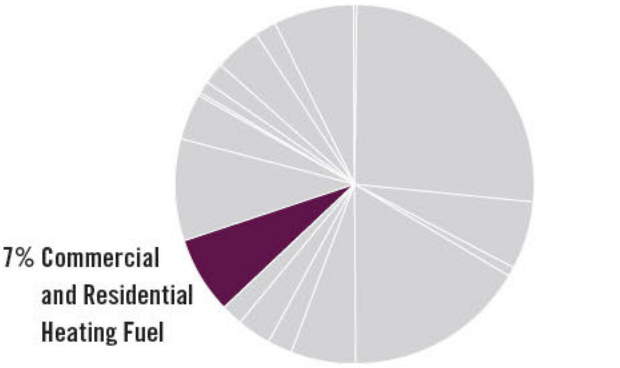


As a Share of U.S. Emissions in 2010

G. COAL MINES

Methane emissions from coal mines represented 1 percent of total U.S. global warming pollution in 2010. EPA may regulate coal mines as a source category under section 111 of the Clean Air Act. As discussed above for power plants and industry, this would entail EPA issuing performance standards for new coal mines and regulations to guide states in their regulation of existing coal mines. The statute does not prescribe the specific form of regulations applied to existing sources. For the lackluster, middle-of-the-road, and go-getter scenarios, we projected reductions from coal mines of 24 percent, 32 percent, and 39 percent, respectively, compared to business-as-usual projections.

FIGURE 15 Commercial & Residential Heating Emissions

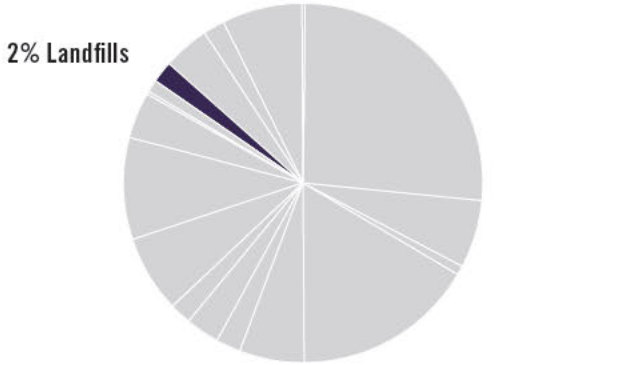


As a Share of U.S. Emissions in 2010

H. COMMERCIAL AND RESIDENTIAL HEATING

Carbon pollution from commercial and residential heating, mostly through natural gas combustion, accounted for 7 percent of U.S. emissions in 2010. This includes things such as home heating, cooking, and water heating. The most effective way to decrease emissions in this sector is to improve the building envelope—a path traditionally the province of state and local governments in the United States. However, the federal government can promulgate efficiency standards for appliances and equipment used to heat buildings. Based on our survey of the available literature, we conclude that efficiency standards implemented in 2015 could reduce natural gas demand by 126 Trillion British thermal units (TBtu) in 2025 and 235 TBtu in 2035, reducing GHG emissions by 6.7 million tons of CO_2 in 2025 and 12.5 million tons CO_2 in 2035 compared to business-as-usual projections. Due to limitations in the available literature, we project the same reductions level for all three scenarios.

FIGURE 16 Landfill Emissions



As a Share of U.S. Emissions in 2010

I. LANDFILLS

Methane emissions from landfills represented 2 percent of total U.S. global warming pollution in 2010. EPA already regulates emissions of volatile organic compounds from landfills under section 111 of the Clean Air Act. These standards provide the co-benefit of reducing methane emissions. EPA could either strengthen those standards or establish new standards for GHG emissions. The statute does not prescribe the form of regulations applied to existing sources. For the lackluster, middle-of-the-road, and go-getter scenarios, we projected reductions of 5 percent, 9 percent, and 9 percent, respectively, compared to our business-as-usual projections. The reductions we

project for landfills in this report are substantially smaller than the reductions projected in the 2010 report. These differences are attributable to changes in the EPA data used in the analysis.

V. Understanding the State Reduction Pathways

Policy action to address environmental challenges frequently begins at the state level, and greenhouse gases are no exception. States were the first to push ambitious emissions standards for vehicles, adopt greenhouse gas regulations for the power sector, and establish economy-wide reduction targets. Many states already have programs that reduce emissions from transportation, improve energy efficiency, and promote renewable generation. In the state scenarios, we examine what would happen if states continue to adopt policies that reduce their GHG footprint.

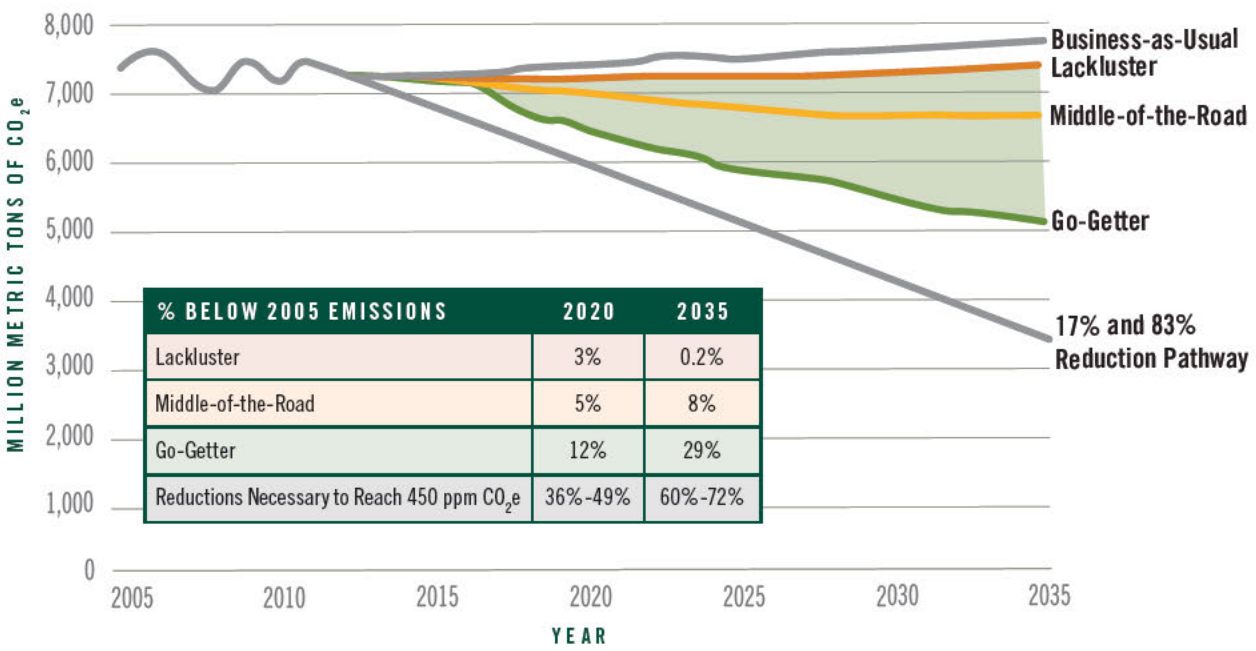
A. ABOUT THE STATES APPROACH

The state analysis takes a two-pronged approach. First, we project the potential greenhouse gas emissions reductions from transportation, end-use energy efficiency, and renewable electricity policies typically undertaken by states. Second, we consider the potential for state action in areas we also consider for the federal government, such as emissions standards for power plants and industry. This is based on the observation that the Constitution grants states broad authority to regulate their energy sources and emissions. States thus have the ability to implement many of the same policies as federal agencies.

In this analysis, the difference between lackluster and go-getter action at the state level is a function of the number and size of the states that adopt the measures modeled, and in some cases the ambition of the policies pursued. Unlike the federal analysis, in some cases state action would require new state legislation. However, we did not attempt to determine which states would require new legislation to implement the state measures and which states could implement without new legislation. A detailed discussion of our state methods is provided in Appendix II.

In addition to the direct emission reduction opportunities modeled here, state-level action can help trigger more ambitious action at the federal level. In the words of Justice Brandeis, states can serve as "laboratories of democracy," testing out approaches that provide possible models for federal action. Action at the state level can also lead to broader support for federal action, with the most ambitious states helping establish a floor for federal ambition.

FIGURE 17 Projected U.S Emissions when States Pursue the Full Range of Policies within their Authority (No Federal Action)



% BELOW 2005 EMISSIONS	2020	2035
Lackluster	3%	0.2%
Middle-of-the-Road	5%	8%
Go-Getter	12%	29%
Reductions Necessary to Reach 450 ppm CO_2e	36%-49%	60%-72%

Note: Due to modeling limitations, this figure depicts HFC consumption, which is generally thought to be equivalent to life-cycle emissions.

B. TRANSPORTATION

As noted above, the transport sector is responsible for about 30 percent of GHG emissions in the United States, making it the second largest emitting sector behind power plants. State and local policies have traditionally played a significant role in transportation, and as a result we project reductions that states might be able to achieve in this area, including through policies to encourage the use of lower carbon fuels and reduce vehicle miles traveled.

1. Lower Carbon Fuels

States may establish requirements for the fuels delivered in their jurisdictions to reduce the carbon profile of those fuels. To project potential reductions through state policies that reduce the life-cycle emissions of transportation fuels, we do not select specific policies in specific states. Rather, we model percent improvements in the carbon profile of fuels generally. These general improvements in the carbon profile of fuels are a proxy for what is likely to be a diverse set of measures across numerous states.

For modeling purposes, we assume that those policies further reduce the average life-cycle carbon intensity of transportation fuels by 1 percent per year between 2015 and 2035. In the lackluster scenario, we assume this annual reduction is achieved by states accounting for 15 percent of total energy consumption from U.S. transportation fuels. In the middle-of-the-road and go-getter scenarios, we assume that these policies are pursued by states accounting for 25 percent and 35 percent of total U.S. transportation fuel consumption, respectively.[18]

2. Reducing Vehicle Miles Traveled

States play a big role in designing and implementing policies that directly impact the number of vehicle miles traveled. These include smart growth strategies, such as targeting new development near public transportation, favoring infill, limiting sprawl, mixed-use development, and provision of smartly located affordable housing options. These strategies can be complemented by a variety of strategies, including improving and expanding public transportation options, bike and pedestrian pathways, car sharing, and HOV lanes, as well as through speed limit restrictions, intercity tolls, and strategies to limit driving within urban centers (e.g., parking restrictions).

In our lackluster and middle-of-the-road scenarios, we assume that states that implement policies and programs achieve VMT reductions of 0.5 percent per year beginning in 2016, leading to a 10 percent reduction below business-as-usual projections in 2035.

18. See Appendix II for context about what it would take to achieve the state uptake in this and the other state scenarios.

TABLE 7 State Transportation Measures

ACTION	POLICIES AND PROGRAMS DRIVING ACTION	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Reduce carbon content of fuels by 1 percent per year from 2015 to 2035	■ Low-carbon fuel standard ■ Clean fuel standard ■ Advanced biofuels standard ■ Infrastructure incentives	States accounting for 15 percent of transportation fuel consumption implement measures to achieve a reduction.	States accounting for 25 percent of transportation fuel consumption implement measures to achieve a reduction.	States accounting for 35 percent of transportation fuel consumption implement measures to achieve a reduction.
Vehicle miles traveled reductions of 0.5 or 1 percent per year from 2016 to 2035	■ Smart growth ■ Improved public transit ■ Pedestrian and biking infrastructure ■ Improved traffic systems operations	States accounting for 15 percent of GHG emissions from light-duty vehicles implement measures to achieve a reduction of 0.5 percent per year.	States accounting for 25 percent of GHG emissions from light-duty vehicles implement measures to achieve a reduction of 0.5 percent per year.	States accounting for 35 percent of GHG emissions from light-duty vehicles implement measures to achieve a reduction of 1 percent per year.

This is on the conservative end of the range found in the state programs under way. Therefore, in our go-getter scenario we assume that states reduce VMT 1 percent per year. We assume that these policies and programs are implemented by states accounting for 15, 25, and 35 percent of GHG emissions from light-duty vehicles in our lackluster, middle-of-the-road, and go-getter scenarios, respectively.

C. ENERGY EFFICIENCY

Energy efficiency measures avoid the need to use fossil fuels and save consumers money, creating significant economic benefits.[19] States are on the front lines in designing and implementing programs to enhance energy efficiency, both for end-use electricity and heating fuels. Our analysis projects the emissions reductions states may achieve implementing energy efficiency programs, building codes, and the increased penetration of combined heat and power. Each type of measure is outlined below.

1. Electricity Savings

States have been the primary drivers of end-use energy efficiency within their borders. Many states have implemented energy efficiency portfolio standards and/or other ratepayer-funded programs to fund energy efficiency investments. Other states have sought to integrate energy efficiency into the process for procuring new generation resources (e.g., in the context of long-term resource planning), so that energy efficiency can compete as a viable alternative to more traditional generating resources.

To project potential emissions reductions from increased state-level energy efficiency policies, we made different assumptions about states with and without such policies. We assume that some states with and without existing energy efficiency targets adopt policies and programs that lead to electricity savings beginning in 2015. Both the rate of savings and the number of states covered varies across the scenarios, as shown in Table 8.

2. Natural Gas Savings

A number of states have also begun to implement energy efficiency programs targeted at natural gas consumption. These programs can resemble those for electricity savings, taking the form of energy efficiency portfolio standards or system benefit charges. As with the electricity savings scenarios, we assume that some states with targets increase those targets, and that some states without targets implement those targets. The scenarios are shown in Table 8.

3. Improving Building Performance

States and municipalities are generally responsible for adopting and updating state and local building energy codes, which apply to new construction and major renovations. Responsibility for enforcing these codes is part of the states' police powers. In our lackluster scenario, we assume that states accounting for 10 percent of the energy consumed by the building sector implement more ambitious building codes. In our middle-of-the-road and go-getter scenarios, we assume that states accounting for 30 and 50 percent of the energy consumed by the building sector implement more ambitious building codes, respectively.

4. Increased Penetration of Combined Heat and Power

The U.S. electricity system is designed to accommodate large central station power plants located away from the electricity customers. Fossil-fuel generating plants operate at 30 to 60 percent efficiency, wasting significant energy in unused heat from the combustion process. Combined heat and power (CHP), or cogeneration, is a form of distributed generation located at or very near end-use customers that captures and puts waste heat to beneficial use.

States have been at the forefront in driving the spread of CHP. They have done so through a variety of policies, including standard interconnection rules, reduced standby rates, net metering policies, friendly air quality regulations (such as output-based emissions regulations), technical assistance programs, and various financial incentives.[20] In our lackluster, middle-of-the-road, and go-getter scenarios, we assume that state action results in deployment of an additional 10, 20, and 40 GW of new CHP by 2025, respectively, beyond business-as-usual projections.[21]

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19. *The Long-Term Energy Efficiency Potential: What the Evidence Suggests.* American Council for an Energy Efficient Economy, Research Report E121, January 2012. Accessible at: < http://www.aceee.org/research-report/e121>.
20. *Challenges Facing Combined Heat and Power Today: A State-by-State Assessment.* ACEEE Report Number IE111, September 2011.
21. In the go-getter scenario, we assume that state action results in deployment of 27 GW of CHP in 2020, in addition to the 13 GW built into our business-as-usual projections. Combined, they result in CHP deployment consistent with the executive order target of 40 GW of new CHP by 2020.

TABLE 8 State Energy Efficiency Measures

ACTION	POLICIES AND PROGRAMS DRIVING ACTION	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Electricity savings from states with EE targets	■ Energy efficiency resource standards ■ System benefit charge funds or other funds ■ Least-cost procurement requirements	States responsible for 75 percent of electricity consumption that have annual energy efficiency targets below 1.5 percent increase their annual target to 1.5 percent from 2015 to 2035.	States responsible for 75 percent of electricity consumption that have annual energy efficiency targets below 2 percent increase their annual targets to 2 percent from 2015 to 2035.	States responsible for 75 percent of electricity consumption that have annual energy efficiency targets below 2.5 percent increase their annual targets to 2.5 percent from 2015 to 2035.
Electricity savings from states without EE targets		States responsible for 25 percent of electricity consumption achieve electricity savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 25 percent of electricity consumption achieve electricity savings of 1.5 percent of total demand per year from 2015 to 2035.	States responsible for 50 percent of electricity consumption achieve electricity savings of 1.5 percent of total demand per year from 2015 to 2035.
Natural gas savings from states with EE targets	■ Energy efficiency resource standards ■ System benefit charge funds or other funds	States responsible for 25 percent of natural gas consumption that have energy efficiency targets below 1 percent achieve savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 50 percent of natural gas consumption that have energy efficiency targets below 1 percent achieve savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 75 percent of natural gas consumption that have energy efficiency targets below 1.5 percent achieve savings of 1.5 percent of total demand per year from 2015 to 2035.
Natural gas savings from states without EE targets		States responsible for 10 percent of natural gas consumption achieve natural gas savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 25 percent of natural gas consumption achieve natural gas savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 50 percent of natural gas consumption achieve natural gas savings of 1.5 percent of total demand per year from 2015 to 2035.
Reduced energy consumption in buildings	■ Commercial and residential building codes ■ Financial incentives	States accounting for 10 percent of the energy consumed by the building sector implement more ambitious building codes.	States accounting for 30 percent of the energy consumed by the building sector implement more ambitious building codes.	States accounting for 50 percent of the energy consumed by the building sector implement more ambitious building codes.
Increased penetration of combined heat and power	■ Standard interconnection rules ■ Reduced standby rates ■ Net metering policies ■ Output-based emissions regulations	State action results in deployment of an additional 10 GW of new CHP beyond business-as-usual projections by 2025.	State action results in deployment of an additional 20 GW of new CHP beyond business-as-usual projections by 2025.	State action results in deployment of an additional 40 GW of new CHP beyond business-as-usual projections by 2025.

TABLE 9 State Renewable Energy Policies

	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Increased renewables from states with renewables targets	States responsible for 25 percent of electricity consumption increase their renewable generation by 1 percent annually after the last year for which a standard is set.	States responsible for 50 percent of electricity consumption increase their renewable generation by 1 percent annually after the last year for which a standard is set.	States responsible for 75 percent of electricity consumption increase their renewable generation by 1 percent annually after the last year for which a standard is set.
Increased renewables from states without renewables targets	States responsible for 10 percent of electricity consumption increase their renewable generation 0.5 percent annually beginning in 2015.	States responsible for 25 percent of electricity consumption increase their renewable generation 0.5 percent annually beginning in 2015.	States responsible for 50 percent of electricity consumption increase their renewable generation 0.5 percent annually beginning in 2015.

D. RENEWABLE ELECTRICITY GENERATION

Similar to energy efficiency, state policies have been major drivers of renewable electricity generation in the United States. Twenty-nine states and the District of Columbia have renewable energy portfolio standards or advanced energy standards. Numerous states also support distributed or customer-sited renewables as part of their RPS or through other ratepayer-funded programs. In order to capture the reductions possible from states taking new or additional action to increase renewable generation serving their residents, we assumed that a certain number of states without renewable energy targets add 0.5 percent renewables per year beginning in 2015. For those states that already have renewables targets, we assumed they continued to add 1 percent a year to those targets after the target is achieved. Table 9 provides details on differences across the scenarios.

E. WHEN STATES TAKE A MORE EXPANSIVE TACK

States have broad authority to regulate energy sources and emissions within their boundaries. They may therefore implement many of the same policies that we ascribe to the federal government in the federal analysis. In determining what reductions states might make in the future, the analysis considers not only traditional state energy policies, but also scenarios in which states decide to approach carbon pollution more expansively. For example, the states participating in the Northeast and Mid-Atlantic Regional Greenhouse Gas Initiative (RGGI) have chosen to design and implement a multistate cap-and-trade program to reduce carbon pollution from power plants in their states. Other states could join them, or take alternative approaches to reducing carbon pollution from power plants. The most significant example of this is California, which has taken an expansive approach to reducing GHGs in its Global Warming Solutions Act of 2006 and the regulations adopted under that law.

Because it is hard to predict which other states, if any, will pursue ambitious standards for greenhouse gases, we modeled more broad-based action by assuming a portion of total national emissions within each sector would be covered by the reduction measures analyzed for the federal government in section IV above. In the lackluster, middle-of-the-road, and go-getter scenarios, we assume these measures are adopted by states accounting for 10, 25, and 50 percent of GHG emissions from a given sector, respectively.

These approaches include state action for all sectors discussed in the federal action section, except for those policies that are ill-suited for state implementation. We deemed policies that eliminate HFCs, regulate off-highway vehicles, adopt appliance and equipment efficiency standards where federal standards already exist, or regulate aviation to be ill-suited to state implementation because they are preempted by federal law.

It is important to note that we vary both the number of states taking action and the level of ambition they each pursue. In all sectors, the level of ambition pursued is the same as the ambition defined in the federal scenario described in Section IV. Therefore, in our lackluster scenario for power plants, we assume states accounting for 10 percent of GHG emissions from the power sector

implement policies equivalent to the lackluster scenario for federal action. In our go-getter scenario, we assume states accounting for 50 percent of GHG emissions from the power sector implement policies equivalent to the go-getter scenario for federal action.

VI. Conclusion: Finding Our Way to a Low-Carbon Future

The enormous economic and social costs of climate disruption are increasingly evident in the United States. Yet the urgency conveyed by the mounting evidence is not yet reflected in U.S. federal and state actions or climate policies. The United States is not currently on path to meet its international pledge to reduce GHG emissions to 17 percent below 2005 levels by 2020, though it could meet this goal with go-getter action by the U.S. Administration under current laws. In order to achieve adequate mid-century reductions, it appears almost certain that the U.S. Congress will eventually have to enact new legislation aimed at getting deep reductions. Ultimately, a cooperative approach bringing together Congress, states, and the executive branch will be necessary for the United States to do its part.

States can contribute to U.S. emissions reductions, both through state-level transportation, energy efficiency, and renewables programs, as well as through new legislative efforts to initiate a wide array of other policies aimed at reducing GHGs. It appears unlikely that state actions alone will put the United States on the necessary course. However, they can help complement federal action, and can enable the United States to meet its 17 percent target if federal agencies fail to pursue go-getter-level action.

KEY RECOMMENDATIONS

- In the short term, federal agencies and the states should aggressively move forward with a "go-getter" emissions reduction scenario. This will necessitate taking action in the following key areas that present the greatest opportunities for GHG emissions reductions through 2020:
  - EPA and the states should focus on achieving significant reductions in carbon pollution from power plants and natural gas systems.
    - For power plants, EPA should finalize its proposed greenhouse gas emissions standards for new power plants and should move ahead with flexible and ambitious standards for existing power plants. States should move ahead with measures to reduce emissions from the power sector, such as increasing the use of renewable power and cogeneration and reducing electricity demand.
    - For natural gas systems, EPA and the states should propose rules that address methane as a greenhouse gas pollutant, which can result in significant reduction of methane leakage throughout the natural gas life cycle. Such rules would complement the volatile organic compound and air toxics rules established in 2012 for natural gas systems that have the co-benefit of reducing methane leakage.
  - The State Department should continue to seek reductions in hydrofluorocarbons through amendments to the Montreal Protocol. But, in the meantime, EPA should begin reducing consumption in the United States using its authority under the Clean Air Act.
  - EPA and the states should also work to improve energy efficiency in the residential, commercial, and industrial sectors.
- Over time, we will need to see reductions from all sectors, and the Administration should use its existing authorities to achieve go-getter-level reductions across the economy.
- Even with go-getter-level action, however, reductions will fall short of the long-term targets necessary to avoid the worst impacts of climate disruption. As a result, congressional action will be necessary.

BOX 4 Risks and Uncertainties

Uncertainties associated with the methods and results of this analysis include:

- **Uncertainties inherent in the models.** As with any modeling analysis of this sort, there is significant uncertainty in projecting the future. The analysis relies heavily on the Energy Information Administration's *Annual Energy Outlook 2012*, which attempts to project energy and emissions trends into the future based on a number of assumptions, including likely fuel costs, economic activity, and source turnover rates. There are also considerable uncertainties in the estimates of fugitive emissions from natural gas systems. All projections are only as good as the assumptions that go into them and the quality of the data modeled.

- **Regulatory impetus.** As the different scenarios suggest, a major uncertainty in the analysis is whether the federal administration will carry out the regulatory actions in a manner sufficient to achieve the reductions that available studies suggest are technically feasible. The lackluster, middle-of-the-road, and go-getter scenarios stand for different levels of regulatory ambition. The go-getter scenario, it should be emphasized, will require steadfast resolve on the part of the Administration and the states.

- **Congressional action.** Federal agencies depend on the U.S. Congress for their budgets. In order to carry out a series of new regulatory actions, federal agencies will require sufficient resources through the annual budget process. In addition, it should be noted that existing authorities can be curtailed through new legislation.

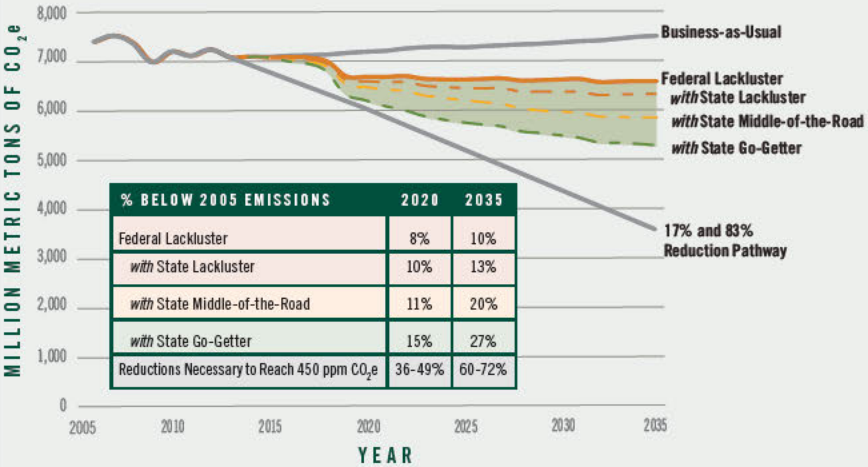
- **Legal risk.** The assumptions made in this analysis were informed by sound legal analysis and vetted with legal experts in the field. Nevertheless, when federal agencies take new actions under existing statutes, the new actions are often challenged in federal court on the grounds that the agency has exceeded the authority originally granted to it in the statute. It is impossible to predict with any precision whether the challenges will be successful.

- **Technological development.** The results modeled depend in part on the development and deployment of new technologies over time. Indeed, many of the regulatory policies are technology-based and must be revised by federal agencies as technology progresses. If technologies emerge rapidly, emissions reductions are more likely. Conversely, if technologies are slow to appear, emissions reductions will slow. This uncertainty is especially important further out into the future.

Supplemental Figures

BOX S-1 Greenhouse Gas Emissions Reductions from State Action Coupled with Lackluster Federal Action

FIGURE S-1 Projected U.S Emissions with State Action Coupled with Lackluster Federal Action



% BELOW 2005 EMISSIONS	2020	2035
Federal Lackluster	8%	10%
with State Lackluster	10%	13%
with State Middle-of-the-Road	11%	20%
with State Go-Getter	15%	27%
Reductions Necessary to Reach 450 ppm CO_2e	36-49%	60-72%

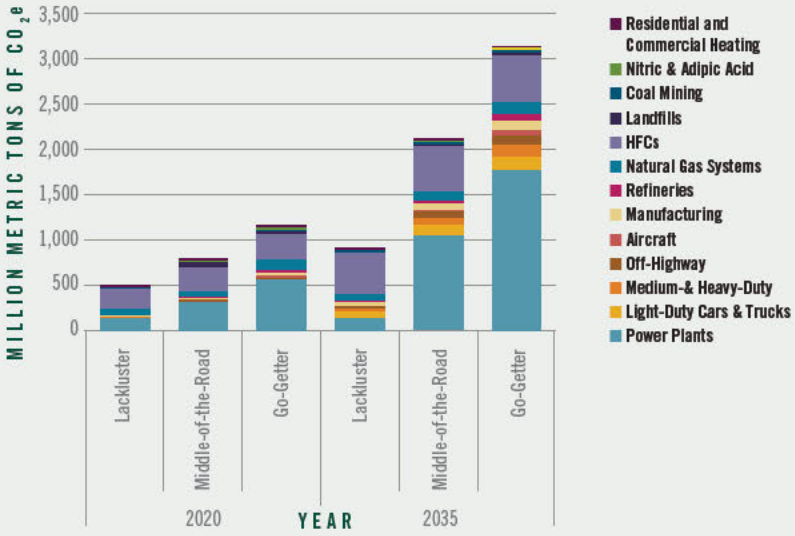
Note: Figure depicts changes in consumption of HFCs.

If the U.S. Administration pursues a lackluster effort, go-getter state action will not be sufficient to make up the emissions gap and reduce GHG emissions 17 percent below 2005 levels by 2020. However, as shown in Figure 2, the 17 percent GHG reduction goal can be achieved with a state go-getter effort along with middle-of-the-road federal action. State action with go-getter federal action is not shown, as it does not provide significant reductions above and beyond other combinations of state and federal action that were considered as a result of the way the scenarios are defined.

BOX S-2 Greenhouse Gas Emissions Reductions from Federal Action

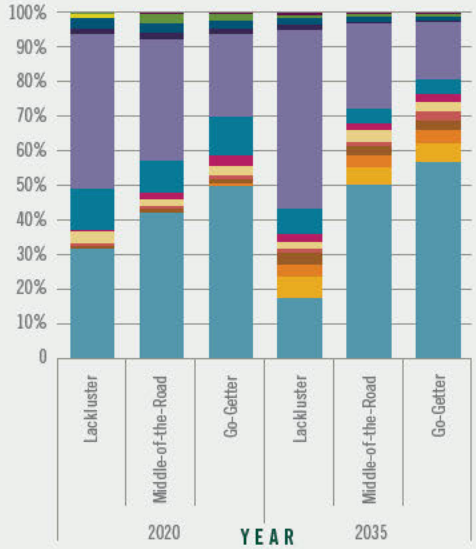
The majority of potential GHG benefits come from actions taken in the power sector, energy efficiency improvements, reducing HFC consumption, and reducing methane emissions from natural gas systems. These actions represent between 80 and 93 percent of potential GHG reductions across all scenarios in 2020 and 2035, and are necessary to achieve a 17 percent reduction below 2005 GHG emissions levels.

FIGURE S-2 Greenhouse Gas Emissions Reductions from Federal Action, in million metric tons



Note: Figure depicts changes in consumption of HFCs.

FIGURE S-3 Greenhouse Gas Emissions Reductions from Federal Action, as a percent of total reductions



Note: Figure depicts changes in consumption of HFCs.

BOX S-3 Greenhouse Gas Emissions Reductions from State Action Only

Improvements in the power sector largely drive reductions in all of the scenarios that examine the impact of state actions without any new federal actions. This is accomplished through a combination of GHG performance standards, renewable and energy efficiency standards, building codes, and policies to promote combined heat and power. In our scenarios those actions can alleviate the demand for up to 1,280 terra watt-hours of conventional sources of electricity in 2035. This is offset to a limited extent through increased vehicle electrification, which increases demand by up to 66 terra watt-hours of electricity in 2035.

States can implement many of the same types of policies as federal agencies. They can also take additional actions that increase electric efficiency, renewable electricity generation, building performance, and combined heat and power penetration.

However, states are less well-equipped to reduce HFC consumption, adopt appliance and equipment efficiency standards where federal standards already exist, and to drive reductions in GHG emissions from off-highway vehicles and aviation. As a result, under our scenarios, state action alone is insufficient to achieve the near-term and long-term GHG reduction targets.

FIGURE S-4 State Actions that Affect Electricity Supply and Demand

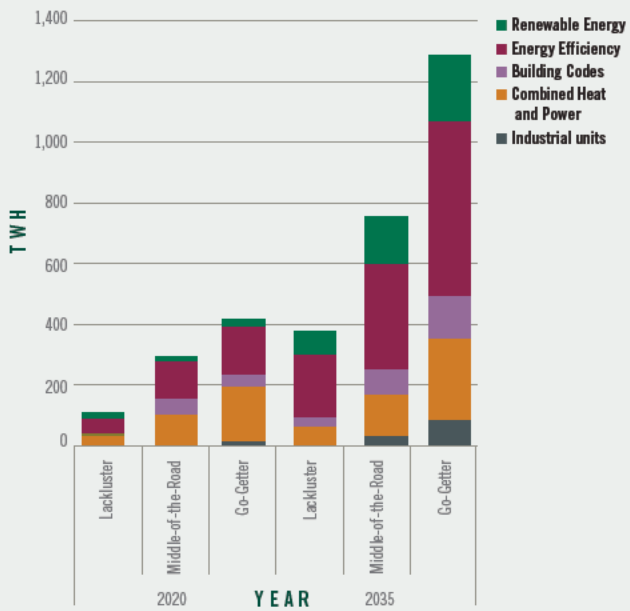


FIGURE S-5 Greenhouse Gas Emissions Reductions from State Action, in million metric tons

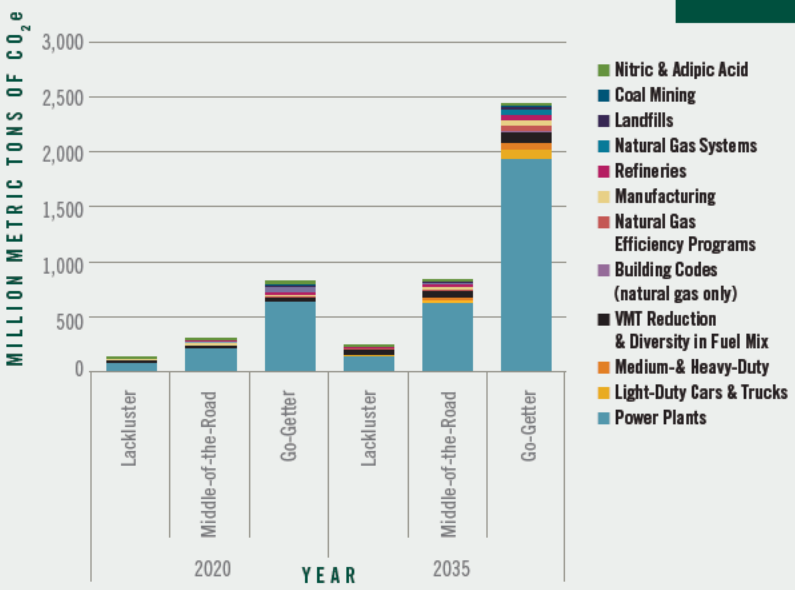
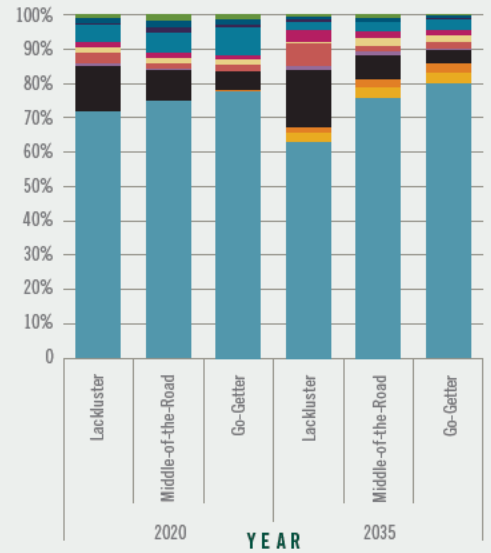


FIGURE S-6 Greenhouse Gas Emissions Reductions from State Action, as a percent of total reductions from state actions



Appendix I: Federal Methods

I. Overview

This analysis projects the range of greenhouse gas (GHG) emissions reductions achievable through regulations and policies implemented by federal agencies under existing federal law and by states under existing or new state laws. This assessment builds on our 2010 report, which began by examining the 2008 national emissions inventory to determine the major sources of emissions. The 2010 report examined both the boundaries of existing federal law and evaluated the published literature to determine the level of emissions reductions achievable from sources in key sectors and subsectors. Due to the difficulty in predicting how federal agencies will act within the bounds of their legal authority, we continue the approach from our 2010 report, which defines three scenarios meant to capture a range of potential reductions in each sector or subsector. Reflecting the available literature, we have defined the scenarios to span a range of different costs, technological assumptions, and types of policies.

Our literature survey examined government and independent reports. We focused on those analyses whose scale was translatable to our model inputs. For example, we focused on studies of entire industrial categories (such as pulp and paper) and not process components (such as steam cracking). We also relied more heavily on studies that provided some assessment of cost in order to provide a sense of the federal regulatory resolve necessary to achieve those reductions. Where a federal agency has provided preliminary estimates of the reductions achievable through regulatory activity, we have attempted to incorporate those estimates into one of the scenarios.

This analysis contains bottom-up analyses of both federal and state action, assessing the total emissions reductions achievable through regulatory actions and policies sector by sector. This appendix provides a summary of the federal analysis. Appendix II provides details on the state analysis.

We calculated the emissions reductions associated with each scenario using an Excel-based model that utilizes publicly available detailed emissions reports, as well as outputs from a publicly available off-the-shelf transportation model (Argonne National Laboratory's VISION model). Most sectoral analyses were independent and did not interact with each other; for example, reductions in coal or natural gas demand from one set of policies did not affect utilization of those fuels in another sector. We account for changes in electric demand through an electric demand module that selectively turned units on and off in a predetermined manner (see Section III.C for more information). We also account for changes in emissions from refineries and natural gas systems due to changes in demand for petroleum products and natural gas, respectively.

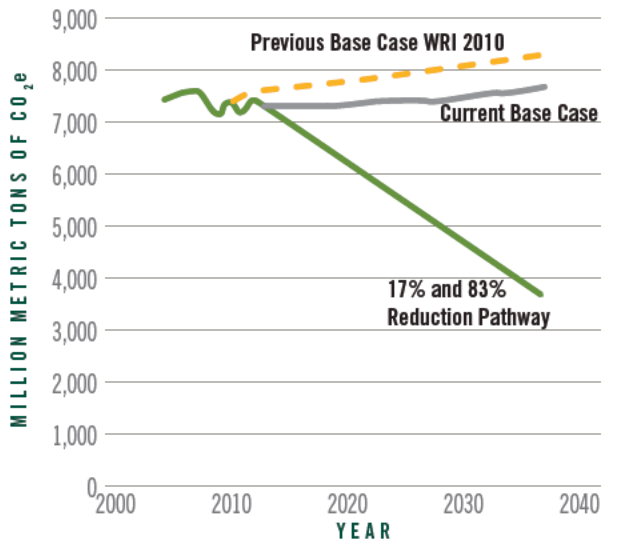
In the pages that follow we describe the base case, modeling assumptions, and scenarios.

II. Base Case

The base case, or "business-as-usual" case, was developed using several different projections. Carbon dioxide (CO_2) emissions from fossil fuel combustion come from the U.S. Energy Information's (EIA's) *Annual Energy Outlook 2012* (AEO2012). Non-CO_2 emissions projections were obtained from EPA's *Draft Global Non*-CO_2 Emissions Projections Report: 1990–2030.[1] Non-energy CO_2 emissions projections were obtained from EPA's ADAGE model reference scenario, as developed for their analysis of HR 2454, the American Climate and Energy Security Act of 2009.[2] The base case emissions projections for natural gas systems come from analysis conducted for *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas*, a forthcoming WRI working paper that examines emissions and abatement opportunities for natural gas systems.[3]

Base case emissions in this report are lower than the base case projections in our 2010 report *Reducing Greenhouse Gas Emissions in the United States Using Existing Federal Authorities and State Action* (see Figure A-1.1). This is largely due to reductions in CO_2 emissions from fossil fuel combustion, driven by a variety of factors, including lower natural gas prices, less optimistic economic projections, and new standards for power plants and light-, medium-, and heavy-duty vehicles. In addition, new standards for natural gas systems have reduced projections of methane emissions.

FIGURE A-1.1 Comparison of Base Case Emissions Projections (2010 v. 2013 Analysis)



A. EIA AEO2012

The AEO is updated annually and is one of the leading sources of economy-wide energy emissions projections through 2035. Data outputs are disaggregated, and more detailed data tables are publicly available upon request, making this an attractive starting point. The 2035 timeline provides enough time to see noticeable impacts from unit turnover. Longer time frames would allow for greater unit turnover, but were not desirable due to the considerable uncertainty in predicting technological availability in future time frames. AEO2012 incorporates updated economic projections, which include a slightly lower growth in GDP through 2035 compared to previous projections. Increases in the natural gas supply, along with lower natural gas prices, are also incorporated into this AEO. It also incorporates several new rules and regulations not included in AEO2009, which was used in our previous report. These include (in a side case) standards for light-, medium-, and heavy-duty vehicles, as well as several regulations affecting the power sector. AEO2012 is described in greater detail in the sections that follow.

B. EPA'S DRAFT GLOBAL NON-CO_2 EMISSIONS PROJECTIONS REPORT: 1990–2030

The AEO does not generally include non-energy and non-CO_2 emissions. Non-CO_2 emission projections for all sources, except for natural gas and petroleum systems and HFC consumption, came from EPA's *Draft Global Non-CO_2 Emissions Projections Report: 1990–2030.*[4] In this report, EPA developed country-specific emissions projections using assumptions about economic activity, technology development, emissions reduction programs and agreements, and other factors. Results were provided in five-year intervals. We estimated emissions between the five-year intervals by applying a linear rate of change. Emissions for 2030 through 2035 were estimated by applying the same rate of change observed from 2025 to 2030.

C. ADAGE

Non-energy CO_2 emissions projections come from the Applied Dynamic Analysis of the Global Economy (ADAGE) reference scenario of EPA's modeling of the American Clean Energy and Security Act of 2009 (ACES).[5] ADAGE is a dynamic computable general equilibrium model run by RTI International.[6] ADAGE projects emissions in five-year intervals from 2010 to 2050. To estimate emissions between those intervals, we applied a linear rate of change between intervals. EPA does not run the ADAGE model annually, but does so in response to congressional requests. For purposes of this report, we are using the most recent publically available results.

D. ADDITIONAL DATA SOURCES

Base case emissions projections for natural gas systems come from analysis conducted for *Clearing the Air on Shale Gas Emissions*, a forthcoming WRI working paper that examines emissions and abatement opportunities for natural gas systems.[7] Their base case projections were developed using EPA's *Inventory of Greenhouse Gas Emissions and Sinks 2012*[8], shale gas production projections from AEO2012, and emissions factors from *Life Cycle Carbon Footprint of Shale Gas: Review of Evidence and Implications.*[9] This report only considers abatement opportunities from natural gas systems. However, because EPA's *Draft Global Non-CO_2 Emissions Projections Report: 1990-2030* lumped natural gas systems with petroleum systems, we also developed projections for petroleum systems using historical emissions[10] and historical production data,[11] as well as projected production data.[12]

Base case projections for HFC consumption come from EPA's *Benefits of Addressing HFCs under the Montreal Protocol.*[13] Additional discussion of this approach is provided in Section V.C. on hydrofluorocarbons. Aspects of the transportation analysis require

assumptions about the vehicle fleet, including stock turnover. For this part of the analysis, we used Argonne National Laboratory's VISION model,[14] adjusting their base case to incorporate the latest EPA and NHTSA standards for light-duty vehicles.

E. NOTE ABOUT GLOBAL WARMING POTENTIALS

Where possible, we have attempted to provide emissions and consumption estimates using the latest state of the science, as reported in the Intergovernmental Panel on Climate Change's (IPCC) *Fourth Assessment Report.* Several data sources—including EPA's *Draft Global Non-CO_2 Emissions Projections Report: 1990-2030*—utilize the global warming potential estimates reported in IPCC's Second Assessment Report. This is done in order to be consistent with international reporting standards under UNFCCC. We do not follow this convention, however, and instead seek to use a more accurate accounting of the actual global warming impact of the different gases. This allows for a more accurate accounting of the actual GHG impacts of new policies as well as inaction.

Unfortunately, we could not update all gases to the global warming potentials reported in the *Fourth Assessment Report*. Detailed speciation is not available for projections of F-gases, and therefore it was not possible to accurately update their projections. Therefore, we did not update historical emissions for F-gases in order to remain consistent with our approach for projected emissions.

III. Power Plants

A. GREENHOUSE GAS PERFORMANCE STANDARDS

1. Base Case

Modeling of the electric sector was based on the AEO2012 reference case and utilized detailed AEO2012 outputs provided by the U.S. Energy Information Administration (EIA) that indicate annual capacity, generation, consumption, and emissions changes by technology type.[15] AEO2012 projects that end-use efficiency will increase over time, and the emissions intensity of generation will decrease. However, it also predicts that electric demand will grow from 3.8 trillion kWh in 2010 to 4.7 trillion kWh in 2035, resulting in an increase in CO_2 emissions to 2.3 billion metric tons in 2035, which is 3 percent above 2010 levels.[16]

The AEO2012 reference case includes mandatory state renewable portfolio standards, the Northeastern and Mid-Atlantic Regional Greenhouse Gas Initiative (RGGI), and California Assembly Bill 32 (AB32).[17] It also includes the Mercury and Air Toxics Standard (MATS) issued by the U.S. Environmental Protection Agency (EPA) in December 2011, as well as the Cross-State Air Pollution Rule (CSAPR) finalized by EPA in July 2011, which reduces sulfur dioxide (SO_2) and nitrous oxide (NO_x) emissions from power plants. CSAPR was vacated by the Federal Circuit Court for the D.C. Circuit in August 2012, marking an inconsistency between the model assumptions and real-world regulatory requirements for power plants. EPA has petitioned for a rehearing of the CSAPR appeal en banc and is expected to appeal the DC

BOX A-1 Modeling New Source Performance Standards under Section 111 of the Clean Air Act

Few performance standards for existing units have been issued to date, and thus far there are no such standards that cover greenhouse gases. In modeling the impact of any future standards, we made certain assumptions about the timing of the implementation of those standards. That timeline is described below. EPA announced their intention to establish emissions standards for existing power plants and refineries in December 2010. Therefore, for modeling purposes we assume that some of the background analysis has been done and that it would be possible for those standards to take effect within five years; that is, beginning in 2018.

TIMELINE
1.5–2 years to adopt federal standards & guidelines to states
1–2 years for states to develop standards for existing sources
3 years for existing units to comply
Total: 6-year lag

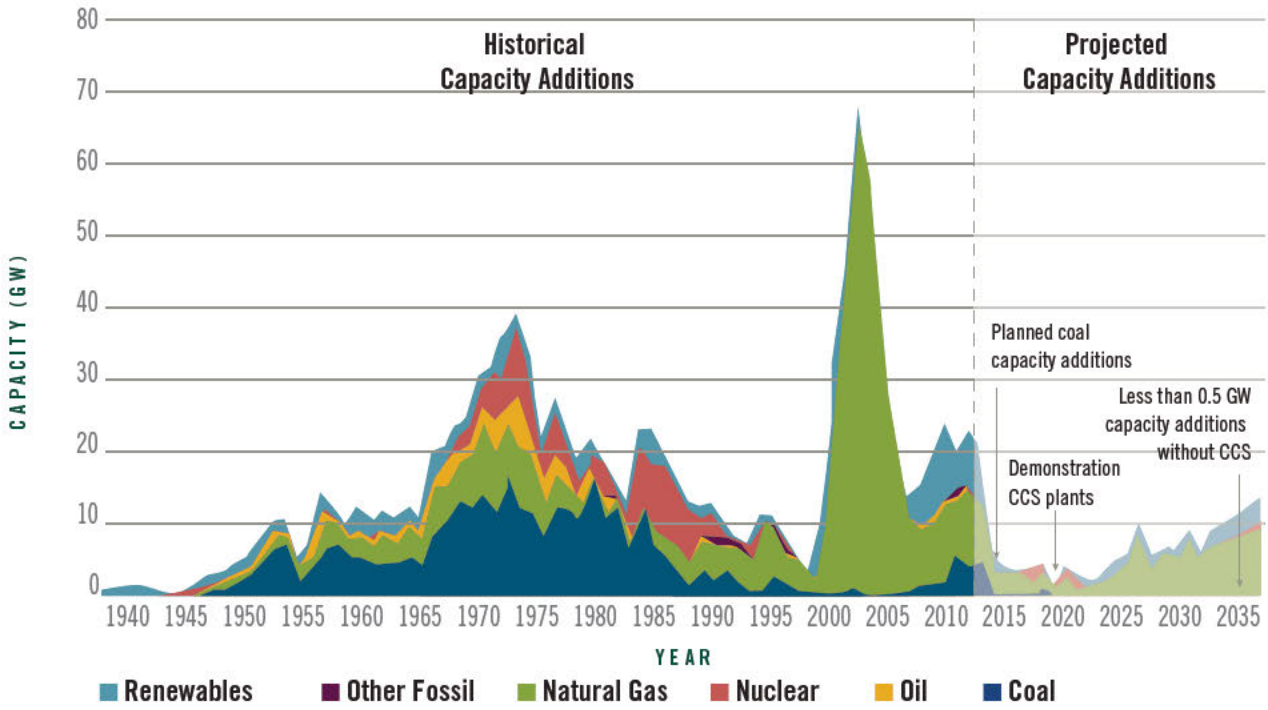
Circuit's decision if it stands. In the meantime, SO_2 and NO_x emissions will be regulated under the Clean Air Interstate Rule (CAIR), which remains in effect.

AEO2012 does not predict any new unplanned coal generation that does not include carbon capture and storage until 2030. This is consistent with trends in new power plant construction since the late 1990s (see Figure A-1.2).

2. Lackluster Scenario for Power Plants

In December 2010 EPA announced they would establish GHG performance standards for new and existing power plants using their authority under section 111 of the Clean Air Act, and that they would finalize those standards by May 2012.[18] In April 2012 EPA proposed performance standards for new power plants. These standards have not yet been finalized, and thus they do not meet the necessary criteria for

FIGURE A-1.2 New Electric Generating Capacity Additions by Fuel Type



Sources: This figure was developed using projections from U.S. EIA's AEO2012 and historical data from EIA Form EIA-860.
Notes: Planned units are defined in the AEO as those units that have commenced construction, but not yet begun operation.

TABLE A-1.1 New Source Performance Standards for Power Plants

	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Existing plants	NSPS are established for existing coal units that achieve fleet-wide average efficiency improvement of 5 percent starting in 2018.	Standards achieve an 18 percent reduction in emissions in 2021 compared to 2012 emission levels, and a 33 percent reduction in 2035.	Standards achieve a 38 percent reduction in emissions in 2021 compared to 2012 emission levels, and a 74 percent reduction in 2035.
New plants	EPA finalizes NSPS as proposed, which set a standard of 1,000 pounds of CO_2 per megawatt-hour of output. After eight years (2020), EPA updates these standards so that new unit performance gradually improves to 570 pounds of CO_2 per megawatt-hour in 2030.	EPA finalizes standards consistent with our lackluster scenario until 2028, at which time they establish new standards equivalent to CCS with a 90 percent capture rate.	EPA finalizes NSPS of 1,000 pounds of CO_2 per megawatt-hour of output. In 2020, they establish new standards equivalent to CCS with a 90 percent capture rate.

inclusion in the base case. EPA has not yet proposed performance standards for existing power plants. For the lackluster scenario (and all subsequent scenarios), we assume that EPA establishes performance standards for new and existing fossil-fuel-fired plants.

a. New Power Plants

In general, EPA's proposed New Source Performance Standards (NSPS) would require new power plants with a base load rating more than 73 MW to meet an annual emissions rate of 454 kgCO_2/MWh (1,000 lbs per MWh).[19] To achieve this emissions rate, new plants will need to employ natural gas, carbon capture and storage, waste heat recovery, or possibly biomass.[20] In all three scenarios, we assume that EPA finalizes an emissions standard that is equivalent to their proposed standards. The Clean Air Act stipulates that once the new standards are finalized they will apply to any covered source that commences construction after the date the **draft** rule was proposed. Therefore, the actual date of finalization is not relevant to this analysis. Consistent with EPA's proposed standards for new units, we assume that coal plants that have already broken ground will not be subject to the proposed standards for new power plants. We therefore do not apply the new standards to the 9.3 GW of "planned" coal units in EIA's reference case.

The Clean Air Act requires EPA to evaluate standards for new units every eight years. Thus, in the lackluster scenario we assume that EPA updates these standards after eight years, and that the new standard requires new units to gradually improve their emissions rate so that they reach 570 lbs/MWh by 2030. This target is consistent with increasing the efficiency of a natural gas unit to 70 percent, a target set by the Electric Power Research Institute (EPRI) in their 2009 Prism/MERGE analysis. This study identifies itself as a "technically and economically feasible roadmap for the electricity sector as it seeks to reduce its greenhouse gas emissions over the next few decades."[21] We assume EPA holds this 570 lbs per MWh emissions standard constant from 2030 through 2035.

As noted previously, AEO2012 does not predict any new unplanned coal generation that does not include CCS until 2030. We also note that GE has reported achieving 61 percent efficiency in their new combined cycle units, which is not required under the lackluster scenario until 2021.[22]

b. Existing Power Plants

In the lackluster scenario, we assume that performance standards achieve a modest 5 percent reduction in the emissions rate at existing coal plants through efficiency improvements. The average 5 percent improvement rate comes from EPA's *Advanced Notice of Proposed Rulemaking: Regulating Greenhouse Gas Emissions under the Clean Air Act* (ANPR) issued on July 11, 2008. In the ANPR, EPA noted that heat rate reductions of up to 10 percent are feasible at many coal-fired power plants, and that the potential average heat rate reduction for the entire coal fleet would likely be about 5 percent.[23] A 5 percent improvement in heat rate would reduce greenhouse gas emissions by 5 percent at existing coal plants. Alternatively, plants could achieve (or exceed) a 5 percent reduction in emissions by switching in whole or in part to lower carbon fuels such as natural gas and sustainably harvested biomass, or through greater use of waste heat.

The 5 percent improvement rate is assumed to be a fleet-wide average as some units may be able to achieve greater or fewer reductions. This average improvement rate could be realized through the establishment of unique standards for various subcategories of power plants.[24,25]

We assume that the new standards take effect in 2018. This is one year earlier than performance standards for most other source categories. We believe that this more expedited time frame is relevant, however, because EPA's December 2010 announcement about their development of performance standards for existing units (and for refineries) suggests that some of the regulatory analysis should already be completed.

After consulting with a variety of technical experts and conducting a literature review, we were unable to find a reliable public source that would support an assumption about immediately available opportunities for improving the efficiency of the existing natural gas fleet. As a result, we do not include reductions from existing gas plants in the reductions for the lackluster scenario.

c. Modeling Notes

To model reductions achieved through these standards, we made use of intermediary coal modeling results for the AEO2012 reference case, which were furnished upon request from EIA.[26] Those results show projected capacity, generation, consumption, and emissions by technology type for new, planned, and existing units through 2035.

We relied on the AEO2012 reference case for predictions of new unit construction and generation. We assume that all new units meet the new source standard applicable at the time of construction, with the exception of simple cycle units, which are excluded from EPA's new unit standards.

For modeling purposes, the 5 percent average improvement was applied evenly across all existing coal-fired units. We assumed that improving the efficiency of coal plants would decrease the marginal cost of generation, which would increase their competitiveness and lead to increased operation at those plants (and decreased generation by gas plants). This phenomenon has been examined by two recent studies by Resources for the Future, *Retail Electricity Price Savings from Compliance Flexibility in GHG Standards for Stationary Sources*,[27] and *Regulating Greenhouse Gases from Coal Power Plants under the Clean Air Act*.[28] The studies did not examine this precise scenario. However, based on conversation with the authors (Burtraw and Woerman), we decided that the greatest parallels were with the unit-specific subcategorization approach they presented at the annual meeting of the Association of Environmental and Resource Economists. Therefore, we modeled a 0.83 percent increase in coal generation as a result of the efficiency gains driven by the performance standards.[29]

3. Middle-of-the-Road Scenario for Power Plants

a. New Power Plants

The middle-of-the-road scenario builds off the assumptions in the lackluster scenario, establishing an initial standard of 1,000 lb/MWh, and the subsequent improvement period, which would achieve 570 lbs per MWh by 2030. Before reaching that 2030 goal, however, we assume that EPA updates their standards again (eight years after the previous update), so that in 2028 new units are held to a standard that is consistent with the utilization of carbon capture and storage at a 90 percent capture rate. We assume that this emissions rate would apply to all units regardless of fuel type. This treatment is consistent with EPA's proposed emissions standards for new power plants.

b. Existing Power Plants

For the middle-of-the-road and go-getter scenarios, we assume that EPA takes a more flexible approach when establishing performance standards for existing power plants. Thus, instead of requiring source-by-source compliance with a fixed emissions rate (as we did in the lackluster scenario), we assume that sources can comply through a range of other measures that reduce emissions from regulated emissions sources in the power sector. Such options could include fuel switching, low-carbon dispatch of existing power plants (e.g., operating a gas plant more and a coal plant less), increased generation by renewable sources, and energy efficiency, among other actions. These reductions could be recognized through a range of different programs such as fleet-wide averaging, rate-based trading programs, a portfolio of measures, or cap and trade.

In the middle-of-the-road scenario, we assume that standards take effect in 2018 and gradually improve, resulting in an 18 percent reduction in emissions in 2021 compared to 2012 emission levels. We assume that EPA would subsequently update these standards in 2026, which would lead to an additional 18 percent reduction in emissions in 2029 compared to 2021 emissions levels. These standards result in 33 percent fewer CO_2 emissions from power plants in 2035 compared to 2012.

Several recent proposals—introduced in conferences and meetings by academics and environmental organizations—have discussed potential approaches to regulating greenhouse gas emissions under the Clean Air Act. The level of reductions included here is comparable to a recently published proposal by the Natural Resources Defense Council (NRDC), though we did not model their specific proposal.[30] NRDC's proposal would allow for power plants to comply through onsite efficiency improvements, by shifting power generation to lower or non-emitting plants, and through demand-side efficiency improvements. However, we also note that analysis of EIA's AEO2012 projections of natural gas-fired plant capacity shows that there is sufficient slack capacity in existing natural gas units to achieve the initial 18 percent reduction entirely from re-dispatch of the existing fleet (i.e., increasing generation from natural gas plants and decreasing generation from coal plants).[31] Further reductions of the magnitude we model through 2035, however, would likely require new sources of carbon-free electricity (e.g., renewable or nuclear), increased deployment of carbon capture and storage, or a significant expansion of energy efficiency programs.

c. Modeling Notes

Note that due to the low projections of unit turnover in AEO2012, for modeling purposes we did not explicitly include additional NSPS for new units in the middle-of-the-road scenario; instead, we assumed that more stringent standards for new sources will make it easier to achieve the reductions required under the existing unit standards, as new units covered by the standard will emit fewer GHG emissions than the units that they are replacing.[32]

4. Go-Getter Scenario for Power Plants

a. New Power Plants

Similar to the lackluster and middle-of-the-road scenarios for new plants, the go-getter scenario assumes that EPA finalizes emissions standards for new units that mirror their proposed standards. The go-getter scenario assumes that EPA updates these standards again in 2020 to a standard that is consistent with the utilization of carbon capture and storage at a 90 percent capture rate, eight years earlier than assumed in the middle-of-the-road scenario.

b. Existing Power Plants

The go-getter scenario assumes EPA sets emissions standards for existing units that lead to a 38 percent and 74 percent reduction in energy CO_2 in 2020 and 2035 (respectively) compared to 2012. This level of reductions would likely require implementation of a flexible compliance program, such as the one described in the middle-of-the-road scenario. Because no NSPS for existing units have been proposed to date that cover greenhouse gases, we made the assumption that implementation of those standards would not start until 2018, and that EPA would provide a three-year glide path before achieving the emissions reduction target.

To establish the emission targets for this scenario, we used carbon price modeling results from EIA. Specifically, we utilized a side case from EIA's AEO2012 that examined the impact of an initial $25 price on carbon starting in 2013 that increases by 5 percent each year above inflation and reaches $35 per metric ton in 2020 and $73 per metric ton in 2035. It is clear that EPA does not have the authority to establish a carbon tax. These results are valuable, however, as they help elucidate the cost of abatement, and thus offer insight into the level of reductions that could be achieved through flexible standards under section 111(d).

c. Modeling Notes

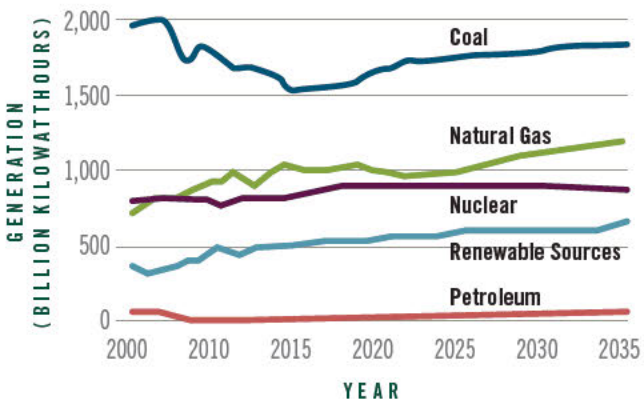
To model the existing standards for power plants, we assumed that generation and emissions would remain consistent with the base case (AEO2012 reference case) through 2017, and steadily change so that in 2021, generation and emissions would be the same as those projected in EIA's carbon price side cases.

The go-getter scenario assumes more than 2.5 times more new generation capacity will be built by 2035 compared to the base case scenario. The vast majority of this new capacity consists of renewable, nuclear and natural gas sources. The only coal units built under this scenario have carbon capture and storage technology installed. Because of the trend for installing low- or no-carbon emitting power units inherent under this scenario, for modeling purposes we did not explicitly include additional NSPS for new units; instead, we assumed that these standards help achieve the more flexible and ambitious existing unit standards.

5. Additional Notes for Power Plants

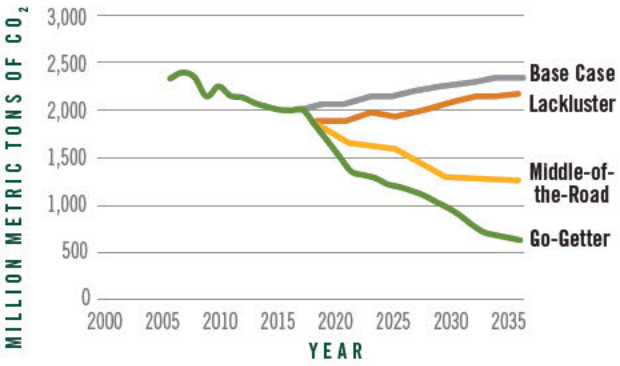
In addition to performance standards for new and existing power plants, emissions from electric generation are also affected by changes in the demand for electricity. We account for demand changes resulting from a wide-range of actions in an electric demand module, as described in section III.C.

FIGURE A-1.3 Base Case Electricity Generation by Fuel Type



Source: AEO2012, EIA

FIGURE A-1.4 Power Sector Emissions After Accounting for Changes in Demand



B. APPLIANCE AND EQUIPMENT EFFICIENCY STANDARDS (ELECTRIC)

1. Base Case for Appliance and Equipment Efficiency Standards (Electric)

The base case uses the AEO2012 reference case. The AEO2012 reference case assumes total electricity consumption in the residential sector increases over time, but the delivered energy per household declines at an average rate of 0.9 percent. About one-half of the decline in energy delivered per household can be attributed to more efficient space heating. Additional demand decreases for space heating is predicted to result from population shifts to warmer and drier climates. The reference case also assumes that despite growth in commercial floor space, improved commercial equipment efficiency slows the increase in purchased electricity through 2035.[33] Between 2009 and 2011, the Department of Energy established 17 new equipment standards that are expected to save 126 TWh in 2025 and 147 TWh in 2035.[34]

The Department of Energy may promulgate efficiency standards for consumer appliances and non-consumer equipment under existing federal law.[35] The law lists appliances and equipment that may be the subject of efficiency standards, prescribes minimum standards for certain appliances and equipment, and also prescribes a process through which the Secretary of Energy may add additional appliances and equipment to those regulated.[36]

2. Lackluster Scenario for Appliance and Equipment Efficiency Standards (Electric)

We identified three studies that quantify energy savings achievable through enhanced energy efficiency standards beyond the base case. Those three studies are summarized below. For the lackluster scenario, we chose the lowest range of energy efficiency improvements over the study period from all of the studies, which was estimated to result in 192 TWh of savings from the residential and commercial consumers in 2025, plus an additional 36 TWh of savings from the industrial sector.

In *The Efficiency Boom: Cashing In on the Savings from Appliance Standards*, the American Council for an Energy-Efficient Economy (ACEEE) and the Appliance Standards Awareness Project (ASAP)[37] quantified the benefits from potential new or updated standards for 34 product categories that could be adopted within the next several years. They estimate that those standards could result in 212 TWh savings from residential and commercial consumers in 2025, and 306 TWh savings in 2035. Energy savings were calculated as reductions compared to current units, assuming fixed demand for the appliances. The authors note that many important standards are due between 2013 and 2015. The standards included were found to save consumers money over the life of the product, with an average simple payback period of 3.3 years. Individual product payback periods range from less than a year to 10.1 years.

TABLE A-1.2 Appliance and Equipment Efficiency Standards (Electric)

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
192 TWh savings in 2025 from the residential and commercial sectors, plus additional savings from the industrial sector. Annual savings remain constant through 2035.	212 TWh savings in 2025 and 306 TWh savings in 2035 from the residential and commercial sectors, plus additional savings from the industrial sector.	364 TWh savings in 2025 and 525 TWh savings in 2035 from the residential and commercial sectors, plus additional savings from the industrial sector.

The Institute for Electric Efficiency's (IEE)[38] study—*Assessment of Electricity Savings in the U.S. Achievable through New Appliance/Equipment Efficiency Standards and Building Efficiency Codes (2010-2025)*[39]— examined what IEE deemed "moderate" and "aggressive" efficiency improvement scenarios. IEE's moderate scenario assumes existing efficiency standards are increased to levels consistent with currently available products, and efficiency standards are created for some appliances and equipment that do not currently have standards. The IEE moderate scenario was found to result in electricity savings of 228 TWh in 2025 from the AEO2011 reference case for the residential, commercial, and industrial sectors. Of those savings, 192 TWh were projected to come from the residential and commercial consumers, and 36 TWh were projected to come from the industrial sector. The IEE aggressive scenario contains "more aggressive efficiency assumptions onto those embedded in the moderate case." The IEE study concluded that 364 TWh could be saved in 2025 compared to the AEO2011 reference case under the IEE aggressive scenario for the residential and commercial sectors. Another 63 TWh of savings were projected to come from the industrial sector.

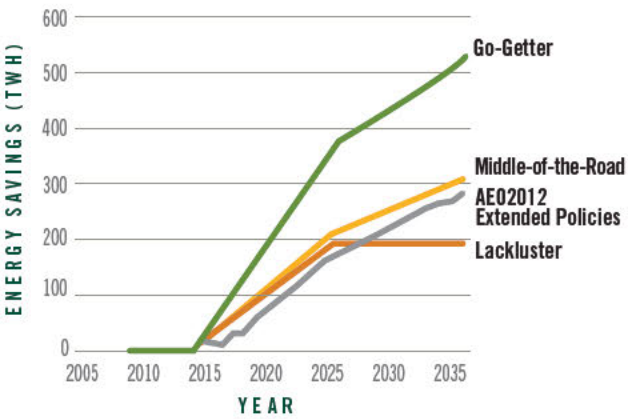
The third study we considered was the "extended policies" side case from AEO2012. This side case "examined updates to existing efficiency standards for residential and commercial products as well as the creation of efficiency standards for products not currently covered." Energy savings in this side case reach about 164 TWh in 2025 and nearly 280 TWh in 2035 from the residential and commercial sectors.

For the lackluster scenario, we chose the lowest range of energy efficiency improvements from all of the studies over the entire study period, which was the IEE moderate scenario. This scenario estimated 192 TWh of electricity savings in 2025 from the AEO2011 reference case in the residential and commercial sectors, and an additional 36 TWh of savings from the industrial sector. Applying these savings to the AEO reference case in 2025 results in a 5 percent reduction in electric demand. For this analysis, we assumed that standards commence in 2015 and result in a constant increase in savings between 2015 and 2025.Unfortunately, 2035 results were not provided. In order to develop intentionally conservative results, we hold the reported reductions achievable in 2025 constant through 2035. We do this even though stock turnover continues, in part because the AEO2012 reference case continues to increase appliance efficiency through 2035. While this study compares its savings to those modeled in AEO2011, we assumed that the potential energy savings reported in these studies can be applied to the base case, which utilizes AEO2012.[40]

3. Middle-of-the-Road Scenario for Appliance and Equipment Efficiency Standards (Electric)

The middle-of-the-road scenario is based on the middle range of energy efficiency improvements from the studies. Specifically, we use *The Efficiency Boom: Cashing In on the Savings from Appliance Standards*, which concluded that the 34 standards considered would save residential and commercial consumers 212 TWh in 2025 and 306 TWh in 2035. These savings amount to a 5 percent and 7 percent reduction in electric demand in 2025 and 2035, respectively, compared to the AEO2012 reference case. These results are comparable to those found by EIA in their side case. We relied on *The Efficiency Boom* because it lists specific product standards and dates, so that future actions can be easily compared. The EIA side case also included updated standards as well as new standards for products not yet covered by efficiency standards. AEO did not provide this same level of detail. For purposes of this analysis, we assumed that standards commence in 2015 and result in a constant increase in savings between 2015 and 2025 and from 2025 to 2035. The middle-of-the-road scenario for GHG performance standards for industry, as detailed in Section XI, includes considerable efficiency gains. Therefore, to avoid double counting, we do not assume any additional industrial efficiency gains are obtained as a result of appliance and equipment efficiency standards for industry. This does not mean that equipment efficiency standards would not be beneficial, just that we do not consider them here to ensure the development of conservative emissions reduction estimates.

FIGURE A-1.5 Energy Savings (TWh) from Residential and Commercial Appliance Efficiency Standards



4. Go-Getter Scenario for Appliance and Equipment Efficiency Standards (Electric)

The go-getter scenario is based on the highest level of reductions reported in the three reports, which was the aggressive scenario in the IEE study. IEE's aggressive scenario resulted in energy savings from equipment standards in the residential and commercial sectors of 364 TWh in 2025 from the AEO2011 reference case. It also resulted in 63 TWh of savings from industrial consumers in 2025. For the reasons outlined in the middle-of-the-road scenario for appliance and equipment efficiency standards, above, we did not include savings from industrial equipment standards.

We assumed that standards commence in 2015 and result in a constant increase in savings between 2015 and 2025. This study did not provide 2035 results. However, the other study we relied on—*The Efficiency Boom*—found that electricity savings increased between 2025 and 2035 due to stock turnover. We also note that additional standards are possible after 2020. Therefore, in our go-getter scenario, we take a less conservative approach to estimating savings in 2035 than we do in the lackluster scenario. We assume that annual energy savings increase between 2025 and 2035 at an annual rate consistent with the middle-of-the-road scenario (3.7 percent per year). This results in 525 TWh of savings in 2035. These savings amount to a 9 percent and 11 percent reduction in electric demand in 2025 and 2035, respectively, compared to the AEO2012 reference case.

5. Modeling Notes for Appliance and Equipment Efficiency Standards (Electric)

The energy savings from increased appliance and equipment efficiency standards in each of the three scenarios was fed into the electric demand module, which incorporates the full range of changes to electricity demand due to factors such as increased energy demand from electrification of light-duty and off-highway vehicles, and reduced demand for electricity as a result of increased deployment of combined heat and power (CHP) in the industrial sector. For more information about the electric demand model, see Section III.C.

Because we relied on EIA's AEO2012 $25 carbon tax scenario for the go-getter power sector generation projections, we had to make further adjustments to these efficiency savings. EIA's scenario predicts that the carbon price will increase electric rates and that this will lead to additional energy savings beyond the AEO2012 reference case. We assume that these savings will overlap with those resulting from increased appliance and equipment efficiency standards, and therefore discount them in the model. In 2035, for example, though the standards are predicted to result in 525 TWh of savings, we only model 270 TWh of incremental efficiency savings because the carbon price scenario already included 255 TWh of efficiency savings.

C. ELECTRICITY DEMAND

1. Lackluster Scenario for Electricity Demand

In order to provide a conservative estimate of the benefit of policies that reduce electricity demand, we begin by preventing the building of the "average" unplanned fossil-fired unit (i.e., new units that have not yet commenced construction). Through most years this is natural gas. In later years this affects the small amount of new coal plants that do not have carbon capture and storage in the AEO reference case (less than 0.5 GW). Next, we turn off the "average" existing fossil-fired unit. We reduce CO_2 emissions according to the average emissions rate because it is challenging to predict what the marginal emissions rate will be nationwide throughout the time frame considered. Furthermore, while marginal units tend to be natural gas in some regions of the country (such as New England),[41] they are coal in other regions. Due to the predominance of coal in the system, this results in the retirement of about 1.5 MW of electricity from coal plants for every 1 MW of electricity from every gas

plant. We do not turn off existing renewable or nuclear sources, as we assume that the bulk of the capital costs are already sunk, and the operational costs are lower than fossil units.

Depending on the specific combination of state and federal action, we account for four types of measures, which have slightly different impacts on the generation mix:

- Those that reduce overall electricity demand (e.g., appliance standards and building codes);
- Those that generate electricity that does not get put onto the grid (e.g., CHP programs where the electricity used is predicted to be behind-the-meter);
- Those that increase demand (e.g., vehicle electrification); and
- Those that generate electricity that is put onto the grid from other clean sources (e.g., renewable programs).

Policies that reduce demand or that generate electricity that does not get put onto the grid reduce the total amount of electricity sold onto the grid. This can reduce renewable generation driven by state renewable mandates because those mandates are typically set as a percentage of total electricity sales. Most of the renewable energy built through 2030 in the lackluster scenario (which is modeled off of the AEO2012 reference case) appears to be due to renewable standards. Therefore, we reduce new renewable generation in a manner that is proportional to the predicted reduction in electricity sales due to electricity demand reduction and programs and policies that generate electricity that does not get put onto the grid.

Policies that increase demand offset the impact of programs that reduce demand or that generate electricity that is not sold on the grid. In none of the modeled scenarios do we predict that demand reductions will be outstripped by electricity demand increase due to various policies considered.

Policies that generate electricity that is put onto the grid from other clean sources do not reduce total sales, and thus do not impact the renewable mandates. They do, however, reduce the demand for other sources of electricity, and thus affect the construction of new units and the operation of existing fossil units in a manner that is similar to policies that reduce electricity demand.

None of the scenarios shut down the lone carbon capture and storage project that is predicted to be built as this demonstration project is hardwired into the AEO, and is not the result of economic factors.

2. Middle-of-the-Road Scenario for Electricity Demand

To evaluate the middle-of-the-road scenario for electricity demand, we had to consider the dynamics of the middle-of-the-road scenario for performance standards for existing power plants, which is an amalgamation of a number of proposals being considered at the federal level. There are currently no detailed sector outputs for any of those proposals that display the predicted generation, consumption, and emissions from existing and new units by type. Therefore, we cannot readily turn off discrete types of new or existing units in response to changes in electricity demand. However, this may be less problematic than would otherwise appear. Several of the proposals under discussion establish a target emissions rate for fossil-fired power plants. Under such an approach, demand reductions could provide a benefit that is proportional to the emissions rate for regulated sources. In this scenario, the emissions rates ranged from 0.67 tons of CO_2/MWh in 2021 to 0.5 tons of CO_2/MWh in 2035.

3. Go-Getter Scenario for Electricity Demand

The go-getter approach is based on the $25 carbon tax scenario from EIA's AEO2012. Thus we have detailed sector outputs that allow us to follow a very similar process as the lackluster scenario, with one key difference. In this scenario renewable projects become cost competitive with fossil plants, and thus there is a three-fold increase in renewable energy development. Therefore, we treat new renewables the same as other new non-renewable resources, and prevent their construction on a proportional basis in response to reductions in demand, as long as the residual renewable generation meets the appropriate set of state renewable standards. This causes any change in demand to have a lower impact in terms of GHG emissions than it does in the lackluster and middle-of-the-road scenarios.

EIA's AEO2012 $25 carbon tax scenario predicts lower electric demand compared to their reference case due to higher electricity prices. We assume that much of that reduction will be driven by the purchase of more efficient appliances, and thus discount

electricity demand savings otherwise predicted by new efficiency standards for appliances and equipment.

4. Additional Modeling Notes for Electricity Demand

The state action scenarios result in a mixture of states with and without carbon policies for the electric sector and potentially a different mix of states with and without state-specific policies that affect electricity demand. Since we do not predetermine which states might pursue each of these policies, and since the scenarios assume that up to 50 percent of states pursue any particular policy, we assume for modeling purposes that the impact of policies that affect demand will be shared across all states.

Because we consider increases and decreases in electric demand associated with a number of activities (e.g., electrification of light-duty vehicles and improved industrial energy efficiency), we do not separately determine CO_2 emissions reductions associated with appliance efficiency standards. Instead, those reductions are included in the overall emissions reductions for electric generation.

IV. Transportation

A. LIGHT-DUTY VEHICLES

1. Base Case for Light-Duty Vehicles

In August 2012 EPA and the National Highway Traffic Safety Administration (NHTSA) finalized new GHG emissions standards and CAFE standards for light-duty vehicles.[42] EPA's GHG emissions standards affect vehicles sold from model years 2017 through 2025. Due to statutory limitations, NHTSA only finalized CAFE standards for vehicles of model years 2017 through 2021. NHTSA also announced possible CAFE standards for model year 2021 through 2025 vehicles, though finalization of those standards will require additional rulemaking. EPA's standards establish a CO_2 emissions standard of 163 grams per mile in model year 2025, which is equivalent to a fuel economy standard of 54.5 mpg (if met solely through fuel economy improvements). This is equivalent to a CAFE standard of 49.7 mpg because NHTSA considers only drive train improvements and does not consider improvements in air conditioning leakage of HFCs for purposes of establishing CAFE standards.[43] To avoid double counting, we account for the HFC benefits in the HFC module and do not account for them in the figures that follow.

For the analysis, we used Argonne National Laboratory's VISION model,[44] which relies on the EIA *Annual Energy Outlook 2012* and does not include the latest EPA and NHTSA standards for light-duty vehicles.[45] Thus, we developed our own base case scenario by inputting the new federal standards into the VISION model. We note that EPA has the ability to revisit the standards for model years 2022 to 2025, and adjust them based on the best and most current information available at that time. In the base case scenario, however, we assumed that the standards through model year 2025 are achieved as outlined in the most recent rulemaking, and are not revised upwards or downwards. We further assume that the 2025 model year standards remain constant through 2035.

The recently finalized emissions standards for model years 2017 through 2025 include incentives for electric vehicles (EVs), plug-in hybrid electric vehicles (PHEVs), fuel cell vehicles (FCVs), and compressed natural gas (CNG) vehicles. The incentives include a temporary per-vehicle multiplier that allows EVs, PHEVs, FCVs, and CNG vehicles to "count" as more than one vehicle in the manufacturer's compliance calculation for model years 2017 through 2021. The standards also provide for the temporary use of an increased fuel economy value and a reduced GHG emissions compliance value in order to spur deployment of vehicles that consume less gasoline and emit fewer GHG emissions.[46] We incorporate each of these credits into the model.

2. Lackluster Scenario for Light-Duty Vehicles

For all of the scenarios, we relied on the *Interim Joint Technical Assessment Report* (TAR) produced by EPA, NHTSA, and the California Air Resource Board (CARB).[47] The agencies analyzed four scenarios of future stringency for model years 2020 and 2025, starting with a 250 gram/mile estimated fleet-wide level in model year 2016 and four different levels of CO_2 standard improvement rates: 3 percent per year, 4 percent per year, 5 percent per year, and 6 percent per year. For reference, the 4 percent improvement rate results in a 51 mpg standard by model year 2025, while the 6 percent improvement rate results in a 62 mpg standard by model year 2025. For each of these rates of increased stringency, the agencies considered the effects of the industry following four potential "technology pathways." Each of these rely on varying market penetrations of different sets of technology, including HEV, PHEV, EVs, and mass reduction. The agencies'

TABLE A-1.3 Vehicle Emissions and Efficiency Standards Scenarios, Light-Duty Vehicles

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
August 2012 Joint EPA-DOT Standards: 54.5 mpg by model year 2025 (Included in the base case)		
Standards continue to improve from 2026–2035 at roughly half the rate of the 2017–2025 standards (2 percent). This results in a 131 grams per mile emissions standard and a 61 mpg CAFE standard by 2035. Under this scenario, 9 percent of the miles traveled by MY 2035 vehicles are powered by electricity.	Standards continue to improve from 2026–2035 at roughly the same rate as the 2017–2025 standards. This equates to about a 4 percent annual improvement through 2035, and results in a 104 gram per mile emissions standard and a 74.6 mpg CAFE standard. Under this scenario, 12 percent of the miles traveled by MY 2035 vehicles are powered by electricity.	Six percent annual improvement rate in emissions standards. This results in a 81 grams per mile emissions standard and a 92 mpg CAFE standard. Under this scenario, 34 percent of the miles traveled by MY 2035 vehicles are powered by electricity.

Note: CAFE standards do not include benefits from HFC emissions reductions, which EPA projects to result in credits amounting to 14.3 grams CO_2 per mile in 2025. Also note that the rate of change for the standards is applied to the GHG emissions standards (grams per mile) and fuel consumption rate (gallons per mile).

results illustrate that a variety of technologies can be used to meet each of the standards.

Our lackluster scenario assumes vehicle standards achieve a 131 gram per mile emissions standard in 2035, and a 61 mpg CAFE standard.[48] This is equivalent to a 2 percent annual improvement rate from 2026 through 2035, which is about half the rate required in the finalized standards for model years 2017 through 2025. The 2 percent rate of improvement is only applied to vehicle efficiency improvements and not HFCs because the opportunities to achieve incremental HFC benefits beyond those driven by the current round of standards are more limited. Consistent with EPA and NHTSA's *Interim Joint Technical Assessment Report*, in all of our scenarios the rate of change is applied to the GHG emissions standards (grams per mile) and fuel consumption rate (gallons per mile).

We assume that under this scenario, 9 percent of the miles traveled by MY 2035 vehicles are powered by electricity. We made this assumption because we are unable to predict exactly how these alternative vehicles will penetrate the market and wanted to account for a range of possible outcomes. However, for modeling purposes, we assume that EVs reach 4 percent of sales by 2025. This is consistent with one of the technology pathways the agencies found could achieve a set of standards with similar stringency to those finalized in August. We assumed that sales would escalate over time, so that in 2035 EV's accounted for 8 percent of total sales and PHEVs accounted for 1.5 percent of total sales. This is consistent with the average penetration rates assumed in the four scenarios analyzed by the agencies that achieve 62 mpg in their *Interim Joint Technical Assessment Report*.

3. Middle-of-the-Road Scenario for Light-Duty Vehicles

We assume that vehicle standards continue to improve though 2035 at roughly the same rate as the 2017–2025 standards (4 percent), and achieve an emissions standard of 104 grams of CO_2 per mile traveled and a fleet-wide CAFE standard of 74.6 mpg in 2035. Like the lackluster scenario, the middle-of-the-road scenario assumes that EVs reach 4 percent of new vehicle sales by 2025. Consistent with the lackluster scenario, we only apply the rate of improvement to vehicle efficiency improvements, and do not include HFC emissions in those calculations because there are limited opportunities to achieve incremental HFC benefits beyond those driven by the current round of standards.

Under this scenario, the light-duty fleet achieves approximately 63 mpg in 2031. The TAR considered a scenario where roughly the same fuel economy was achieved in 2025, and examined several technology pathways for achieving that standard. For modeling

purposes, we assumed that EV and PHEV penetration would follow the average of these pathways. This results in EV and PHEV penetration of 8 percent and 1.5 percent of sales in 2031, respectively, when the light-duty fleet reaches 62 mpg. We assume that EV and PHEV sales continue to increase at a constant rate so that in 2035, EV's reach 10.7 percent and PHEV's reach 2.5 percent of vehicle sales. In order to account for a wider range of possible outcomes, we assume that 12 percent of the miles travelled by MY 2035 vehicles are powered by electricity.

4. Go-Getter Scenario for Light-Duty Vehicles

Our go-getter scenario assumes that the EPA GHG emissions standard improves 6 percent per year between 2025 and 2035. This is the highest improvement rate EPA and NHTSA considered in the proposed model year 2017–2025 standards. Consistent with the other scenarios, we only apply the rate of improvement to vehicle efficiency improvements, and do not include HFC emissions in those calculations because there are limited opportunities to achieve incremental HFC benefits beyond those driven by the current round of standards.

This would lead to a greenhouse gas emissions standard of 81 grams of CO_2 per mile traveled and a CAFE standard of 92 mpg in 2035. For modeling purposes, we assume that EVs reach 14 percent of new vehicle sales by 2025 and 31.5 percent by 2035, and that PHEVs reach 2 percent of new vehicle sales by 2025 and 4.5 percent by 2035. These rates were determined in a manner consistent with the middle-of-the-road scenario. However, instead of applying the average EV and PHEV penetration rate from the TAR, we applied the highest EV and PHEV penetration rate in 2025 and assumed that penetration rates continued through 2035 at a continuous rate.[49] In order to account for a wider range of possible outcomes, we assume that 34 percent of the miles traveled by MY 2035 vehicles are powered by electricity.

5. Modeling Notes for Light-Duty Vehicles

The VISION model allows users to edit the default fuel economies of light-, medium-, and heavy-duty vehicle categories between 2000–2100. We estimated fuel economies (mpg) for each major vehicle technology (e.g., internal combustion vehicles, EVs, PHEVs) using each vehicle technology's annual sales, applicable incentives for EVs and PHEVs, and VISION's assumed relative efficiency of vehicle types (e.g., EVs versus internal combustion engines).

In addition, for purposes of this analysis we made the following assumptions for all scenarios:

- We assume that the incentives and credits for electric vehicles (EVs), plug-in hybrid electric vehicles (PHEVs), fuel cell vehicles (FCVs), and compressed natural gas (CNG) vehicles expire, or wind down, as scheduled. This results in the evaluation of EV and PHEV emissions on the basis of the GHG emissions associated with electricity generation, which relates to the GHG performance standards in place for the power sector.
- PHEVs on average drive 50 percent of their miles using electricity, which is consistent with the assumptions in EPA's *Analysis of the Transportation Sector: Greenhouse Gas and Oil Reduction Scenarios,*[50] as well as the upper estimate in Argonne National Laboratory's VISION 2012 AEO base case. The emissions from electricity associated with the operation of these vehicles are accounted for in the electric sector through increased demand.
- Any differences in driving habits between EVs and internal combustion vehicles were not incorporated into the model because these trends are not considered in the VISION model.
- GHG benefits from reduced HFC emissions were not included in tailpipe emissions estimates, and instead were calculated separately in the HFC module.
- On-road mpg remains approximately 80 percent of the test mpg in accordance with standard practice and VISION model design.
- Consistent with common accounting practice and EIA's *Annual Energy Outlook*, we do not include emissions associated with the combustion of biofuels in emissions estimates for light-duty vehicles. This is commonly done due to an assumption that such fuels are carbon neutral. While recent studies suggest that this is not actually the case, for purposes of our analysis we do not include those emissions here.

FIGURE A-1.6 Fuel Economy Improvements Modeled for Light-Duty Vehicles

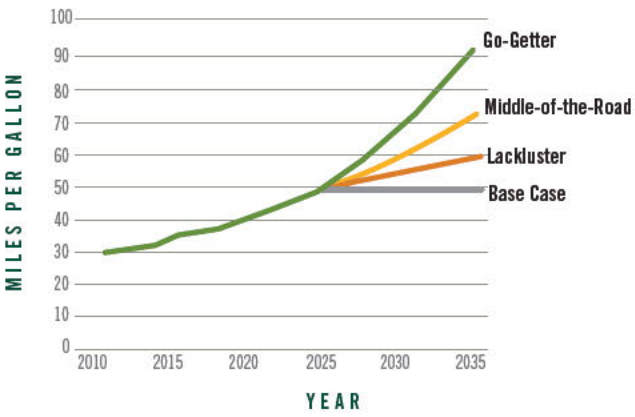
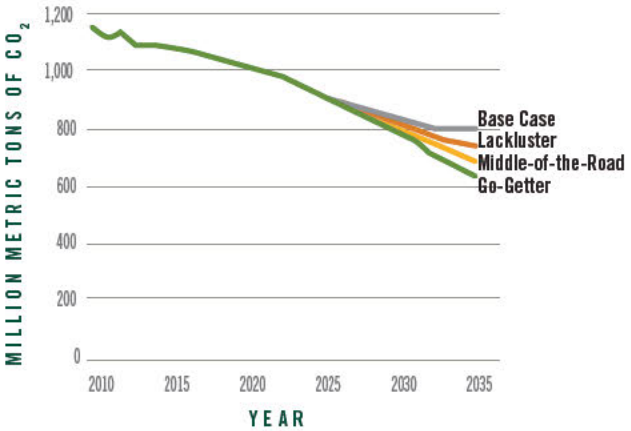


FIGURE A-1.7 Tailpipe Carbon Dioxide Emissions from Light-Duty Vehicles



B. MEDIUM- AND HEAVY-DUTY VEHICLES

1. Base Case for Medium- and Heavy-Duty Vehicles

In August 2011 EPA and NHTSA finalized a joint rulemaking that established the first-ever standards for GHG emissions and fuel consumption for medium- and heavy- duty vehicles.

Medium-duty vehicles (class 2b-6) are defined as those with a gross vehicle rate between 8,500 and 26,000 pounds, while heavy-duty vehicles (class 7-8) have a gross vehicle rate above 26,000 pounds. These vehicles are commonly divided into the following categories:

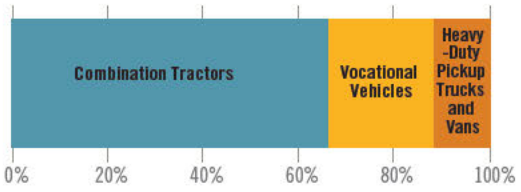
- **Combination tractors** (class 7-8): used for freight transportation and usually pull one or more trailers and emit about two-thirds of medium- and heavy-duty CO_2 emissions (Figure A-1.8);[51]
- **Vocational vehicles** (class 2b-8): used for a wide range of purposes, including fire trucks, dump trucks, refuse trucks, and others;[52] and
- **Heavy duty pick-up trucks and vans** (class 2b-3): used mainly for work purposes, as well as shuttle vehicles.[53,54]

The EPA and NHTSA standards, however, divide these medium- and heavy-duty vehicle categories into 13 subcategories, and establish vehicle GHG emissions and fuel consumption standards for each. Because the manufacturer of the vehicle can differ from the manufacturer of the engine, in some cases EPA and NHTSA established separate engine standards. However, these engine standards are built into the vehicle standards, and thus we do not separately consider them in our scenario development or modeling.

The rule covers vehicles sold from model years 2014 through 2018. EPA's standards are mandatory for model years 2014–2018. NHTSA's fuel consumption standards, however, are voluntary for model years 2014 and 2015 and don't become mandatory until model year 2016.[55] This is due to the regulatory lead-time requirements built into the Energy Independence and Security Act of 2007 (EISA), which cites a need for "regulatory stability."[56]

EPA established a separate standard for HFC leakage from AC systems in heavy-duty pickup trucks and vans as well as class 7 and 8 tractors, based on the

FIGURE A-1.8 Medium- and Heavy-Duty Carbon Dioxide Emissions by Vehicle Type, 2005



Source: *Final Rulemaking to Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles: Regulatory Impact Analysis*, U.S. EPA and NHTSA, August 2011.

refrigerant capacity of the installed AC system. For purposes of this analysis, we applied EPA's estimated GHG benefits from this standard to base case emission projections for HFCs. Thus HFC benefits are not reflected in the GHG emissions projections from this sector shown in the figures that follow.

In the base case scenario, we assumed that the standards are not updated after the current regulatory period and thus the 2018 model year standards remain unchanged through 2035.

2. Lackluster Scenario for Medium- and Heavy-Duty Vehicles

Our lackluster scenario assumes that improvement in the standards continues at a rate consistent with half the rate of improvement achieved by the recent standards, or on average, 1.3 percent annually.[57] This would lead to an average fuel economy of 11 mpg and a GHG emissions standard of 949 grams CO_2 per mile across all medium- and heavy-duty vehicles in 2035.[58] As a result of the standards, we estimate that medium and heavy-duty vehicles sold in 2035 will consume 21 percent less fuel than vehicles sold in 2010.

The Energy Independence and Security Act of 2007 (EISA) requires at least three years of "regulatory stability" whereby standards for medium- and heavy-duty vehicles remain fixed. Therefore, in all three of the scenarios, we assume that CAFE standards are updated as frequently as possible, and that updates to the GHG emissions standards occur at the same time interval—once every three years.

3. Middle-of-the-Road Scenario for Medium- and Heavy-Duty Vehicles

In the middle-of-the-road scenario, we assume that the standards increase at the same rate as the standards for model years 2014–2018 (roughly 2.6 percent annually). This would lead to an average fuel economy of 13.3 mpg and a GHG emissions standard of 781 grams CO_2 per mile across all medium- and heavy-duty vehicles in 2035. As a result of the standards, medium- and heavy-duty vehicles sold in 2035 will consume 35 percent less fuel than vehicles sold in 2010.

4. Go-Getter Scenario for Medium- and Heavy-Duty Vehicles

The go-getter scenario for medium-duty and most heavy-duty vehicles assumes that the GHG emissions standards improve by an average 42 percent in 2023 across all vehicle categories compared to 2010 vehicles. This magnitude of improvement is likely only possible if EPA begins to regulate trailers, which are not covered by current standards. We assume standards for 2020 to 2022 split the difference between the standards set in 2019 and 2023 for each vehicle category, which results in an average improvement rate of 26 percent across all vehicle types. We assume that emissions standards increase by 3 percent every three years (1 percent annually) thereafter. This would lead to an average fuel economy of 16.0 mpg (657 grams CO_2 per mile) across all medium- and heavy-duty vehicles in 2035. As a result of the standards, medium- and heavy-duty vehicles sold in 2035 will consume 46 percent less fuel than vehicles sold in 2010.

TABLE A-1.4 Vehicle Emissions and Efficiency Standards, Medium- and Heavy-Duty Vehicles

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Joint EPA-DOT Standards from August 2011 will improve the GHG emissions rate for vehicles by approximately 2.6 percent per year from 2013–2019		
Standards continue to improve through 2035 at half the rate of the 2014–2018 standards by vehicle category. This equates to an average annual improvement of 1.3 percent across all medium- and heavy-duty vehicles.	Standards continue to improve through 2035 at the same rate as the 2014–2018 standards by vehicle category. This equates to an average annual improvement of 2.6 percent across all medium- and heavy-duty vehicles.	By 2020–2022, the medium- and heavy-duty fleet reduces its emissions rate by an average 26 percent and by 42 percent in 2023–2025 compared to 2010. Standards continue to improve annually by 1 percent through 2035.

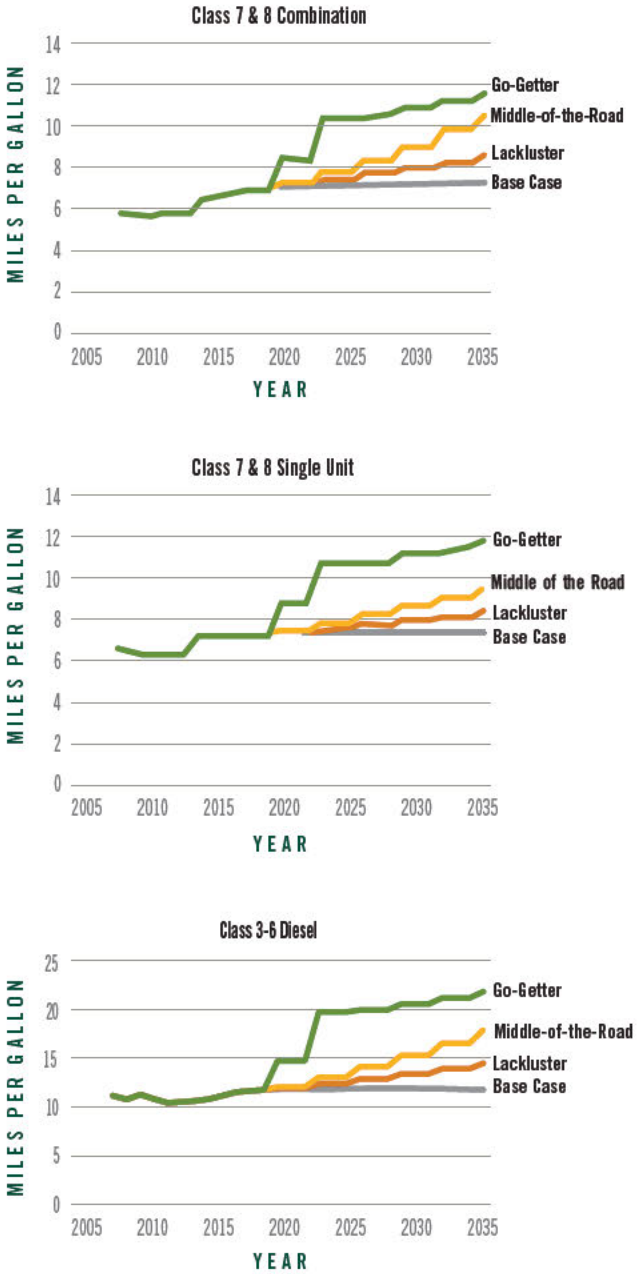
The go-getter scenario for medium- and heavy-duty vehicles was derived from the National Academy of Sciences *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.*[59] That study examines several types of medium- and heavy-duty vehicles, and determines that they can reduce fuel consumption between 32 and 51 percent in the 2015–2020 timeframe by utilizing different technologies, depending on the vehicle class and purpose.[60] These ranges were used to develop average improvement rates for each of the major vehicle classes.

The 2020–2022 standards would reduce fuel consumption by an average 28 percent from 2008 levels. This is slightly higher than the potential fuel savings described in the Presidential Memorandum Regarding Fuel Efficiency Standards from May 21, 2010.[61,62]

5. Modeling Notes for Medium- and Heavy-Duty Vehicles

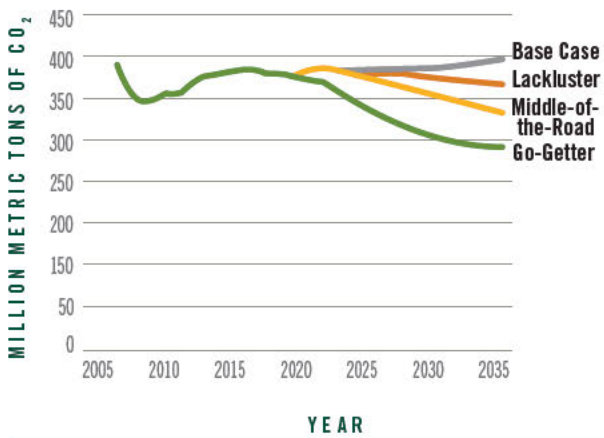
Our analysis relies on Argonne National Laboratory's VISION 2012 model,[63] which includes the latest EPA and NHTSA standards. The VISION model allows users to edit the default fuel economies of new light-, medium-, and heavy-duty vehicles sold from 2000 to 2100. However, VISION breaks the fleet up into different categories than those used by EPA and NHTSA. We therefore relied on EPA's estimated fleet-wide fuel efficiency for model years 2010–2018 under the finalized standards for heavy-duty pickups and vans, vocational vehicles, and combination tractors to help inform the average improvement in fuel efficiency in each of the VISION vehicle categories.[64] Similar to our approach for light-duty vehicles, we applied the improvement rates to the GHG emissions standards (grams per mile) and fuel consumption standards (gallons per ton-mile). These values were converted to fuel economy (miles per gallon) for modeling purposes. Figure A-1.9 shows fuel economy improvements for the three largest vehicle categories, which together account for roughly 94 percent of total GHG emissions from medium- and heavy-duty vehicles in 2010 and 2035.

FIGURE A-1.9 Efficiency Improvements Modeled for Medium- and Heavy-Duty Vehicles



Note: Fuel economy for class 3-6 gasoline, natural gas, and LPG vehicles, as well as class 7-8 single unit natural gas and LPG vehicles, are not shown here. Together, they account for only 6 percent of total GHG emissions in 2010.

FIGURE A-1.10 Tailpipe Carbon Dioxide Emissions from Medium- and Heavy-Duty Vehicles



C. OFF-HIGHWAY MOBILE SOURCES

1. Base Case for Off-Highway Mobile Sources

Off-highway mobile sources include a variety of emissions sources such as engines and equipment used for agriculture (tractors and combines), construction (cranes and bulldozers), lawn and garden, and mining. There is no specific off-highway category in the AEO, and it is beyond the scope of this analysis to reconstruct this sector's emissions from the ground-up. Therefore, we relied on the business-as-usual projections from the *EPA Analysis of the Transportation Sector: Greenhouse Gas and Oil Reduction Scenario*s for the base case, which projects that emissions from these sources will rise from roughly 200 mmtCO_2e in 2012 to roughly 275 mmtCO_2e in 2030.

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Off-Highway Sources

The EPA *Analysis of the Transportation Sector* concludes that there are significant opportunities to reduce GHG emissions from this sector.[65] In the report, EPA posits two greenhouse gas emissions reductions scenarios that are technically achievable. In this analysis, EPA was clear that the "illustrative example scenarios do not imply that EPA considers these to be the appropriate levels or dates for standards."[66] However, we were unable to identify other studies to complement EPA's work, and thus based all three of the scenarios on EPA's study. Therefore, we made the lackluster scenario more conservative by modeling one-half the reductions achieved by EPA's least ambitious scenario, scenario A. The middle-of-the-road scenario was modeled to match EPA's scenario A. The go-getter scenario was modeled to match EPA's most ambitious scenario, scenario B.

Unlike the reductions for light-, medium-, and heavy-duty vehicles, off-highway mobile sources were not independently modeled for this analysis, as sufficient information about the sources and policies is not available. Instead, reductions were taken directly from EPA's study. These reductions were adjusted to remove the contribution from operational improvements because EPA has not mandated such operational improvements to date in these standards. Therefore, for the lackluster, middle-of-the-road, and go-getter scenarios, we assumed that new standards can achieve an additional 0.9 percent, 1.8 percent, and 2.4 percent annual improvement, respectively, in the emissions rate for new equipment and engines from 2018 to 2035.

3. Modeling Notes for Off-Highway Sources

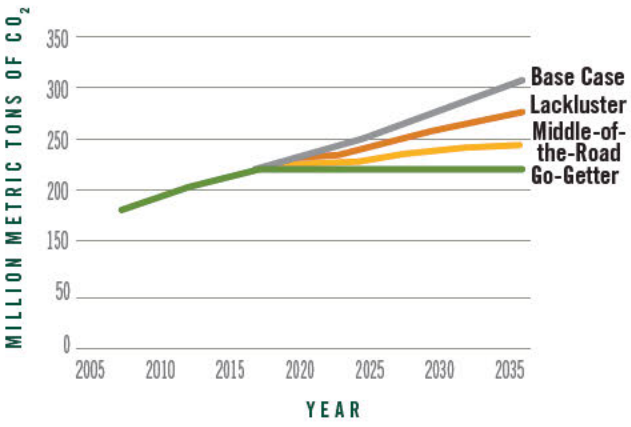
EPA's scenarios result in emissions reductions through increased equipment electrification. We therefore estimated increased electric demand and fed that into the electricity demand module to capture the resulting increases in electricity emissions. For off-highway electrification, the increase in electricity demand in 2035 is 12, 23, and 80 TWh for the lackluster, middle-of-the-road, and go-getter scenarios, respectively. These increases represent 0.3 percent to 1.8 percent of total electricity demand in 2035 under the AEO2012 reference case.

TABLE A-1.5 Vehicle Emissions and Efficiency Standards Scenarios, Off-Highway

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
0.9 percent annual improvement in the emissions rate for new equipment and engines from 2018 to 2035	1.8 percent annual improvement in the emissions rate for new equipment and engines from 2018 to 2035	2.4 percent annual improvement in the emissions rate for new equipment and engines from 2018 to 2035

EPA's analysis was based on AEO2009. We were unable to adjust these results to account for any differences between AEO2012 and AEO2009 because the analyses do not clearly break out emissions from off-highway mobile sources.

FIGURE A-1.11 Carbon Dioxide Emissions from Off-Highway Mobile Sources



D. AVIATION

1. Base Case for Aviation

The emissions base case for aviation emissions was developed using projected energy use as found in the AEO2012 table, *Transportation Sector Key Indicators and Delivered Energy Consumption*. AEO2012 builds in a steady improvement in energy efficiency. Nevertheless, emissions are expected to increase through 2035 due to increased miles traveled; in 2035, aircraft CO_2 emissions are about 11 percent higher than 2010 levels.

2. Lackluster & Middle-of-the-Road Scenarios for Aviation

The FAA can reduce GHG emissions from aircraft by enhancing the way that air travel is managed in the United States. Through its Next Generation Air Transport Systems (NextGen), FAA is proactively managing aviation environmental issues with several programs and initiatives.[67]

Operational improvement scenarios were developed using the *EPA Analysis of the Transportation Sector*.[68] In this report, EPA concluded that it was possible to achieve operational improvements in the range of 0.7 percent to 1.4 percent per year, but noted that the FAA thought that operational improvements realized through NextGen would only reach between 0.17 and 0.4 percent per year. To remain conservative in the lackluster scenario, we modeled a 0.17 percent annual improvement starting in 2014. This results in emissions that are 3 percent below base case levels in 2035, but which are 7 percent greater than 2010 levels. In the middle-of-the-road scenario, we use the higher range reported by FAA, 0.4 percent per year. This results in an 8 percent reduction in emissions compared to the base case in 2035, which is 2 percent above 2010 levels.

3. Go-Getter Scenario for Aviation

In the go-getter scenarios, we relied on the most ambitious estimates from the *EPA Analysis of the Transportation Sector* (scenario B), which concludes that it is possible to achieve a 1.4 percent annual operational improvement. We assume that this rate of change remains constant through 2035.

In addition, we assume that EPA implements GHG emissions standards for airplanes under Title II of the Clean Air Act in 2018. (Note that while EPA may

TABLE A-1.6 Vehicle Emissions, Efficiency Standards, and Operational Improvements Scenarios, Aviation

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
0.17 percent annual emissions reduction through 2035 via operational improvements through the FAA NextGen program.	0.4 percent annual emissions reduction through 2035 via operational improvements through the FAA NextGen program.	1.4 percent annual operational improvement via FAA's NextGen program, plus a 2.3 percent annual improvement in the performance of new aircraft and engines. Both rates remain constant through 2035.

implement GHG emissions standards, FAA enforces those standards.) This also comes from EPA's transportation analysis, which concludes that by 2030, it may be possible to see engine improvements around 20 percent, and airframe weight and drag reductions between 5 and 20 percent. They model this as a 2.3 percent per year annual improvement in aircraft efficiency.

EPA's estimates are comparable to the International Civil Aviation Organization (ICAO) *Report of the Independent Experts of Fuel Burn Reduction Technology Goals*, which suggests efficiency gains of 19–25 percent (in fuel-burn) could be achieved by 2020, and efficiency gains between 26 and 41 percent could be achieved by 2030.[69] In addition, the *International Air Transport Association Technology Roadmap Report* concludes that it might be possible to reduce emissions 23–30 percent in the 2020 time frame, and 25–50 percent in later years.[70] FAA's Continuous Lower Emissions, Energy, and Noise (CLEEN) program has a near-term goal of a 33 percent reduction in fuel burn relative to current technology.[71]

We acknowledge that EPA has never before established aircraft emissions standards for any air pollutant that are more stringent than those set by ICAO, and therefore do not include aircraft standards in the lackluster or middle-of-the-road scenarios. However, the ability to establish aircraft emissions standards lies soundly within their authority under Title II of the Clean Air Act. It is worth noting that there may be other paths forward to achieve these improvements in new aircraft standards. ICAO's Committee on Aviation Environmental Protection is also in the process of developing a new international standard for aircraft carbon dioxide emissions levels and is aiming for a 2013 completion date for the standard.[72]

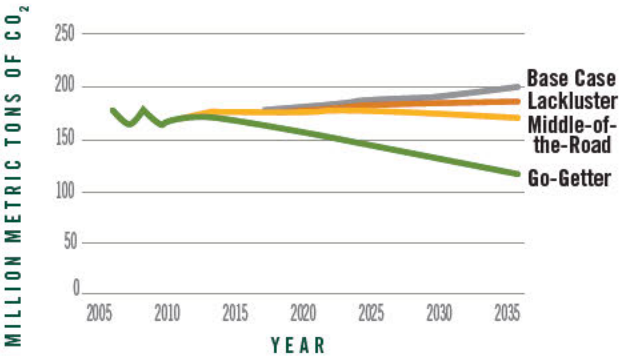
As a point of comparison, the European Union's (EU's) Emission Trading System (ETS) for aircraft requires a 3 percent reduction in 2005 emission levels starting in 2012 and a 5 percent reduction from the same base year from 2013 through 2020. This is comparable to the results for the middle-of-the-road scenario. In November 2012, the EU ETS proposed deferring participation in these emissions reductions for flights to and from Europe in anticipation of progress toward an international market-based approach to regulating GHG emissions from aviation by ICAO in 2013. The legislation still applies to all flights within and between the 30 participating European countries within the EU ETS.[73]

4. Model Uncertainty for Aviation

There are uncertainties regarding projected unit turnover, aircraft efficiency, and demand. In addition, based on EPA's analysis there appear to also be considerable uncertainties about the actual benefits from FAA's NextGen program. All of these will impact actual CO_2 emissions in the future.

There is no guarantee that the level of efficiency improvements (and thus emissions reductions) built into the AEO2012 will occur without regulations. Emissions standards on aircraft may therefore be necessary to capture efficiency improvements assumed by AEO2012, and thus in the base case as well as lackluster and middle-of-the-road scenarios.

FIGURE A-1.12 Carbon Dioxide Emissions from Aircraft



V. Non-Energy CO_2 and Non-CO_2 Emissions

A. BASE CASE FOR NON-ENERGY EMISSIONS

According to EPA's latest emissions inventory, non-energy emissions accounted for roughly 20 percent of 2010 emissions. Due to data limitations and an evolving understanding of natural gas systems, the base case projections for non-energy CO_2 emissions and non-CO_2 gases come from several different sources. We project that non-energy emissions will increase roughly 18 percent above 2005 levels by 2020 and 36 percent above 2005 levels by 2035, even after accounting for recently finalized regulations that affect natural gas systems and HFCs emissions from vehicles (based on HFC emissions, not consumption).[74]

Non-CO_2 gas projections for all sources except for natural gas systems and HFCs came from EPA's *Draft*

Global Non-CO_2 Emissions Projections Report: 1990-2030.[75] In this report, EPA developed country-specific emission projections using assumptions about economic activity, technology development, emissions reductions from well-established programs or international sector agreements, and other factors. Results were provided in five-year intervals. We estimated emissions between the five-year intervals by applying a linear rate of change. Emissions for 2030 through 2035 were estimated by applying the same rate of change observed from 2025 to 2030.

The technical understanding of emissions from natural gas systems is continually evolving, particularly with regard to shale gas. Therefore, historical emission levels and base case projections utilized analysis conducted for a forthcoming working paper by WRI, *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas.*[76] This report builds on the synthesis of recent lifecycle analyses by Weber and Clavin, *Life Cycle Carbon Footprint of Shale Gas: Review of Evidence and Implications,*[77] EPA's Inventory of Greenhouse Gas Emissions and Sinks 2012,[78] and AEO2012.

Because EPA's *Draft Global Non-CO_2 Emissions Projections Report: 1990–2030* lumped natural gas systems with petroleum systems, we projected methane emissions from petroleum systems separately using historical emissions,[79] historical production data,[80] as well as projected production data.[81]

For the base case, we rely on projections of HFC consumption estimated by EPA in *Benefits of Addressing HFCs under the Montreal Protocol.*[82] Consumption is roughly equal to life-cycle emissions due to low rates of HFC reclamation and destruction. The main difference is that emissions for some products can be delayed many years after their production. As discussed below, annual emissions estimates could be developed using more detailed models of equipment and products. However, those models and underlying data are proprietary.

Non-energy CO_2 emissions projections were not provided in EPA's *Draft Global Non-CO_2 Emissions Projections Report: 1990–2030*, and so instead come from the Applied Dynamic Analysis of the Global Economy (ADAGE) reference scenario of EPA's modeling of the American Clean Energy and Security Act of 2009 (ACES).[83] ADAGE is a dynamic computable general equilibrium model run by RTI International.[84] ADAGE projects emissions in five-year intervals from 2010 to 2050. To estimate emissions between those intervals, we applied a linear rate of change between intervals.

The sources of the base case projections do not present the same level of detail as does the AEO reference case for energy-related CO_2 emissions. Therefore, in the sections that follow we simply describe the reported output for each of the base case emissions projections and where appropriate, describe any steps we took to adjust these projections.

B. NATURAL GAS SYSTEMS

1. Base Case for Natural Gas Systems

Natural gas production has increased by over 20 percent over the past five years[85] on account of rapid development of shale gas resources. Technology advancements in horizontal drilling and hydraulic fracturing have enabled access to vast supplies of natural gas deposits in shale rock formations.[86] The climate implications of shale gas development have been a point of particular controversy due to uncertainty around the methane emissions associated with development of shale gas wells and other portions of the natural gas system.

Our base case emissions projections come from analysis conducted for *Clearing the Air on Shale Gas Emissions,* a forthcoming WRI working paper that examines emissions and abatement opportunities for natural gas systems. Their base case projections were developed using EPA's 2012 *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010,*[87] shale gas production projections from AEO2012, and fugitive emissions rates from *Life Cycle Carbon Footprint of Shale Gas: Review of Evidence and Implications.*[88]

Our base case includes a suite of standards finalized by EPA in April 2012, including New Source Performance Standards (NSPS)[89] for volatile organic compound (VOC) emissions and National Emissions Standards for Hazardous Air Pollutants (HAP) from U.S. natural gas systems.[90] While not explicitly addressing GHGs, the NSPS will reduce methane emissions from natural gas systems by requiring "green completions" that capture gases leaked from wells.[91] The NSPS will result in further reductions of GHGs and VOCs from high-bleed

TABLE A-1.7 Performance Standards for Natural Gas Systems

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
EPA performance and emissions standards achieve 21-29 percent reduction in CH_4 emissions compared to projections without standards through the use of green completions and dry seal processors		
Emissions reductions of 26 percent from base case starting in 2019. Assumes implementation of plunger lift systems to reduce emissions from liquids unloading at new and existing wells, and leak monitoring and repair to reduce fugitive emissions from production, processing, and compressor stations.	Emissions reductions of 37 percent from base case in 2019. Assumes implementation of measures in lackluster scenario and conversion of existing high-bleed pneumatic controllers to low-bleed or no-bleed controllers to reduce emissions from production, processing, and transmission.	Emissions reductions of 67 percent from base case starting in 2019. Assumes implementation of measures in middle-of-the-road scenario as well as: desiccant dehydrators to reduce emissions during dehydration of wet gas; improved compressor maintenance to reduce emissions during processing; hot taps in maintenance of pipelines during transmission; and vapor recovery units to reduce emissions during storage.

compressors. The NSPS and emission standards for HAPs from storage tanks will also reduce GHGs and VOCs, though to a lesser extent.[92]

Clearing the Air on Shale Gas Emissions projects that the new standards will reduce methane emissions by approximately 65 mmtCO_2e in 2020 and 85 mmtCO_2e in 2035, and as a result total base case emissions (methane and carbon dioxide) will be 240 mmtCO_2e in 2020 and 250 mmtCO_2e in 2035.

2. Lackluster Scenario for Natural Gas Systems

Our lackluster scenario assumes that EPA implements regulations that require natural gas systems to employ:

1. Plunger lift systems to reduce emissions from liquids unloading at new and existing wells; and
2. Leak monitoring and repair to reduce fugitive emissions from production, processing, and compressor stations.[93]

These emissions control technologies are projected to pay for themselves within one to two years, even without a price on carbon.[94] *Clearing the Air on Shale Gas Emissions* projects that widespread adoption of these technologies would reduce methane emissions 26 percent below base case projections.[95] We assume that reductions commence in 2019.

3. Middle-of-the-Road Scenario for Natural Gas Systems

Our middle-of-the-road scenario assumes that EPA implements regulations that require natural gas systems to employ the above emissions control technologies—as well as conversion of existing high-bleed pneumatic controllers to low-bleed or no-bleed controllers—to reduce emissions from processing and transmission. This technology is predicted to have a payback period of less than two years with a $20 price on carbon, and is projected to pay for itself within three years even without a price on carbon. Clearing the Air on Shale Gas Emissions projects that widespread adoption of these three technologies would reduce methane emissions roughly 37 percent below base case projections.[96] We assume that these reductions commence in 2019.

4. Go-Getter Scenario for Natural Gas Systems

Our go-getter scenario assumes that EPA implements regulations that require natural gas systems to employ all of the emission control technologies identified in the lackluster and middle-of-the-road scenarios, as well as:

1. Hot taps to reduce emissions from pipeline maintenance and repair during transmission;
2. Desiccant dehydrators to reduce emissions during dehydration of wet gas;
3. Improved compressor maintenance to reduce emissions during processing; and
4. Vapor recovery units to reduce emissions during storage.

The technologies were identified by the Natural Resource Defense Council's Leaking Profits report as being both technically feasible and profitable, each with a payback period of less than three years under NRDC's assumptions.[97] Using the same methodology

and conservative assumptions as were employed in the WRI working paper Clearing the Air on Shale Gas Emissions, these emission control technologies are found to achieve 67 percent reduction in emissions from the base case projections.[98] We assume that the standards lead to reductions beginning in 2019.

5. Modeling Notes for Natural Gas Systems

Emissions from natural gas systems are related to the amount of natural gas produced. While the AEO2012 reference case shows the U.S. going from being a net importer to a net exporter of natural gas by the early 2020s, consumption and production levels remain within 5 percent of each other through most of our study period.[99] Based on this observation, in this analysis we employ the simplifying assumption that changes in natural gas demand will result in equivalent changes in natural gas production in the United States. In each of the scenarios, methane and carbon dioxide emissions levels were adjusted to account for changes in natural demand from electricity generation, residential and commercial appliances, and industry.

We do not attempt to sort out the relative change in conventional and unconventional production. This is not expected to significantly impact the results, as we project the emissions rate for conventional and unconventional sources to be within 5 to 30 percent of one another across all scenarios.[100] Across all scenarios, natural gas demand is not expected to change by more than 12 percent,[101] and changes in upstream emissions of natural gas are estimated to be less than 0.1 percent of total economy-wide GHG emissions reductions.

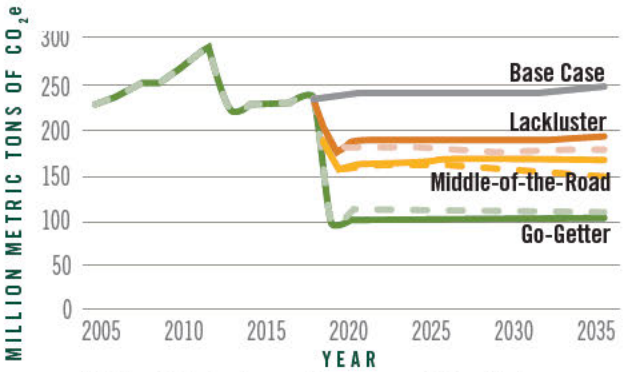
6. Uncertainties for Natural Gas Systems

WRI analysis of greenhouse gas emissions from natural gas systems relies in large part on activity data from EPA's 2012 Inventory, as well as on lifecycle analyses that utilize data from that inventory. However, The American Petroleum Institute (API) and America's Natural Gas Alliance (ANGA) published a joint study in September, 2012 that calls into question some of EPA's assumptions and methodologies in the agency's calculations for the largest sources of leaked and vented methane from natural gas systems. This industry-led study is noteworthy because it presents measurement data from 19 of the 21 largest basins across the U.S. Additional measurement data will be published over the course of the next year – including a study led by Environmental Defense Fund[102] and measurement data provided to the EPA under Subpart W of the Greenhouse Gas Reporting Program[103] – that will help clarify the still-murky picture of natural gas systems emissions.

Specifically, the API and ANGA study reports a much lower frequency of liquids unloading, and a much lower emissions factor for the venting associated with this process, than does EPA in the 2012 Inventory. API and ANGA also estimate a much lower refracture rate for hydraulically fractured wells than is used in the 2012 Inventory.

Using the results from the API/ANGA study in place of the activity data from EPA's 2012 Inventory would reduce historical estimates of methane and carbon dioxide emissions from natural gas systems, the base case projection of those emissions, and the reductions from that baseline from EPA's existing standards and from our three reduction scenarios. The baseline projections would be reduced by 14-21 percent from 2020-2035. The EPA performance and emissions standards finalized in 2012 would achieve a 21-26 percent reduction in methane emissions starting in 2013 compared to projections without standards, compared to 21-29 percent using the 2012 Inventory. Likewise, implementing regulations consistent with our lackluster, middle-of-the-road, and go-getter scenarios

FIGURE A-1.13 Total Methane and Carbon Dioxide Emissions from Natural Gas Systems (Federal)



Solid lines indicate changes in base case emissions due to new emissions standards for natural gas systems.

Dashed lines indicate changes in emissions after accounting for changes in demand.

Note: Carbon dioxide emissions range from around 30MMtCO_2e to 43MMtCO_2e across all scenarios.

described above would lead to reductions in methane emissions from the base case between 2019 and 2035 that are equivalent to roughly 22 percent, 35 percent, and 51 percent, respectively. These compare to 26, 37, and 67, respectively, using the 2012 Inventory. Using the results from the API/ANGA study, the federal go-getter scenario only reduces emissions 16.3 percent below 2005 levels, and thus additional state (or legislative) action would be needed to achieve the 17 percent reduction target.

C. HYDROFLUROCARBONS (HFCS)

1. Base Case Scenario for Hydrofluorocarbons

Emissions of HFCs have been increasing due to the phaseout of chlorofluorocarbons (CFCs) and other ozone-depleting substances under the Montreal Protocol and Clean Air Act. This trend is expected to continue as the interim substitutes, HCFCs, are also phased out as they are currently being replaced with gases that have a high global warming potential.[104] EPA's *Draft Global Non-CO_2 Emissions Projections Report: 1990-2030* projects that if current trends continue, hydroflourocarbon (HFCs) emissions will increase from 143 mmtCO_2e in 2010 to roughly 411 mmtCO_2e in 2035.[105]

EPA's projections were developed using the Vintaging model, a proprietary bottom-up model of "ozone-depleting substances (ODS) and ODS-substitute-containing equipment and products to estimate the use and subsequent emissions of ODS substitutes in the U.S."[106] Without this model, we were unable to develop robust estimates of actual emissions due to changes in consumption. Therefore, we relied on projections of HFC consumption estimated by EPA in *Benefits of Addressing HFCs under the Montreal Protocol* for the base case.[107] In this report, EPA projects that HFC consumption in the U.S. will increase from 300 mmtCO_2e in 2010 to roughly 580 mmtCO_2e in 2035.

These projections do not, however, account for the HFC benefits projected from EPA's GHG emissions standards for light-, medium-, and heavy-duty vehicles. For light-duty vehicles, EPA offers a credit to manufacturers that reduce HFC leakage from AC systems. The emissions standards for medium- and heavy-duty vehicles, on the other hand, establish specific standards for HFC leakage from heavy-duty pickup trucks and vans as well as combination tractors. We adjusted these projections using estimated HFC abatement from light-duty vehicles as reported in EPA's OMEGA model outputs[108] and from medium- and heavy-duty vehicles using EPA and NHTSA's regulatory impact analysis (RIA).[109] We assumed that reported lifetime reductions in HFC emissions for each vehicle model year corresponded to the same level of reductions in consumption. After accounting for these new regulations, we project in the base case that HFC consumption will only increase to 543 mmtCO_2e in 2035 (37 mmtCO_2e less than the 580 mmtCO_2e predicted in *Benefits of Addressing HFCs under the Montreal Protocol*).

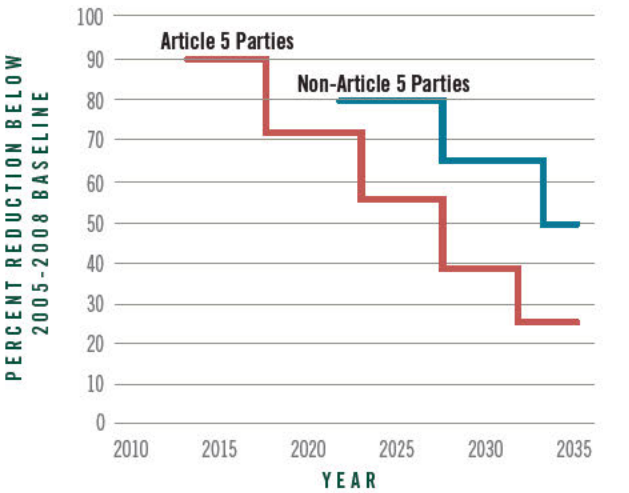
2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Hydrofluorocarbons

On May 9, 2012, the U.S. filed a joint proposal with Canada and Mexico to amend the Montreal Protocol. That proposal calls for a ramp-down of emissions of high global warming potential (GWP) HFCs, so that in 2033 production and consumption of HFCs on a GWP-weighted basis are 15 percent of base case emissions in the U.S. and other developed countries (specifically, non-Article 5 Parties). The baseline is defined as the average of 2005–2008 HFC consumption plus 85 percent of the average 2005–2008 HCFC consumption. The proposal puts forth a separate, slightly less aggressive reduction schedule for developing countries listed under Article 5 of the Montreal Protocol (see Figure A-1.14).

TABLE A-1.8 Emissions Reduction Schedule for Hydrofluorocarbons

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Consumption ramp-down occurs three years later than the schedule detailed in the joint North American Proposal.	Consumption is ramped-down in a manner consistent with the joint North American Proposal, which calls for an 85 percent reduction below 2005–2008 levels by 2033.	Consumption is ramped-down more rapidly than in the joint North American Proposal, achieving the 85 percent reduction target in 2028, five years earlier than detailed in the joint North American Proposal.

FIGURE A-1.14 HFC Reduction Schedules



Source: *Benefits of Addressing HFCs under the Montreal Protocol*, U.S. EPA, June 2012.

EPA's authority for regulating emissions of ozone-depleting substances comes from Title VI of the Clean Air Act. The phasedown of HFCs could be implemented through its Significant New Alternatives Policy (SNAP) program. The SNAP program implements section 612 of the Clean Air Act, which calls for the replacement of ozone-depleting substances with substitutes that reduce the overall risk to human health and the environment. Under the SNAP program, EPA may restrict or prohibit the use of unacceptable substitutes and classify substitutes that are acceptable.[110] In its report, *Benefits of Addressing HFCs under the Montreal Protocol*,[111] EPA notes that the most promising options for reducing HFC consumption through the SNAP program include:

- "Substituting HFCs with low-GWP or no-GWP substances in a variety of applications (where safety and performance requirements can be met);
- Implementing new technologies that use, at installation and/or over the lifetime of the equipment, no or significantly lower amounts of HFCs; and,
- Various process and handling options—including the principles of refrigerant recovery and management implemented during the CFC phaseout—that reduce consumption during the manufacture, use, and disposal of products that contain or use HFCs."

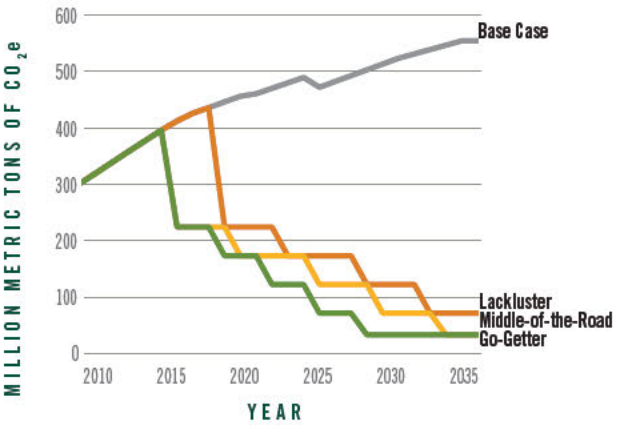
We note that Title VI provides additional authority to EPA to reduce HFCs beyond the SNAP program, including sections 608 and 609. We assume that EPA will either implement the ramp-down schedule after it is included in an international agreement, or will seek to achieve similar reductions through existing authority absent such an agreement. Because the reduction schedule proposed by the United States achieves relatively large reductions from the base case, and because they have signaled a strong intention to pursue this long-term path, in the middle-of-the-road scenario we assume that EPA takes action to achieve the reduction schedule proposed for non-Article 5 Parties.[112] In the lackluster scenario, we assume that a similar reduction schedule is followed, except that the reductions commence beginning in 2019 instead of 2016.

Our go-getter scenario assumes that EPA sets standards that result in a more aggressive reduction schedule so that an 85 percent reduction in consumption is achieved five years before the middle-of-the-road scenario. This results in a 61 percent reduction in consumption in 2020 compared to the base case projections in the same year. The full schedules are detailed in Figure A-1.14.

3. Modeling Notes for Hydrofluorocarbons

Using these HFC consumption-based estimates, we find that go-getter action for HFCs and other sectors will result in economy-wide U.S. GHG emissions that are 17 percent below 2005 levels in 2020. As noted above, we did not have access to the Vintaging model or similar models that would have allowed us to develop robust estimates of actual emissions due to changes in consumption. However, we developed a basic emissions model to provide rough estimates of 2020 emissions. This was only possible due to the relatively short time considered (i.e., 2020 as opposed to emissions through 2035), as it allowed us to minimize the variables of

FIGURE A-1.15 HFC Consumption



equipment turnover and recharging. The results of this analysis, showing economy-wide reductions in the range of 15 to 19 percent, were generally consistent with the consumption-based estimates we used in this study.[113]

D. COAL MINES

1. Base Case for Coal Mines

The base case utilizes EPA's *Draft Global Non-CO_2 Emissions Projections Report: 1990–2030*, which projects methane emissions will increase from 70 mmtCO_2e in 2010 to 87 mmtCO_2e in 2035.

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Coal Mines

All scenarios assume that EPA establishes performance standards for new and existing coal mines in a manner that results in abatement of methane emissions consistent with the cost-effective reductions identified in EPA's marginal abatement cost curves. For example, reductions from coal mines can be achieved through degasification and pipeline injection and through oxidation of ventilation air methane. For simplicity, we assumed that relatively few new coal mines would come online between 2012 and 2017, and thus do not model any reductions until 2019, the earliest expected date that performance standards could be in place for existing coal mines. Table A-1.9 shows the level of GHG emissions reductions achieved under the three scenarios, and the corresponding cost per ton from EPA analysis.

We based our assessment of achievable emissions reductions using these measures on the marginal abatement cost curves found in EPA's *Preliminary Draft Global Mitigation of Non-CO_2 Greenhouse Gases Report (March 2012)*.[114] Marginal abatement cost curves can serve as a useful point of reference because EPA will consider the cost of abatement when setting prescribed emissions rates for new and existing coal mines. EPA's marginal abatement curves provide cost information per ton of emissions reduced, and have been used by EPA with ADAGE emissions forecasts in various analyses. EPA's *Preliminary Draft Global Mitigation of Non-CO_2 Greenhouse Gases Report (March 2012)* represents an update to their 2006 report. Their 2012 analysis incorporates updated mitigation technologies, labor and energy costs, and emissions baselines with an updated modeling approach.

We based the lackluster scenario on the reductions achievable at a cost of $5 per ton of CO_2e. The middle-of-the-road scenario was based on the reductions achievable at a cost of $20 per ton of CO_2e. The go-getter scenario was based on the reductions achievable at a cost of $61 per ton of CO_2e.

The selected costs cover the range of prices that were considered at the federal and state level in cap-and-trade program design.[115] They also cover the range of prices considered in the report— *Technical Support Document: Social Cost of Carbon Regulatory Impact Analysis Under Executive Order 12866*, released in February 2010—prepared by the Interagency Working Group on the Social Cost of Carbon.[116] The social cost of carbon is meant to provide an estimate of the monetized damages associated with the incremental emissions of greenhouse gases. The estimates contained in the report are intended to provide guidance to agencies as they incorporate the benefits of reducing greenhouse gas emissions into the cost-benefit analyses associated with future regulatory actions. The reported range was $6–$73 in 2015 and $10–$100 in 2030.

It bears noting that there may be barriers to achieving the full technical reduction potential for emissions reductions through direct regulation as compared to a voluntary offsets program. According to EPA's inventory of coal mines for 2010, abandoned coal

TABLE A-1.9 Methane Emissions from Coal Mines

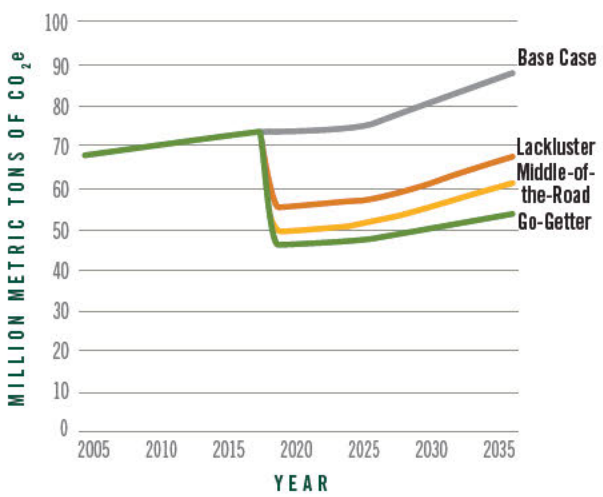
	ABATEMENT COST ($/TON CO_2e)	PERCENT REDUCTION FROM BASE CASE IN 2020 (PERCENT)	EMISSIONS (MMTCO_2e)		
			2010	2020	2035
Base Case	-	-	70	73	87
Lackluster	5	24 percent	-	55	66
Middle-of-the-Road	20	32 percent	-	50	59
Go-Getter	61	39 percent	-	44	53

mines (i.e., those that are not producing coal) account for approximately 6 percent of coal mine emissions.[117] Abandoned mines pose significant challenges to enforcement of standards. Therefore, we assume that only the 94 percent of coal mine methane that comes from active mines is abated in response to NSPS. This is consistent with EPA's P*reliminary Draft Global Mitigation of Non-CO_2 Greenhouse Gases Report (March 2012)*, which derives the abatement curves based on reductions of methane emissions from active mines only.

3. Uncertainties for Coal Mines

Our scenarios establish new standards for new and existing coal mines. EPA's marginal abatement cost curves, however, do not differentiate between new and existing mines. They also do not show significant changes in abatement over time (from 2020 to 2030). This means that the rate that new mines come into production should not significantly affect the abatement rate. Emissions will change, however, if production increases or decreases differently than is predicted by EPA. There is also uncertainty about what percentage of mines will be abandoned in future years. If that percentage increases above 6 percent, then emissions from this sector may increase beyond what is modeled here.

FIGURE A-1.16 Methane Emissions from Coal Mines



E. NITRIC AND ADIPIC ACID MANUFACTURING

A. Base Case for Nitric and Adipic Acid Manufacturing

Nitric acid (HNO_3) is primarily used as a feedstock for synthetic fertilizer, though it is also used in the production of adipic acid and explosives. Adipic acid ($C_6H_{10}O_4$) is used in the production of nylon and as a flavor enhancer in certain foods. The manufacture of nitric and adipic acid generates nitrous oxide (N_2O) as a byproduct, which according to the IPCC's *Fourth Assessment* has a global warming potential 298 times that of carbon dioxide over a 100-year timeframe.[118] For the base case we relied on EPA's *Draft Global Non-CO_2 Emissions Projections Report: 1990-2030*, estimating emissions for 2030 through 2035 by applying the same rate of change from 2025 to 2030. We project that N_2O emissions from nitric and adipic acid production will increase from 28 mmtCO_2e in 2010 to 38 mmtCO_2e in 2035.

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Nitric and Adipic Acid Manufacturing

All three scenarios assume that EPA establishes performance standards for new and existing nitric acid manufacturers in a manner that results in abatement of N_2O emissions consistent with the cost-effective reductions identified in EPA's marginal abatement cost curves. This generally would require some form of catalytic reduction for nitric acid manufacturers. For adipic acid manufacturers, this would likely require thermal destruction using reducing flame burners with premixed methane or natural gas.[119]

TABLE A-1.10 Nitrous Oxide Emissions from Nitric Acid and Adipic Acid Manufacturing

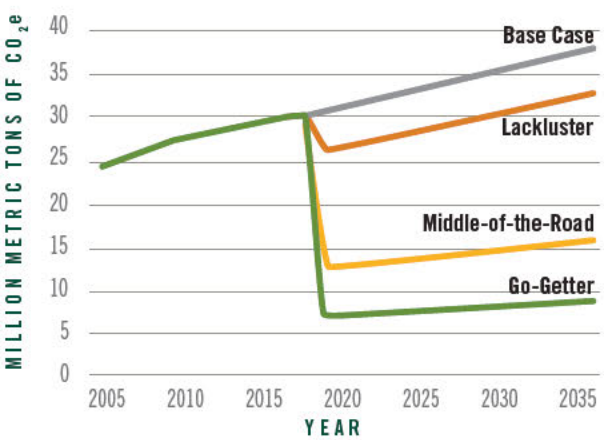
	ABATEMENT COST ($/TON CO_2e)	PERCENT REDUCTION FROM BASE CASE IN 2020 (PERCENT)	EMISSIONS (MMTCO_2e)		
			2010	2020	2035
Base Case	-	-	28	31	38
Lackluster	5	13 percent	-	27	33
Middle-of-the-Road	20	56 percent	-	14	16
Go-Getter	61	75 percent	-	8	9

For simplicity, we assumed that relatively few new production facilities would come online between 2012 and 2017, and thus do not model any reductions until 2019, the earliest expected date that performance standards could be in place for existing production facilities. Table A-1.10 shows the level of GHG emissions reductions achieved for both nitric and adipic acid facilities under the three scenarios, and the corresponding cost per ton from EPA analysis as discussed above in the coal mine section.

3. Uncertainties for Nitric and Adipic Acid Manufacturing

In this section, we model the impact of performance standards on new and existing units. EPA's marginal abatement cost curves do not differentiate between new and existing units, and do not predict significant changes in abatement over time (from 2020 to 2030). This means that the rate that new units come into production should not affect the abatement rate. However, if production increases or decreases differently than predicted by EPA, then emissions will change accordingly.

FIGURE A-1.17 Nitrous Oxide Emissions from Nitric and Adipic Acid Manufacturing



F. LANDFILLS

1. Base Case for Landfills

For the base case, we relied on EPA's D*raft Global Non-CO_2 Emissions Projections Report: 1990-2030*, which projects that methane emissions from landfills will remain relatively constant between 2010 (154 mmtCO_2e) and 2035 (152 mmtCO_2e).

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Landfills

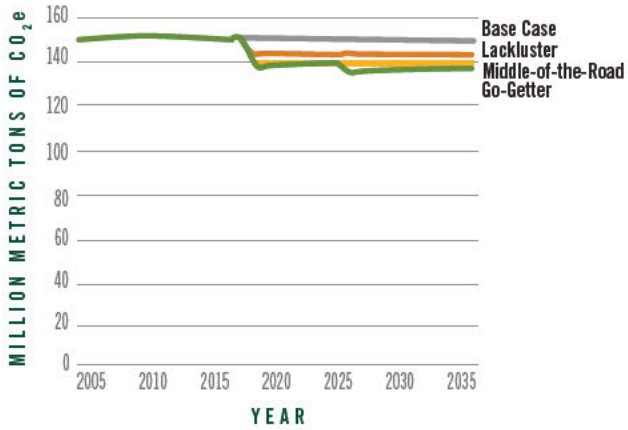
All three scenarios assume that EPA establishes performance standards for new and existing landfills in a manner that results in methane abatement consistent with the cost-effective reductions identified in EPA's marginal abatement cost curves. Abatement at landfills is accomplished through methane capture and destruction. For simplicity, we assumed that relatively few new landfills would come online between 2012 and 2018, and thus do not model any reductions until 2019, the earliest expected date that performance standards could be in place for existing landfills. Table A-1.11 shows the level of GHG emissions reductions achieved under the three scenarios, and the corresponding cost per ton from EPA analysis, as discussed above in the coal mine section.

Our previous analysis suggested that 44 to 74 percent of methane emissions from landfills could be abated under the three scenarios, based on data from EPA's 2006 release of its *Global Mitigation of Non-CO_2 Greenhouse Gases* report.[120] EPA's updated analysis, *Draft Global Non-CO_2 Emissions Projections Report: 1990-2030*, is thought to be more accurate as it includes more information on gas capture rates, mitigation options and costs, and labor costs. It also projects decreased prices for landfill methane gas, which reduces the benefit for methane capture.

TABLE A-1.11 Methane Emissions from Landfills

	ABATEMENT COST ($/TON CO_2e)	PERCENT REDUCTION FROM BASE CASE IN 2020 (PERCENT)	EMISSIONS (MMTCO_2e)		
			2010	2020	2035
Base Case	-	-	154	152	152
Lackluster	5	5 percent	-	145	144
Middle-of-the-Road	20	9 percent	-	139	138
Go-Getter	61	9 percent	-	138	135

FIGURE A-1.18 Methane Emissions from Landfills



3. Uncertainties for Landfills

EPA's marginal abatement cost curves do not differentiate between new and existing units, and predict minimal changes in abatement over time (from 2020 to 2030). This means that changes in the percentage of emissions attributable to new landfills (as opposed to older landfills) should not affect the abatement rate. However, if methane production increases or decreases due to changes in the quantities of waste going to landfills or landfill management practices, then emissions will change accordingly.

VI. Industry

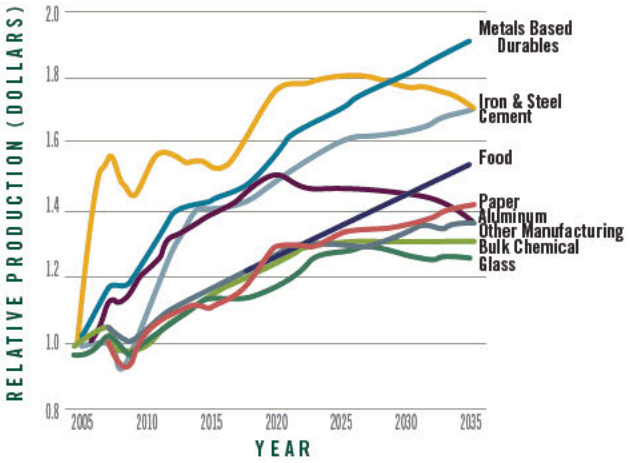
A. MANUFACTURING

1. Base Case for Manufacturing

Baseline emissions for energy-related CO_2 emissions come from EIA's AEO2012. Under the AEO2012 reference scenario, each major manufacturing sector is projected to see an upward trend in production.[121] As a result, in 2035 total production exceeds production levels in 2009. The AEO reference case assumes that overall process efficiency will gradually improve over time. However, overall energy use and emissions are forecast to increase in most subsectors.[122] Due to mature technology and low turnover rates, boiler efficiency, however, remains relatively constant over time.[123]

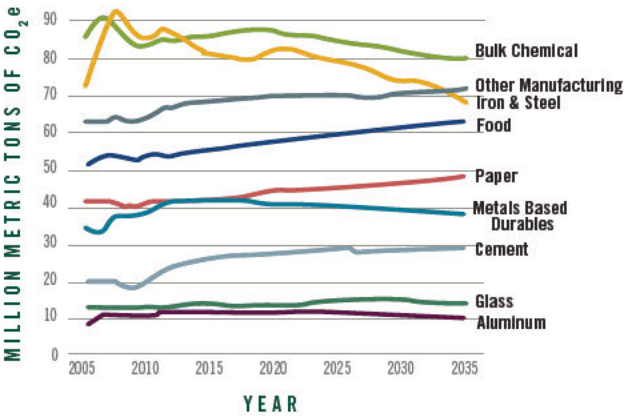
Emissions from onsite combustion and other industrial processes—such as those from limestone calcination in the cement production process—in the manufacturing sector are projected to grow from 527 mmtCO_2e in 2009 to 566 mmtCO_2e in 2035, amounting to a 7 percent increase in emissions over this time period (roughly three-quarters of these emissions result

FIGURE A-1.19 Relative Changes in Production from 2009 for Major Manufacturing Sectors, Expressed in Inflation-adjusted Dollar Value of Shipments



Source: *AEO2012*, U.S. EIA

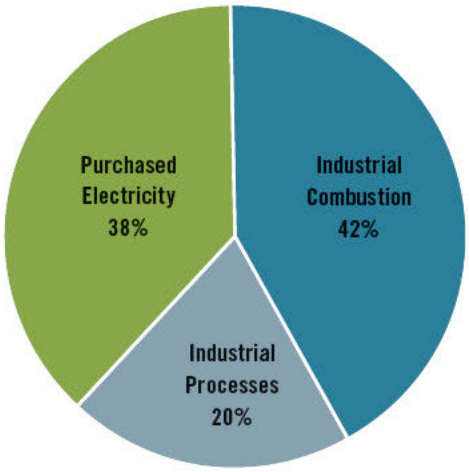
FIGURE A-1.20 Base Case Carbon Dioxide Emissions from Fossil Fuel Combustion at Manufacturing Facilities



Source: *AEO2012*, U.S. EIA

from onsite combustion, while the remainder are process emissions). Increases in emissions from the food, cement, and paper industries offset emissions reductions in the bulk chemical and iron and steel industries. More detailed sector breakdowns are depicted in Figure A-1.20. However, it is important to note that onsite combustion and other industrial processes account for only 62 percent of total emissions. The other 38 percent is due to emissions associated with purchased electricity (see Figure A-1.21).

FIGURE A-1.21 Industrial Greenhouse Gas Emissions by Source, 2010



Source: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010*, EPA.

2. Lackluster Scenario for Manufacturing

In its ANPR, EPA concluded that existing industrial boilers could achieve efficiency improvements of 1–10 percent, and that efficiency improvements of 10–33 percent could be obtained by replacing an existing boiler with a CHP unit.[124]

For the lackluster scenario, we assume that EPA establishes performance standards for new and existing industrial boilers. To simplify the modeling of this scenario, we assume that EPA establishes emissions limits for new and existing industrial boilers that achieve a 10 percent reduction in emissions beyond base case projections. This was modeled as a 10 percent reduction in fuel use across all boilers and fuel types in the manufacturing sector, which includes food, paper, bulk chemical, glass, cement, iron and steel,[125] aluminum, metals-based durables, and other manufacturing.[126] A comparable level of emissions reductions could be achieved through other combinations of new unit and existing unit standards.[127,128] Since in the early years few new units are expected, for simplicity we model these reductions starting in 2019 to account for the six-year time lag for developing performance standards for existing units.

3. Middle-of-the-Road Scenario for Manufacturing

According to NEMS support documentation for AEO2012, industrial boilers account for only 28 percent of manufacturing heat and power energy consumption, excluding byproduct fuels.[129] In the middle-of-the-road scenario, we therefore assume that EPA devises performance standards that account for the entire industrial facility and purchased electricity, instead of merely capturing boiler efficiency opportunities. This more holistic approach would capture efficiencies in the entire industrial process, thereby improving the rate of emissions per unit of output. This would require a slightly more expansive approach to performance standards than EPA has implemented in the past. However, it is worth noting that a similar approach was discussed by the Climate Change Working Group of the Clean Air Act Advisory Committee.[130] Such standards could take the form of output-based emissions rates, or (in the case of existing units) through a flexible compliance program for industry that rewards improvements in emissions per unit of output.

TABLE A-1.12 Performance Standards to Reduce Industry Emissions

	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Fossil-fuel Combustion in Manufacturing and Cement Kilns	Emissions reductions consistent with a 10 percent improvement in efficiency beyond base case levels starting in 2019.	Emissions reductions consistent with harnessing all cost-effective energy efficiency across the entire manufacturing facility. Emissions standards also drive reductions in process emissions from cement kilns.	Emissions reductions consistent with harnessing all cost-effective energy efficiency across the entire manufacturing facility; all new units must meet emissions rate equivalent to natural gas combustion. Emissions standards also drive reductions in process emissions from cement kilns.
Refineries	Emissions reductions consistent with a 1 percent improvement in efficiency.	Emissions reductions consistent with a 5 percent improvement in efficiency.	Emissions reductions consistent with a 10 percent improvement in efficiency.

In order to gauge the additional reductions achievable through process efficiency improvements beyond those included in AEO2012, we relied on a study commissioned by the Department of Energy (DOE), *Scenarios for the Clean Energy Future* (CEF).[131] The CEF study examines the effect of a suite of voluntary policies on reducing industrial emissions. In the CEF, two different policy implementation scenarios are analyzed: a moderate and advanced scenario. The CEF advanced scenario included voluntary sector agreements between government and industry and a suite of complementary policies, including expanded research and development and a domestic carbon dioxide emissions trading system with prices around $19 per ton of carbon dioxide.[132] This valuation of the impact of carbon dioxide emissions could be integrated into the development of sector-appropriate standards, whether they are in the form of source-specific emissions rates, or a more flexible compliance program.

The CEF study, which was completed in November 2000, was based on AEO1999. In *Real Prospects for Energy Efficiency in the United States,*[133] the National Academy of Sciences concluded that the percentage of reductions found in the CEF can be applied to more recent releases of the AEO. This was because "new energy efficiency opportunities arise each year as infrastructure and equipment ages, and as new and improved technologies are introduced into the marketplace."[134] For the middle-of-the-road scenario, we assumed that reductions commence in 2019 due to the time lag for establishing standards on existing units through section 111(d). We then assumed that industrial efficiency ramps up in a linear manner so that in 2025 it achieves the same percent improvement, relative to business-as-usual projections, as was found in the CEF study for 2010. We assumed that the relative energy efficiency benefits modeled in the CEF study for 2020 would be achieved in 2035. We also assume a linear rate of change between the reductions modeled in 2025 and 2035.

The built-in time lags are intended to provide the sector time to turn over stock and adopt improved efficiency measures at existing facilities. The precise amount of time needed to achieve these changes is uncertain, as the CEF analysis did not provide annual results, but instead presented findings at two separate intervals. For this scenario, we did not need to independently calculate unit turnover, as it is already built into the CEF reduction scenario. However, the CEF generally assumed a slightly higher unit retirement rate than is incorporated into the AEO, based on their own assessment of the retirement rates commonly observed across industrial classes. This level of efficiency and technology improvement leads to GHG emissions reductions of 16 mmtCO_2 in 2020 and 76 mmtCO_2 in 2035 from onsite combustion above what is projected in the base case. It also leads to reductions in purchased electricity of 28 TWh (3 percent) in 2020 and 168 TWh (21 percent) in 2035 compared to the base case.

4. Go-Getter Scenario for Manufacturing

In the go-getter scenario, we again assume that EPA captures efficiencies across the entire industrial process by establishing equipment efficiency standards, sector-wide benchmark standards, or some other flexible compliance program for industry. This is modeled using the CEF improvements in the same manner as the middle-of-the-road scenario. In the go-getter scenario, we also assume that EPA establishes emissions standards for all new combustion sources (not just boilers) equivalent to natural gas combustion. This could be accomplished through co-firing of biomass, use of natural gas, carbon capture and sequestration, or built into the reduction schedule of a flexible compliance program. Combined, these standards lead to reductions of 30 mmtCO_2e in 2020 and 97 mmtCO_2e in 2035 compared to the base case projections in the same years. Similar to the middle-of-the-road scenario, purchases of electricity are reduced by 28 TWh in 2020 and 168 TWh in 2035 compared to the base case.

5. Uncertainties for Manufacturing

The CEF's considerations of cost, unit turnover, and its direct comparison to projected efficiency improvements built into the AEO make it a particularly valuable study for incorporation into the model. Since this study was published, other analyses have been completed, but they do not provide these same features. Nevertheless, some of them warrant consideration for comparative purposes. Of note are the series of "bandwidth" studies sponsored by the Department of Energy's Industrial Technologies Program. These studies assess the amount of energy that can be saved from a particular industrial process and compare current average energy use to state-of-the-art practices and the practical minimum energy use. Since each of the bandwidth

studies was conducted independently, there are some inconsistencies. The studies examine state of the art/best practice for each sector, which they generally define as the least energy-intensive option in current use. They also examine what they call the practical minimum, which varies somewhat between the energy required "assuming application of reasonable technologies such as heat recovery, batch preheating, etc,"[135] and the "energy required for a typical plant after deployment of new process technologies developed through applied research and development."[136]

Table A-1.13 compares the sector-specific findings of the bandwidth studies with energy savings modeled under this report's middle-of-the-road and go-getter scenarios. For instance, under our scenarios efficiency improvements from the paper and glass sectors are well below those that would be achieved if they employed the best practices identified in their respective bandwidth studies. Meanwhile, we predict that the GHG emissions reductions from the bulk chemical sector are between the energy savings identified from best practices and those identified with the practical minimum. Projected energy reductions from the iron and steel sector exceed the bandwidth's practical minimum by 3 percent[137] (the practical minimum is not expected to be technically feasible without additional research and development), raising questions about the feasibility of achieving the level of improvement modeled for the iron and steel industry in the CEF. However, in *Real Prospects for Energy Efficiency in the United States*, the National Academy of Sciences concludes that significant opportunities exist to reduce energy use in the iron and steel sector, pointing to a McKinsey and Company study that found 22 percent energy savings were obtainable by 2020 compared to 2007 levels, which is much greater than the 3 percent improvement the bandwidth study found for current best practices.[138] Furthermore, an American Iron and Steel Institute study, *Saving One Barrel of Oil per Ton*,[139] sets an industry-wide goal of reducing energy-use per ton of steel production by 39 percent in 2025 compared to 2003 levels. Due to this lack of consensus in the available literature in terms of potential efficiency improvements and a common baseline, we did not adjust the iron and steel numbers from those found in the CEF.

TABLE A-13 Energy Savings and Energy-Related Carbon Dioxide Intensity Improvements in the Manufacturing Sector (percent)

	ENERGY SAVINGS WITH BEST PRACTICE (BANDWIDTH)	ENERGY SAVINGS WITH PRACTICAL MINIMUM (BANDWIDTH)	TOTAL ENERGY SAVINGS IN 2035 WHEN COMBINE SAVINGS FROM CEF AND AEO2012	MODELED CO_2 INTENSITY IMPROVEMENT 2035 VS. 2012 (TONS CO_2 FROM COMBUSTION/VALUE OF SHIPMENT)			
				Base Case	Lackluster (10 percent efficiency gain all boilers)	Middle-of-the-Road (CEF)	Go-Getter (CEF + natural gas emissions rate for new units)
Food Products	NA	NA	33	20	26	37	40
Paper	26	39	11	19	25	38	42
Bulk Chemical	18	71	38	27	33	37	38
Glass	35	52	21	11	12	18	19
Cement	NA	NA	31	9	9	32	46
Iron & Steel	3	31	34	33	33	37	45
Aluminum	NA	NA	48	25	28	47	51

Note: The bandwidth study determined baseline energy consumption for paper manufacturing using 2002 Manufacturing Energy Consumption Survey (MECS) data, plus data collected for the report. The bandwidth study for glass was based on data collected through surveys collected for the report prior to publication in 2007. The bandwidth study for steel was based on energy-use data from 2000. The bandwidth study for bulk chemicals was based on energy data collected in 2004 for the report.[140]

Source: Steel Industry Energy Bandwidth Study. Energetics, Inc., U.S. Department of Energy, October 2004; Chemical Bandwidth Study Exergy Analysis: A Powerful Tool for Identifying Process Inefficiencies in the U.S. Chemical Industry. Dickson Ozokwelu, Joseph Porcelli, and Peter Akinjiola, U.S. Department of Energy, December 2006; Industrial Glass Bandwidth Analysis, David Rue, James Servaites, and Warren Wolf, U.S. Department of Energy, December 2006; Pulp and Paper Industry Energy Bandwidth Study, Jacobs Institute of Paper Science and Technology, American Institute of Chemical Engineers, August 2006.

There is considerable uncertainty in industrial unit turnover. Greater equipment turnover could lead to more significant reductions depending on the pace of new technology development and actual standards that are set for new units. Lower turnover would lead to fewer reductions.

There is also considerable uncertainty about the long-term production forecast for each manufacturing subsector. Increased production beyond what is modeled in the AEO2012 could increase emissions, but may also signal improved economics for domestic industry that would allow for greater investments in efficiency technologies and deeper cuts in GHG emissions.

Furthermore, this study relies heavily on the CEF to estimate the emissions reductions achievable if plant-wide efficiency opportunities were incorporated into GHG performance standards. The CEF study considers cost, unit turnover, and directly compares efficiency gains to those built into the AEO. More current assessments would be necessary before regulatory standards could be established for these sectors. New assessments would likely produce different estimates for each manufacturing sector than what we modeled here. Nevertheless, we believe that this analysis provides a sense of the range of reductions achievable through federal authority given the assessments currently available.

6. Modeling Notes for Manufacturing

Changes in purchases of electricity are accounted for in the electricity demand module. Because we relied on EIA's AEO2012 $25 carbon tax scenario for the go-getter power sector generation projections, we had to make adjustments to industrial efficiency savings. This is because the $25 carbon tax scenario includes industrial efficiency savings beyond those modeled in the AEO2012 reference case. Therefore, we incorporated only the benefits that occur beyond those included in the $25 carbon tax scenario, amounting to roughly 45 TWh of additional electricity savings in 2035.

Changes in natural gas consumption are accounted for in the natural gas demand module that adjusts upstream natural gas emissions to reflect downstream consumption patterns.

AEO2012 does not separate out new and older units in intermediary or final outputs for the industrial sector module. Therefore, we had to estimate unit turnover in order to account for the new unit standards in the go-getter scenario. Since the scenario is based on the CEF study, we employed the retirement rates found in the CEF, which are generally higher than those used in the AEO2012. In this analysis, modeling of new unit development is somewhat simplified and can lead to the overdeployment of new units if production rapidly changes for a very brief period of time. To prevent that from occurring, we smoothed the production curves upon which turnover was based. The model did not build out new units if it projected that sector production would result in a surplus supply within seven years of new unit construction. Seven years was chosen because it parallels the AEO2012 assumption that new units are not eligible to retire within the first seven years of construction.

B. CEMENT KILNS

1. Base Case for Cement Kilns

Base case emissions for energy-related CO_2 emissions are discussed above in Section VI.A. In 2010 CO_2 emissions from energy consumption accounted for 46 percent of total CO_2 from cement plants, while the remaining CO_2 emissions were the result of chemical processes (limestone calcination) associated with cement production.[141] In the analysis, we relied on ADAGE for the base case projections of non-energy CO_2 emissions. However, ADAGE does not include a separate line item for cement process emissions, but instead folds them into a broader category that includes process emissions from all energy-intensive manufacturing. Therefore, we developed our own projections. We determined the percentage of industrial process CO_2 emissions attributable to cement production in 2010 using EPA's *2012 Inventory of Greenhouse Gas Emissions and Sinks*,[142] and multiplied this by AEO2012 projections. We then multiplied 2010 emissions by the percent change in cement output for all subsequent years, as obtained from Table 30 of AEO2012, "Cement and Lime Industry Energy Consumption." Using this approach, we estimate that process emissions will increase from 36 mmtCO_2 in 2010 to 42.5 mmtCO_2 in 2035 under the base case. This methodology is viable because AEO2012 does not increase the use of blended cements. Even though section 108 of the Energy

Policy Act of 2005 requires federally funded projects to increase the recovered mineral fraction in cement (e.g., fly ash or blast furnace slag), AEO2012 does not include this requirement because the proportion of mineral component is not specified in the legislation or subsequent regulations.[143]

2. Lackluster Scenario for Cement Kilns

In the ANPR, EPA concluded that the range of effectiveness of individual efficiency measures for existing cement plants was less than 1 percent to 10 percent.[144] EPA also notes that benchmarking and other studies have demonstrated that the most efficient new plants can use 40 percent less energy than older plants using wet kilns. However, AEO2012 assumes that no new wet kilns are built and that all new cement plants are dry kilns,[145] making this comparison less relevant for purposes of this analysis. Therefore, for the lackluster scenario, we assume that EPA establishes performance standards for GHGs for new and existing boilers at cement plants that achieve a 10 percent reduction in emissions beyond business-as-usual projections, which is consistent with the manufacturing lackluster scenario above. Facilities could meet these standards through efficiency improvements or fuel switching.

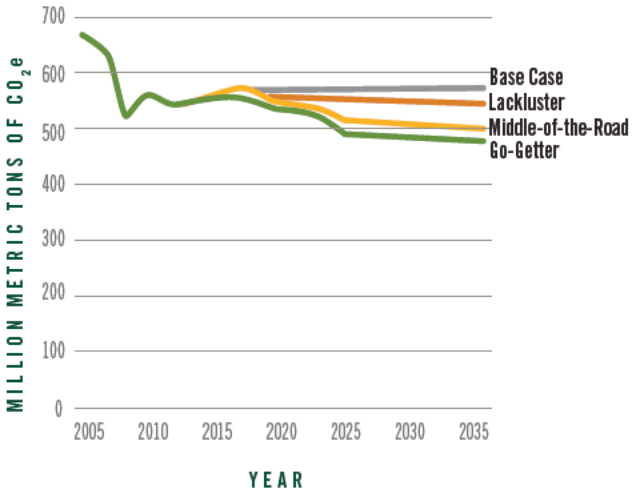
3. Middle-of-the-Road and Go-Getter Scenarios for Cement Kilns

According to AEO2012, boilers are projected to only account for 3 percent of total energy consumption at cement plants in 2012. Therefore, in the middle-of-the-road and go-getter scenarios, we assume that EPA requires facilities to capture emissions reduction opportunities in the entire industrial process that reduce emissions from onsite combustion and purchased electricity. This could be accomplished through output-based emission rate standards or through a more flexible compliance mechanism. In the go-getter scenario, we also assume that EPA establishes emissions standards for all combustion sources in new cement kilns (not just boilers) through New Source Performance Standards, and that those standards require an emissions rate equal to the emissions rate of natural gas combustion. This could be accomplished through co-firing of biomass, fuel switching, carbon capture and sequestration, or built into the reduction schedule of a flexible compliance program. We modeled the middle-of-the-road and go-getter scenarios for cement kilns using the same methodology that we employed for the manufacturing sector middle-of-the-road and go-getter scenarios. The only difference between the cement scenarios and the other manufacturing scenarios is that we also consider reductions in process emissions from the cement sector in our middle-of-the-road and go-getter scenarios. We assume that this is primarily accomplished through greater use of blended cements. Alternatively, cement kilns could comply through the employment of carbon capture and storage. Applying CEF reduction percentages based on more widespread use of blended cements leads to reductions in CO_2 process emissions of 2 percent in 2020 and 13 percent in 2035. CO_2 emissions reductions are detailed in Figure A-1.22 in the middle-of-the-road and go-getter scenarios

4. Uncertainties for Cement Kilns

The uncertainties detailed in the manufacturing sector also apply to the cement sector. We note, however, that there is also considerable uncertainty about the long-term production forecast for cement. Increased production beyond that modeled in AEO2012 could increase emissions, but may also signal improved economics for domestic industry that would allow for greater investments in efficiency technologies and deeper cuts in GHG emissions.

FIGURE A-1.17 Carbon Dioxide Emissions from Industrial Fossil Fuel Combustion and Processes



C. PETROLEUM REFINERIES

1. Base Case for Petroleum Refineries

Base case emissions start with the AEO2012 reference case, which predicts that CO_2 emissions from combustion at refineries will increase from 268 mmtCO_2 in 2012 to 323 mmtCO_2 in 2035. However, the AEO2012 reference case does not include the EPA and NHTSA extension of the national GHG emissions and CAFE standards for model year 2017 through 2025 light-duty vehicles, finalized in August 2012.[146] These standards are included in the base case, and thus we adjusted the base case projections for refineries to account for this reduced demand for refinery products. To calculate the refinery emissions reductions from decreased refinery product demand, we used the simplifying assumption of treating all refinery outputs as though their production required the same relative energy input. This resulted in comparable emissions per unit of production. We also assumed that imports and domestic production would decline at a similar rate, and thus a 10 percent reduction in demand would result in a 10 percent reduction in emissions at refineries located in the United States.

Using the above approach, we estimate that the existing standards will reduce refinery output by 5.2 percent by 2025 and 10.7 percent by 2035 in the base case. These projections are comparable to the AEO side case that considered the proposed vehicle standards.

Our base case assumptions for the projected relative contribution of each refinery product for years 2009–2035 comes from AEO2012.[147] The relative reduction in each refinery product was based on transportation scenario outputs and the relative contribution from each transportation sector in 2010, as reported in EPA's 2012 *Inventory of Greenhouse Gas Emissions and Sinks*.[148]

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Petroleum Refineries

In December 2010, U.S. EPA announced they would establish GHG performance standards for new and existing refineries using their authority under section 111 of the Clean Air Act. As part of this announcement they established a timeline to propose standards by December 2011 and finalize those standards by November 2012.[149] EPA has not met these deadlines, and has not yet issued proposed standards.

Therefore, in all scenarios, we assume that emissions from refineries are reduced by the establishment of performance standards for new and existing units. In the Advanced Notice of Proposed Rulemaking, EPA concludes that benchmarking data suggests that most existing refineries could economically improve energy efficiency by 10–20 percent, and that new refineries could be designed to be at least 20 percent more efficient than existing refineries.[150] One recent study, Energy Bandwidth for Petroleum Refining Processes, published in 2006 by industry experts for the DOE Industrial Technologies Program (ITP), reviewed five major industrial processes that account for roughly 70 percent of energy use in the refining sector. This study concluded that total energy savings of more than 35 percent are achievable using existing "best practices and state-of-the-art technologies under real-world conditions" for these five major processes, and that "plant-wide refinery energy savings potential is usually found to be around 30 percent."[151]

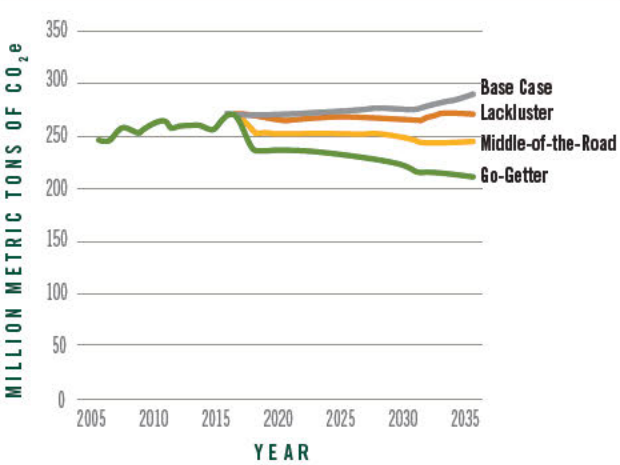
Also, according to a study by the National Academy of Sciences, *Real Prospects for Energy Efficiency in the United States*, identifying plant-wide energy savings of approximately 30 percent would be typical. However, the study also concludes that these gains will be offset by the use of increasingly heavier crude slates in the coming years, resulting in an overall increase in energy consumption per unit of refined product. To some extent these trends are being mitigated by recent production increases of light sweet crude oil from domestic shale plays.[152] The specific efficiency improvements built into the refinery module of AEO2012 are confidential, making it impossible to examine the specific efficiency improvements built into its projections. According to the AEO2012 table *Refining Industry Energy Consumption*, the total energy consumption per unit of refinery input remains relatively constant from 2010 through 2030. If crude slates become increasingly heavy, it may be challenging to get additional emissions reductions beyond those already included in AEO2012.

Given the lack of access to the data underlying AEO2012 projections and the limited inferences that can be drawn from available data, we take a conservative approach to modeling the refinery sector. All three of the reduction scenarios are derived from the lower range of estimates provided for existing

units (i.e., 10 percent) by EPA in the ANPR. For the go-getter scenario, we assumed EPA would require existing units to reduce emissions 10 percent below future projected levels beginning in 2018 through GHG performance standards. For the middle-of-the-road scenario, we assumed that EPA would require existing units to reduce emissions 5 percent below future projected levels, and for the lackluster scenario, we assumed that EPA would require existing units to reduce emissions 1 percent below future projected levels. While we assume that EPA would establish standards for new and existing units, we only modeled reductions for existing sources. This is because AEO2012 does not predict significant deployment of new refineries after 2012,[153] and new development could be offset by reductions in demand caused by the transportation scenarios.

In addition, we examine GHG emissions reductions that result from decreased refinery operation. This is caused by further reductions in petroleum demand due to additional emissions standards for vehicles and industry, energy efficiency standards for home appliances, GHG performance standards for industry, and operational changes for aircraft. The model predicts a 4.8, 9.8, and 17.1 percent decrease in petroleum demand by 2035 compared to base case demand projections under the federal action-only scenarios (and even more when layering in state action). These demand reductions are thus major drivers of emissions reductions across the scenarios.

FIGURE A-1.23 Carbon Dioxide Emissions from Refineries



3. Uncertainties for Refineries Scenarios

The impact of changes in crude slates is uncertain. It is also not entirely clear what efficiency improvements have been built into the AEO2012 base case for refineries. Little unit turnover is projected and this could change, making the emissions reductions projections too low. Under the scenarios we considered, which were intentionally conservative, the primary source of emissions reductions in 2035 was reductions in demand, and not NSPS for refineries. Thus, actual refinery emissions will vary mostly based on actual fuel economy standards, fuel content standards, and changes in vehicle miles traveled.

VII. Appliance and Equipment Efficiency Standards (Heating)

A. MODELING APPROACH FOR APPLIANCE AND EQUIPMENT STANDARDS (HEATING)

Here we focus on opportunities to reduce GHG emissions by increasing the efficiency of appliances that use fossil fuel for purposes such as home heating, cooking, and water heating. We note that there are even greater opportunities to reduce direct combustion of fossil fuels in residential and commercial buildings through improved performance of the building envelope. However, building code policies directly affecting new and existing buildings have historically been controlled by U.S. states and municipalities. These policies are explored in the state scenarios.

Natural gas consumption accounts for the vast majority of onsite fuel consumption for residential and commercial buildings. According to AEO2012, natural gas is expected to account for about 78 to 80 percent of total onsite fuel consumption for residential and commercial buildings from 2012 through 2035. The next largest contributor is distillate fuel, which is only expected to account for about 6 to 9 percent of onsite fuel consumption. Due to this significant disparity, the energy savings primarily affect natural gas consumption.

B. LACKLUSTER, MIDDLE-OF-THE-ROAD, AND GO-GETTER SCENARIOS FOR APPLIANCE AND EQUIPMENT STANDARDS (HEATING)

We base our assumptions about the reductions achievable through increased federal standards for residential and commercial appliances that combust fossil fuels on the *Efficiency Boom* study, discussed in Section III.B. The Efficiency Boom analysis examines efficiency opportunities for the following residential appliances: boilers, clothes washers, dishwashers, and faucets, as well as commercial clothes washers, warm-air furnaces, pre-rinse spray valves, and unit heaters. The study concludes that standards for those sources could reduce gas demand by 126 TBtu in 2025 and 235 TBtu in 2035. For purposes of this analysis, we assumed that standards commence in 2015, and result in a constant increase in savings between 2015 and 2025, and from 2025 through 2035. The net result of the standards is a reduction in CO_2 emissions of 6.7 mmtCO_2 in 2025 and 12.5 mmtCO_2 in 2035.

Opportunities for improving efficiency are also detailed in the AEO2011 expanded standards side case, which found 110 TBtu of savings in 2025 and 230 TBtu of savings in 2035. We rely exclusively on *Efficiency Boom,* however, as it lists specific product standards upon which future actions can be easily compared. No such list is provided for the EIA side case.

Endnotes

1. *Draft Global Non-CO2 Emissions Projections Report: 1990–2030.* Office of Atmospheric Programs, Climate Change Division, U.S. Environmental Protection Agency, EPA 430-D-11-003, August 2011. Accessible at: <http://www.epa.gov/climatechange/EPAactivities/economics/nonco2projections.html>.

2. To download data annex, see: <http://www.epa.gov/climatechange/economics/economicanalyses.html>.

3. *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas.* James Bradbury, Michael Obeiter, Laura Draucker, Wen Wang, and Amanda Stevens. World Resources Institute, Working Paper, forthcoming.

4. *Draft Global Non-CO2 Emissions Projections Report: 1990–2030.* Office of Atmospheric Programs, Climate Change Division, U.S. Environmental Protection Agency, EPA 430-D-11-003, August 2011. Accessible at: <http://www.epa.gov/climatechange/EPAactivities/economics/nonco2projections.html>.

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7. *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas.* James Bradbury, Michael Obeiter, Laura Draucker, Wen Wang, and Amanda Stevens.World Resources Institute, Working Paper, forthcoming.

8. For more information, see: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

9. *Life Cycle Carbon Footprint of Shale Gas: Review of Evidence and Implications.* Christopher Weber and Christopher Clavin. Environ Sci Technol,2012,doi:10.1021/es300375n.Available at: <http://pubs.acs.org/doi/abs/10.1021/es300375n> (with supplemental document).

10. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010.* U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

11. *Annual Energy Review,* Table 5.1b Petroleum Overview, Selected Years, 1949–2011. U.S. Energy Information Administration. Accessible at: <www.eia.gov/totalenergy/data/annual/pdf/sec5_7.pdf>.

12. *Annual Energy Outlook 2012.* U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/>.

13. *Benefits of Addressing HFCs under the Montreal Protocol.* Office of Atmospheric Programs, U.S. Environmental Protection Agency, June 2012. Accessible at: <http://www.epa.gov/ozone/downloads/Benefits%20of%20Addressing%20HFCs%20Under%20the%20Montreal%20Protocol,%20June%202012.pdf>.

14. *VISION 2012 AEO Base Case.* Argonne National Laboratory. Accessible at: <http://www.transportation.anl.gov/modeling_simulation/VISION/>.

15. *Annual Energy Outlook 2012.* U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/>.

16. This emissions level is lower compared to past AEO projections. The previous year's projections, AEO2011, estimated that 2035 emissions from the power sector would be over 8 percent higher (2.5 billion metric tons) than current projections. This is part of a larger trend of declining projections in the AEO going back to 2005. The change in outlook is due to a variety of factors, such as an assumed slow growth in electricity demand, growing use of renewable technologies and fuels, improved efficiency, and increased use of natural gas.

17. Note that AEO2012 includes the impact of AB32 on power sector emissions only.

18. In its initial announcement, EPA committed to issuing these proposed regulations by July 26, 2011 and finalizing the standards and guidelines by May 26, 2012. EPA has not kept to this timeline. For more information, see: <http://www.epa.gov/carbonpollutionstandards/settlement.html>.

19. In setting NSPS, EPA prescribes emissions limitations based on the "best demonstrated technology" (BDT) for new and modified existing source categories it designates. EPA must consider technological feasibility, cost, lead time, and energy and non-air environmental impacts.

20. EPA is conducting a review of the role biomass may play in meeting regulatory requirements for GHGs. No final determinations have emerged from that review. For more information, see: <http://www.epa.gov/NSR/ghgdocs/McCarthytoMartella.pdf>.

21. *The Power to Reduce CO2 Emissions, The Full Portfolio.* 2009 Technical Report, Electric Power Research Institute, Research Update, Oct. 2009.

22. *New "Flexible" Power Plant from GE Breaks Efficiency Record; Nearly $1.2 Billion in Orders.* GE, September 25, 2012. Accessed December 10, 2012. Accessible at: <http://www.gereports.com/new-flexible-power-plant-from-ge-breaks-efficiency-record/>.

23. *Regulating Greenhouse Gas Emissions Under the Clean Air Act.* 73 Register §147 (2008). Accessible at: <http://www.epa.gov/climatechange/emissions/downloads/ANPRPreamble5.pdf>.

24. I*mproving the Efficiency of Coal-Fired Power Plants for Near Term Greenhouse Gas Emissions Reductions.* Phil DiPetro and Katrina Krulla. National Energy Technology Laboratory, Office of Systems, Analyses and Planning, DOE/NETL-2010/1411, April 16, 2010. Accessible at: <http://www.netl.doe.gov/energy-analyses/pubs/ImpCFPPGHGRdctns_0410.pdf; http://www.netl.doe.gov/energy-analyses/pubs/NETL%20Power%20Plant%20Efficiency%20Workshop%20Report%20Final.pdf>. Analyses Show Benefits of Improving Unit Heat Rate as Part of a Carbon Mitigation Strategy. Lehigh Energy Update, Vol. 28, No. 1, February 2010. Accessible at: <http://www.lehigh.edu/~inenr/leu/leu_65.pdf>. Opportunities to Improve the Efficiency of Existing Coal-fired Power Plants. J. Eisenhauer and R. Scheer. National Energy Technology Laboratory, July 15, 2009. *Regulating Greenhouse Gases from Coal Power Plants under the Clean Air Act.* Joshua Linn, Erin Mastrangelo, and Dallas Burtraw. Resources for the Future, January 2012 (revised February 2012). Accessible at: <http://www.rff.org/documents/RFF-DP-11-43-REV.pdf>.

25. For comparative purposes, we note that the National Energy Technology Laboratory (NETL) has set a vision of improving the generation-weighted average efficiency from 32.5 percent to 36 percent based on improvements to existing units, retirement of lower efficiency units, and increased generation from higher efficiency units. This would improve the average heat rate of existing coal units by 10 percent. Researchers at Lehigh University also found that a 10 percent improvement in the heat rate at existing coal-fired units can be achieved through several technological upgrades. Resources for the Future found that after controlling for a variety of technical features across the boiler fleet—such as design, size, and pollution control equipment—a 5 percent reduction in the fleet-wide emissions rate may be technically feasible.

26. Personal communication with Laura Martin, Energy Information Administration, June 27, 2012.

27. *Retail Electricity Price Savings from Compliance Flexibility in GHG Standards for Stationary Sources.* Dallas Burtraw, Matt Woerman, and Anthony Paul. Energy Policy 42: 67–77. RFF Discussion Paper, 11-30, 2012.

28. *Regulating Greenhouse Gases from Coal Power Plants under the Clean Air Act.* Joshua Linn, Dallas Burtraw, and Erin Mastrangelo. RFF Discussion Paper 11-43,2012.

29. *The Consequences of Subcategorization in a GHG Tradable Performance Standard Policy.* Dallas Burtraw and Matt Woerman. Presentation at the annual meeting of the Association of Environmental and Resource Economists, Asheville TN, June 4, 2012.

30. *Closing the Power Plant Carbon Pollution Loophole: Smart Ways the Clean Air Act Can Clean Up America's Biggest Climate Polluters.* Daniel Lashof, Starla Yeh, David Doniger, Sheryl Carter, and Laurie Johnson. Natural Resources Defense Council, December 2012. Accessible at: <http://www.nrdc.org/air/pollution-standards/files/pollution-standards-report.pdf>.

31. AEO2012 predicts that natural gas combined cycle units will remain at 40 to 48 percent capacity through 2035.

32. Note that the Clean Air Act does not permit trading or averaging when complying with performance standards for new sources.

33. *Annual Energy Outlook 2012*. U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/>.

34. *The Efficiency Boom: Cashing In on the Savings from Appliance Standards*. Amanda Lowenberger, Joanna Mauer, Andrew deLaski, Marianne DiMascio, Jennifer Amann, and Steven Nadel. American Council for an Energy-Efficient Economy, Appliance Standards Awareness Project, ASAP-8/ACEEE-A123, March 2012. Accessible at: <http://www.aceee.org/sites/default/files/publications/researchreports/a123.pdf>.

35. 42 U.S.C. Sections 6291 to 6309.

36. See, e.g., 42 U.S.C. Section 6292(b).

37. *The Efficiency Boom: Cashing In on the Savings from Appliance Standards*. Amanda Lowenberger, Joanna Mauer, Andrew deLaski, Marianne DiMascio, Jennifer Amann, and Steven Nadel. American Council for an Energy-Efficient Economy, Appliance Standards Awareness Project, ASAP-8/ACEEE-A123, March 2012. Accessible at: <http://www.aceee.org/sites/default/files/publications/researchreports/a123.pdf>.

38. IEE is an affiliate of the Edison Electric Institute.

39. *Assessment of Electricity Savings in the U.S. Achievable through New Appliance/Equipment Efficiency Standards and Building Efficiency Codes (2010–2025)*. Institute for Electric Efficiency, May 2011. Accessible at: <http://www.edisonfoundation.net/iee/Documents/IEE_CodesandStandardsAssessment_2010-2025_UPDATE.pdf>.

40. Even though the study utilized AEO2011, we believe the study's findings can be applied to our base case, which relies on AEO2012, as conversations with EIA staff indicated that there were no substantive differences in equipment standards between the AEO2011 and AEO2012 reference case.

41. *2010 ISO New England Electric Generator Air Emissions Report*. System Planning Department, ISO New England, Inc., March 2012. Accessible at: <http://www.iso-ne.com/genrtion_resrcs/reports/emission/final_2010_emissions_report_v2.pdf>.

42. *2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards*. U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, 2011. Accessible at: <http://www.gpo.gov/fdsys/pkg/FR-2011-12-01/pdf/2011-30358.pdf>.

43. This follows a rulemaking in May 2010 that required model year 2016 vehicles to meet an emissions standard of 250 grams of carbon dioxide-equivalent emissions per mile, which is equivalent to a fuel economy standard of 35.5 mpg if the automobile industry were to meet those standards solely through fuel economy improvements. The accompanying NHTSA standard was set at 34.1 mpg. At the time, NHTSA considered only drive train improvements and did not consider air conditioning leakage or efficiency improvements for purposes of establishing CAFE standards.

44. *VISION 2012 AEO Base Case*. Argonne National Laboratory. Accessible at: <http://www.transportation.anl.gov/modeling_simulation/VISION/>.

45. While the VISION model relies on EIA's *Annual Energy Outlook* (AEO) projections as much as possible, there are some differences and so VISION's base case does not match EIA's AEO reference case results.

46. *2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards*. U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, 2011. Accessible at: <http://www.gpo.gov/fdsys/pkg/FR-2011-12-01/pdf/2011-30358.pdf>.

47. Interim Joint Technical Assessment Report: Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2017–2025. Office of Transportation and Air Quality, U.S. Environmental Protection Agency, Office of International Policy, Fuel Economy, and Consumer Programs; National Highway Traffic Safety Administration, U.S. Department of Transportation; California Air Resources Board, September 2010. Accessible at: <http://www.epa.gov/otaq/climate/regulations/ldv-ghg-tar.pdf>.

48. CAFE standards do not include benefits from HFC emissions reductions. EPA projected that these benefits would result in credits amounting to 14.3 grams CO_2 per mile in 2025. We deduct these credits when converting from the EPA CO_2 standards to the equivalent CAFE standard.

49. This level of EV penetration will likely require significant infrastructure development and advances in battery technology, both of which would benefit from additional policy interventions.

50. *Analysis of the Transportation Sector: Greenhouse Gas and Oil Reduction Scenarios*. U.S. Environmental Protection Agency, March 2010. Accessible at: <http://www.epa.gov/oms/climate/GHGtransportation-analysis03-18-2010.pdf>.

51. *Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles*. U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, 2011. Accessible at: <http://www.gpo.gov/fdsys/pkg/FR-2011-09-15/pdf/2011-20740.pdf>.

52. *Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles*. U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, 2011. Accessible at: <http://www.gpo.gov/fdsys/pkg/FR-2011-09-15/pdf/2011-20740.pdf>.

53. *Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles*. U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, 2011. Accessible at: <http://www.gpo.gov/fdsys/pkg/FR-2011-09-15/pdf/2011-20740.pdf>.

54. Class 2b vehicles designed as passenger vehicles (medium-duty passenger vehicles, MDPVs) are covered by the light-duty GHG and fuel economy standards and not addressed in this rule.

55. Both EPA and NHTSA also provide manufacturers with optional alternative implementation schedules, but for purposes of our analysis we assume that all manufacturers comply with EPA's standards under the primary implementation schedule.

56. The Energy Independence and Security Act of 2007 (EISA) requires at least three years of "regulatory stability" whereby fuel efficiency standards for medium- and heavy-duty vehicles remain fixed.

57. The rate of improvement in the standards for our lackluster and middle-of-the-road scenarios was calculated as the annual improvement rate between model year 2013 vehicles and the model year 2018 vehicle standard across the medium- and heavy-duty fleet for each of our scenarios.

58. Average fleet-wide fuel economy was weighted using the projected sales for each vehicle category in VISION.

59. *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles*. Committee to Assess Fuel Economy Technologies for Medium- and Heavy-Duty Vehicles, Board on Energy and Environmental Systems Division on Engineering and Physical Sciences, Transportation Research Board, Washington, DC, National Academies, 2010.

60. The major technologies that the National Academies study found necessary to achieve the highest level of reductions are hybridization, advanced diesel engines, and aerodynamics. Other technologies that could help reduce fuel consumption include low-rolling-resistance tires, improved transmissions, idle-reduction technologies, and weight reduction. While the study included energy reductions resulting from driver management and coaching for combination trucks, we did not include these savings in our analysis because EPA has not mandated such operational improvements to date in these standards.

61. In President Obama's May 2010 memorandum, he directed EPA and NHTSA to begin working on a joint rulemaking to establish fuel efficiency and greenhouse gas emissions standards for medium- and heavy-duty vehicles beginning with model year 2014. The memorandum noted that preliminary estimates indicate that large tractor trailers can reduce greenhouse gas emissions by as much as 20 percent and increase their fuel efficiency as much as 25 percent.

62. *Presidential Memorandum Regarding Fuel Efficiency Standards*. May 21, 2010. Accessible at: <http://www.whitehouse.gov/the-press-office/presidential-memorandum-regarding-fuel-efficiency-standards>.

63. *VISION 2012, New Auto Fuel Economy Ratio to Base ICE* (using gasoline equivalent gallons). Argonne National Laboratory. Accessible at: <http://www.transportation.anl.gov/modeling_simulation/VISION/>.

64. *Final Rulemaking to Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles: Regulatory Impact Analysis.* Table 6-11: Estimated Fleet-Wide Fuel Efficiency by Model Year for Alternative 3 [gallons/100 miles]. U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, August 2011. Accessible at: <http://www.epa.gov/oms/climate/documents/420r11901.pdf>.

65. *EPA Analysis of the Transportation Sector.* U.S. Environmental Protection Agency, March 2010.

66. *EPA Analysis of the Transportation Sector.* U.S. Environmental Protection Agency, March 2010.

67. *Next Gen Implementation Plan.* Federal Aviation Administration, 2012. Accessible at: <http://www.faa.gov/nextgen/implementation/media/NextGen_Implementation_Plan_2012.pdf.

68. *EPA Analysis of the Transportation Sector.* U.S. Environmental Protection Agency, March 2010.

69. *Doc 9963 Report of the Independent Experts on the Medium and Long Term Goals for Aviation Fuel Burn Reduction from Technology.* ENGLISH ISBN 978-92-9231-765-2 Order No. 9963,2010.

70. *Factsheet: Technology Roadmap for Environmental Improvement.* International Air Transport Association, June 2012. Accessible at: <http://www.iata.org/pressroom/facts_figures/fact_sheets/Pages/technology.aspx>.

71. *U.S. Aviation Greenhouse Gas Emissions Reduction Plan.* Federal Aviation Administration, June 2012. Accessible at: <http://www.faa.gov/about/office_org/headquarters_offices/apl/environ_policy_guidance/policy/media/Aviation_Greenhouse_Gas_Emissions_Reduction_Plan.pdf>.

72. *Next Gen Implementation Plan.* Federal Aviation Administration, 2012. Accessible at: <http://www.faa.gov/nextgen/implementation/media/NextGen_Implementation_Plan_2012.pdf>.

73. *Reducing emissions from the aviation sector.* European Commission. For more information, see: <http://ec.europa.eu/clima/policies/transport/aviation/index_en.htm>.

74. It is expected that EPA's most recent rulemakings for light-, medium-, and heavy-duty vehicles will result in emissions savings from reduced HFC leakage. For light-duty vehicles, EPA is offering a credit for manufacturers that choose to reduce HFC leakage from air conditioning equipment, and projects that these benefits would result in credits amounting to 14.3 grams CO_2 per mile in 2025. EPA set a separate standard that requires a reduction in the amount of HFC leakage from AC systems in heavy-duty pickup trucks and vans as well as class 7 and 8 tractors, based on the refrigerant capacity of the installed AC system. Since these regulations have been finalized, we account for these savings in our adjusted base case emission projections for HFCs.

75. *Draft Global Non-CO2 Emissions Projections Report: 1990-2030.* Office of Atmospheric Programs, Climate Change Division, U.S. Environmental Protection Agency, EPA 430-D-11-003, August 2011. Accessible at: <http://www.epa.gov/climatechange/EPAactivities/economics/nonco2projections.html>.

76. *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas.* James Bradbury, Michael Obeiter, Laura Draucker, Wen Wang, and Amanda Stevens. World Resources Institute, Working Paper, forthcoming.

77. *Life Cycle Carbon Footprint of Shale Gas: Review of Evidence and Implications.* Christopher Weber and Christopher Clavin. Environ Sci Technol,2012,doi:10.1021/es300375n.Available at: <http://pubs.acs.org/doi/abs/10.1021/es300375n> (with supplemental document).

78. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010.* U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

79. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010.* U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

80. *Annual Energy Review.* Table 5.1b: Petroleum Overview, Selected Years, 1949–2011, U.S. Energy Information Administration. Accessible at: <www.eia.gov/totalenergy/data/annual/pdf/sec5_7.pdf>.

81. *Annual Energy Outlook 2012.* U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/>.

82. *Benefits of Addressing HFCs under the Montreal Protocol.* Office of Atmospheric Programs, U.S. Environmental Protection Agency, June 2012. Accessible at: <http://www.epa.gov/ozone/downloads/Benefits%20of%20Addressing%20HFCs%20Under%20the%20Montreal%20Protocol,%20June%202012.pdf>.

83. To download data annex, see: <http://www.epa.gov/climatechange/economics/economicanalyses.html>.

84. *RTI Applied Dynamic Analysis of the Global Economy (ADAGE) Model.* RTI International-Scientific Research Development Institute. Accessible at: <http://rti.org/page.cfm?objectid=DDC06637-7973-4B0F-AC46B3C69E09ADA9>.

85. *Annual Energy Review.* Table 6.2: Natural Gas Production, Selected Years, 1949–2011. U.S. Energy Information Administration, September 2012. Accessible at: <http://www.eia.gov/totalenergy/data/annual/pdf/aer.pdf>.

86. *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas.* James Bradbury, Michael Obeiter, Laura Draucker, Wen Wang, and Amanda Stevens. World Resources Institute, Working Paper, forthcoming.

87. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010.* U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

88. *Life Cycle Carbon Footprint of Shale Gas: Review of Evidence and Implications.* Weber, Christopher and Christopher Clavin,Environ Sci Technol,2012,doi:10.1021/es300375n. Available at: http://pubs.acs.org/doi/abs/10.1021/es300375n (with supplemental document).

89. For more information, see: http://www.epa.gov/airquality/oilandgas/actions.html.

90. For more information, see: http://www.epa.gov/airquality/oilandgas/pdfs/20120417finalrule.pdf.

91. *How The EPA's New Oil and Gas Standards Will Reduce Greenhouse Gas Emissions.* Michael Obeiter, World Resources Institute Insights Blog, May 9, 2012. Accessible at: http://insights.wri.org/news/2012/05/how-epas-new-oil-and-gas-standards-will-reduce-greenhouse-gas-emissions.

92. Specifically, the regulations require that high-bleed pneumatic controllers, employed during the processing stage of the natural gas lifecycle to maintain gas pressure, need to meet a new leakage rate of six cubic feet of gas per hour. This results in small reductions in methane emissions, according to emissions data from the EPA GHG inventory. More significant reductions will come from compressors used in gas production and processing, as they are a much larger sources of emissions and they will need to reduce VOC emissions by 95 percent. The new rule should reduce methane emissions from compressors by a similar amount, and can be achieved by converting wet seal compressors to dry seals. Additionally, a new performance standard for storage tanks at well sites will primarily address VOC emissions, with limited GHG co-benefits, as storage tanks are not a major source of GHG emissions, according to the GHG inventory.

93. While leak monitoring and repair can apply to the entire transmission life-cycle stage, it is less cost-effective outside of compressor stations since there are hundreds of thousands of miles of pipeline.

94. The payback period for these technologies assumes natural gas prices from the AEO2012 reference case, which range from $4.59/Mcf in 2019 to $7.58/Mcf in 2035.

95. *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas.* James Bradbury, Michael Obeiter, Laura Draucker, Wen Wang, and Amanda Stevens. World Resources Institute, Working Paper, forthcoming.

96. *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas.* James Bradbury, Michael Obeiter, Laura Draucker, Wen Wang, and Amanda Stevens. World Resources Institute, Working Paper, forthcoming.

97. *Leaking Profits: The U.S. Oil and Gas Industry Can Reduce Pollution, Conserve Resources, and Make Money by Preventing Methane Waste.* Natural Resource Defense Council, March 2012. Accessible at: <http://www.nrdc.org/energy/files/Leaking-Profits-Report.pdf>.

98. These conclusions are based on unpublished analysis conducted for this report by the authors of *Clearing the Air on Shale Gas Emissions.*

99. *Annual Energy Review.* Figure 6.0: Natural Gas Flow 2011. U.S. Energy Information Administration, September 2012. Accessible at: <http://www.eia.gov/totalenergy/data/annual/pdf/sec6_3.pdf>.

100. The relative difference largely depends on the actual impact of plunger lifts.

101. Specifically, we predict that demand for natural gas will decrease by 7 percent and 10 percent in 2035 in our lackluster and middle-of-the-road scenarios, respectively. Meanwhile, we predict that demand for natural gas will increase by 12 percent in our go-getter scenario. Across all of the scenarios, power plant standards and residential and commercial appliance and equipment standards were the primary drivers of changes in natural gas demand.

102. W*hat will it take to get sustained benefits from natural gas?* Examining the climate impacts of methane leakage from natural gas, Environmental Defense Fund. Accessible at: http://www.edf.org/methaneleakage

103. *Greenhouse Gas Reporting Program,* U.S. Environmental Protection Agency. Accessible at: http://www.epa.gov/climate/ghgreporting/index.html

104. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010.* U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

105. *Draft Global Non-CO2 Emissions Projections Report: 1990–2030.* Office of Atmospheric Programs, Climate Change Division, U.S. Environmental Protection Agency, EPA 430-D-11-003, August 2011. Accessible at: <http://www.epa.gov/climatechange/EPAactivities/economics/nonco2projections.html>.

106. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010.* U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

107. *Benefits of Addressing HFCs under the Montreal Protocol.* Office of Atmospheric Programs, U.S. Environmental Protection Agency, June 2012. Accessible at: <http://www.epa.gov/ozone/downloads/Benefits%20of%20Addressing%20HFCs%20Under%20the%20Montreal%20Protocol,%20June%202012.pdf>.

108. *Optimization Model for reducing Emissions of Greenhouse gases from Automobiles (OMEGA).* U.S. Environmental Protection Agency, August 2012. Accessible at: <http://www.epa.gov/oms/climate/models.htm>.

109. *Final Rulemaking to Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles: Regulatory Impact Analysis.* Table 6-11: Estimated Fleet-Wide Fuel Efficiency by Model Year for Alternative 3 [gallons/100 miles]. U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, U.S. Department of Transportation, August 2011. Accessible at: <http://www.epa.gov/oms/climate/documents/420r11901.pdf>.

110. 40 CFR Part 82, Subpart A

111. *Benefits of Addressing HFCs under the Montreal Protocol.* Office of Atmospheric Programs, U.S. Environmental Protection Agency, June 2012. Accessible at: <http://www.epa.gov/ozone/downloads/Benefits%20of%20Addressing%20HFCs%20Under%20the%20Montreal%20Protocol,%20June%202012.pdf>.

112. *Benefits of Addressing HFCs under the Montreal Protocol.* Office of Atmospheric Programs, U.S. Environmental Protection Agency, June 2012. Accessible at: <http://www.epa.gov/ozone/downloads/Benefits%20of%20Addressing%20HFCs%20Under%20the%20Montreal%20Protocol,%20June%202012.pdf>.

113. These calculations assume that emissions from the five main end uses for HFCs were equivalent to the midpoint of their emissions range, as described in EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010.* For each of the five main end uses, reported annual emissions rates are as follows: refrigeration and air conditioning (1–28 percent), aerosols (100 percent), foams (100 percent), solvents (90 percent), and fire protection (5–8 percent). Note that if average emissions are more consistent with the lower range of the reported emissions rates for the five major end uses, then total U.S. GHG emissions in 2020 will be 15 percent below 2005 levels. If average emissions are consistent with the upper-bound emissions rate, then total U.S. GHG emissions in 2020 will be 19 percent below 2005 levels.

114. *Draft Global Non-CO2 Emissions Projections Report: 1990–2030.* Office of Atmospheric Programs, Climate Change Division, U.S. Environmental Protection Agency, EPA 430-D-11-003, August 2011. Accessible at: <http://www.epa.gov/climatechange/EPAactivities/economics/nonco2projections.html>.

115. *Appendix B: Economic Modeling Results, Design Recommendations for the WCI Regional Cap-and-Trade Program.* Western Climate Initiative, September 23, 2008. Accessible at: <http://www.westernclimateinitiative.org/component/remository/func-startdown/18/>. *Cap-and-Trade Modeling: Policy Run Results.* Presentation to the GHG Accord Advisory Group, Midwestern Greenhouse Gas Reduction Accord, Minneapolis, May 11, 2009. *EPA Analysis of the American Clean Energy and Security Act of 2009, H.R. 2454 in the 111th Congress.* U.S. Environmental Protection Agency, Office of Atmospheric Programs, June 23,2009. Accessible at: <http://www.epa.gov.climatechange/economics/pdfs/HR2454_Analysis.pdf>. *Energy Market and Economic Impacts of H.R. 2454, the American Clean Energy and Security Act of 2009.* Office of Integrated Analysis and Forecasting, U.S. Energy Information Administration, 2009. Accessible at: <http://www.eia.doe.gov/oaif/servicerpt/hr2454/pdf/sroiaf(2009)05.pdf>. *Economic Impacts of S. 1733: The Clean Energy Jobs and American Power Act of 2009 in the 111th Congress.* U.S. Environmental Protection Agency, Office of Atmospheric Programs, October 23, 2009.

116. Participants in the Interagency Working Group on the Social Cost of Carbon included the White House Council of Economic Advisers, White House Council on Environmental Quality, Department of Agriculture, Department of Commerce, Department of Energy, Department of Transportation, Environmental Protection Agency, National Economic Council, Office of Energy and Climate Change, Office of Management and Budget, Office of Science and Technology Policy, and Department of the Treasury. For more information, see: <http://www.epa.gov/oms/climate/regulations/scc-tsd.pdf>.

117. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010.* U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

118. *N_2O Emissions from Adipic Acid and Nitric Acid Production.* Heike Mainhardt, ICF Incorporated, Contribution of Working Group 1 to the *Fourth Assessment Report of the Intergovernmental Panel on Climate Change*(S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller, eds). Accessible at: <http://www.ipcc-nggip.iges.or.jp/public/gp/bgp/3_2_Adipic_Acid_Nitric_Acid_Production.pdf>.

119. *Global Mitigation of Non-CO2 Greenhouse Gases.* Micke Gallaher, Deborah Ottinger, Dave Godwin, and Benjamin DeAngelo, Robert Beach, Jochen Harnisch, Sina Wartmann, William Salas, Changsheng Li, Stephen Del Grosso, and Timothy Sulser. U.S. Environmental Protection Agency, EPA Technical Report, June 2005. Accessible at: <http://www.ars.usda.gov/research/publications/publications.htm?seq_no_115=197768>.

120. *Global Mitigation of Non-CO2 Greenhouse Gases.* Micke Gallaher, Deborah Ottinger, Dave Godwin, and Benjamin DeAngelo, Robert Beach, Jochen Harnisch, Sina Wartmann, William Salas, Changsheng Li, Stephen Del Grosso, and Timothy Sulser. U.S. Environmental Protection Agency, EPA Technical Report, June 2005. Accessible at: <http://www.ars.usda.gov/research/publications/publications.htm?seq_no_115=197768>.

121. Here, production levels are defined in terms of the dollar value of shipments. These values are adjusted for inflation.

122. *Assumptions to the AEO2012.* U.S. Energy Information Administration, June 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/assumptions/pdf/0554(2012).pdf>.

123. AEO2012 is built using the National Energy Modeling System (NEMS). NEMS assumes that gas and oil burners meet the standards set by the Energy Policy Act of 1992, which requires gas burners to have heat rates of 1.25 (80 percent efficiency) and oil burners have heat rates of 1.22 (82 percent efficiency). AEO2012 assumes that cogeneration units experience a steady increase in their efficiency through 2035.

124. *Regulating Greenhouse Gases from Coal Power Plants under the Clean Air Act.* Joshua Linn, Erin Mastrangelo, and Dallas Burtraw. Resources for the Future, January 2012 (revised February 2012). Accessible at: <http://www.rff.org/documents/RFF-DP-11-43-REV.pdf>.

125. For the iron and steel sector we assumed that boiler efficiency gains only reduce combustion of main fuel sources (natural gas, residual oil, steam coal, etc.), and not intermediary fuels that are the byproduct of direct combustion in coke ovens and blast furnaces.

126. Refineries were modeled separately. Therefore, for purposes of this analysis, we consider the following categories to be included in the manufacturing sector: food and kindred projects, paper and allied products, bulk chemicals, glass and glass products, cement, iron and steel, aluminum, fabricated metal products, machinery, computer and electronic products, transportation equipment, electrical equipment, appliances and components, wood products, and plastic and rubber products. The remaining manufacturing facilities are grouped into a single subcategory, called balance of manufacturing.

127. EPA finalized new standards for emissions of air toxics from industrial boilers (Boiler MACT) in December 2012.Those standards require boiler tune-ups, which according to EPA have been shown to improve efficiency between 1 and 5 percent. Those standards will lower the marginal improvement from the GHG standards we model. However, we note that the upper range of the efficiency improvements identified by EPA fall well short of those modeled in the lackluster scenario, suggesting that GHG emissions standards could drive additional reductions from industrial boilers.

128. *Regulatory Impact Results for the Reconsideration Proposal for National Emission Standards for Hazardous Air Pollutants for Industrial, Commercial, and Institutional Boilers and Process Heaters at Major Sources.* U.S. Environmental Protection Agency, December 1, 2011. Accessible at: <http://www.epa.gov/ttn/atw/boiler/boilersriaproposalrecon111201.pdf>.

129. *Model Documentation Report: Industrial Sector Demand Module of the National Energy Modeling System, DOE/EIA-M064(2011).* U.S. Energy Information Administration, Office of Integrated Analysis and Forecasting, May 2011. Accessible at: <http://www.eia.gov/FTPROOT/modeldoc/m064(2011).pdf>.

130. See the reports of the Climate Change Working Group at: <http://www.epa.gov/air/caaac/climatechangewg.html>.

131. *Scenarios for a Clean Energy Future.* Interlaboratory Working Group and Lawrence Berkeley National Laboratory, Oak Ridge, TN, Berkeley, CA, ORNL/CON-476 and LBNL-44029, November 2000.

132. We converted the study's listed price ($50 per ton of carbon) into a carbon dioxide price and 2011 dollars using the consumer price index. For more information, see Consumer Price Index, All Urban Consumers, at: <ftp://ftp.bls.gov/pub/special.requests/cpi/cpiai.txt>.

133. *Real Prospects for Energy Efficiency in the United States.* Panel on Energy Efficiency Technologies, Washington, D.C., National Academy Press, 2009. *The Untapped Energy Efficiency Opportunity in the U.S. Industrial S*ector: Details of Research, 2008. McKinsey and Company, 2008.

134. Note that the CEF projects sector-specific fuel-use patterns that were developed before the recent boom in shale gas extraction and consumption.

135. *Industrial Glass Bandwidth Analysis.* David Rue, James Servaites, and Warren Wolf. U.S. Department of Energy, December 2006. Accessible at: <http://www1.eere.energy.gov/manufacturing/industries_technologies/glass/pdfs/industrial_bandwidth.pdf>.

136. *Chemical Bandwidth Study Exergy Analysis: A Powerful Tool for Identifying Process Inefficiencies in the U.S. Chemical Industry.* Dickson Ozokwelu, Joseph Porcelli, and Peter Akinjiola. U.S. Department of Energy, December 2006. Accessible at: <http://www1.eere.energy.gov/industry/chemicals/pdfs/chemical_bandwidth_report.pdf>.

137. This comparison is based on the middle-of-the-road scenario, which only includes efficiency improvements. The go-getter scenario includes fuel switching, leading to greater emissions reductions.

138. *Real Prospects for Energy Efficiency in the United States.* Panel on Energy Efficiency Technologies, Washington, D.C., National Academy Press, 2009. *The Untapped Energy Efficiency Opportunity in the U.S.* Industrial Sector: Details of Research, 2008. McKinsey and Company, 2008.

139. *Saving One Barrel of Oil per Ton.* American Iron and Steel Institute, October 2005.

140. *Steel Industry Energy Bandwidth Study.* Energetics, Inc., U.S. Department of Energy, October 2004. Accessible at: <http://www1.eere.energy.gov/industry/steel/pdfs/steelbandwidthstudy.pdf>. *Chemical Bandwidth Study Exergy Analysis: A Powerful Tool for Identifying Process Inefficiencies in the U.S. Chemical Industry.* Dickson Ozokwelu, Joseph Porcelli, and Peter Akinjiola. U.S. Department of Energy, December 2006. Accessible at: <http://www1.eere.energy.gov/industry/chemicals/pdfs/chemical_bandwidth_report.pdf>. *Industrial Glass Bandwidth Analysis.* David Rue, James Servaites, and Warren Wolf. U.S. Department of Energy, December 2006. Accessible at: <http://www1.eere.energy.gov/manufacturing/industries_technologies/glass/pdfs/industrial_bandwidth.pdf>. *Pulp and Paper Industry Energy Bandwidth Study.* Jacobs Institute of Paper Science and Technology, American Institute of Chemical Engineers, August 2006. Accessible at: <http://www1.eere.energy.gov/industry/forest/pdfs/doe_bandwidth.pdf>.

141. Energy-CO_2 emissions from *Annual Energy Outlook 2012.* U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/>. Process CO_2 emissions from *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010.* U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

142. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010.* U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

143. *Model Documentation Report: Industrial Sector Demand Module of the National Energy Modeling System, DOE/EIA-M064(2011).* U.S. Energy Information Administration, Office of Integrated Analysis and Forecasting, May 2011. Accessible at: <http://www.eia.gov/FTPROOT/modeldoc/m064(2011).pdf>.

144. For more information, see: <http://www.epa.gov/climatechange/Downloads/anpr/ANPRFactSheet.pdf>.

145. *Model Documentation Report: Industrial Sector Demand Module of the National Energy Modeling System, DOE/EIA-M064(2011).* U.S. Energy Information Administration, Office of Integrated Analysis and Forecasting, May 2011. Accessible at: <http://www.eia.gov/FTPROOT/modeldoc/m064(2011).pdf>.

146. *2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards.* U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, 2011. Accessible at: <http://www.gpo.gov/fdsys/pkg/FR-2011-12-01/pdf/2011-30358.pdf>.

147. *Annual Energy Outlook 2012.* U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/>.

148. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010.* U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

149. For more information, see: <http://www.epa.gov/airquality/cps/pdfs/refineryghgsettlement.pdf>.

150. *Regulating Greenhouse Gases from Coal Power Plants under the Clean Air Act.* Joshua Linn, Erin Mastrangelo, and Dallas Burtraw. Resources for the Future, January 2012 (revised February 2012). Accessible at: <http://www.rff.org/documents/RFF-DP-11-43-REV.pdf>.

151. *Energy Bandwidth for Petroleum Refining Processes.* Energetics Inc., U.S. Department of Energy, October 2006. Accessible at: <http://www1.eere.energy.gov/industry/petroleum_refining/pdfs/bandwidth.pdf>.

152. Personal communication, U.S. Energy Information Administration, October 29, 2012.

153. *Annual Energy Outlook 2012.* Table 59: Domestic Refinery Distillation Base Capacity and Expansion. U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/>.

Appendix II: State Methods

I. State Action

This analysis seeks to understand the impact state actions can have on U.S. greenhouse gas emissions. It has two components: the first considers the impact of states taking action in the absence of federal action; the second considers the impact of states taking action in the presence of varying levels of federal action. In both components we examine the implication of states implementing the same types of policies modeled for the federal government, as well as more traditional state-level actions in the transportation, energy efficiency, and renewables areas.

This approach is based on the observation that the Constitution grants states broad authority to regulate their energy sources and emissions. Thus, states have the ability to implement many of the same policies as federal agencies. We also note that states are more likely to pursue these options when federal action falls short.

State-level actions generally complement federal authorities in transportation, energy efficiency, and renewable energy. Regarding transportation, the state scenarios consider measures to encourage low-carbon fuels and reduce vehicle miles traveled to complement federal vehicle efficiency measures. In the energy efficiency area, actions modeled include reduced energy consumption through end-use energy efficiency for electricity and natural gas, improved building performance, and increased deployment of combined heat and power. For renewables, the analysis adds new and additional renewable energy deployment across a certain number of states.

Unlike the federal analysis, many of the state actions modeled would require new legislation at the state level. Also unlike the federal scenario, the categorization of state action—whether "lackluster," "middle-of-the-road," or "go-getter"—is partially a function of how many states adopt the actions modeled. Thus a lackluster state trajectory does not necessarily mean that individual states have failed to take ambitious action. Instead, it can represent a scenario where a limited number of states have taken action and the result is that the combination of state actions has affected the national trajectory in a lackluster manner.

In the state scenarios, we do not identify specific states that take action. Rather, we identify percentages of the relevant sector that are subject to a new or expanded action, thus accounting for a variety of possible combinations of states and policies that can result in a similar level of GHG benefits. For example, to model the middle-of-the-road scenario for low-carbon fuels, we assume that states that account for 25 percent of energy consumption from transportation fuels reduce the carbon intensity of fuels by 1 percent per year beginning in 2015. This scenario, however, is not meant to be limited to this specific set of assumptions. Other combinations of numbers of states and levels of stringency could achieve this same "middle-of-the-road" result. For example, the same level of reductions could be achieved if states that accounted for 12.5 percent of energy consumption from transportation fuels reduced the carbon intensity of fuels by 2 percent per year. In this way, we capture a variety of possible combinations of policy ambition and state adoption levels under the same scenario.

II. Transportation

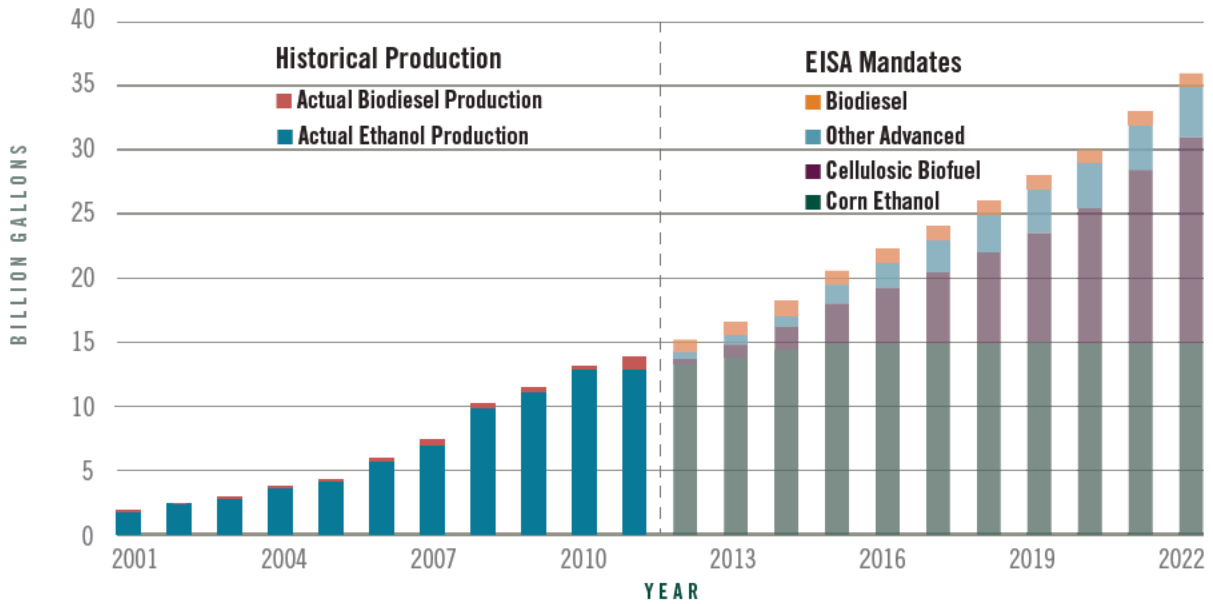
A. DIVERSIFICATION OF FUEL MIX REDUCES THE AVERAGE CARBON CONTENT OF FUELS

1. Base Case for Diversification of Fuel Mix

As described in Appendix I (Sections VII.A and VII.B), we developed our base case assumptions for light-, medium-, and heavy- duty vehicles from Argonne National Laboratory's "VISION 2012 AEO base case," which is calibrated to the *Annual Energy Outlook 2012.* However, we updated the base case to reflect new standards for light-duty vehicles sold through the 2025 model year.

The Energy Independence and Security Act of 2007 (EISA 2007) increases the volume of renewable fuel required to be blended into transportation fuel sold in the U.S. from nine billion gallons in 2008 to thirty-six billion gallons in 2022 (See Figure A-2.1). The law requires that the vast majority of the increase from current production levels come from cellulosic biofuel and other advanced biofuels. EISA 2007 requires EPA to annually estimate projected biofuel capacity for the following year, and if necessary adjust the production

FIGURE A-2.1 Biofuel Production Required by the Energy Independence and Security Act of 2007



Sources: Figure created using data from U.S. EIA's Annual Energy Review 2011 and U.S. EIA's Annual Energy Outlook 2012.

mandates downward. In each of the past three years, EPA determined it was not possible to meet the annual cellulosic biofuel target and adjusted the target downward compared to the level mandated in the initial rule.[1,2,3] Based on this recent history, and their own assessment of financial and technological barriers, the AEO 2012 assumes that the advanced biofuel targets will not be met until 2033.[4]

To qualify for credit under EISA 2007, transportation fuels sold in the U.S. must meet specified life-cycle emissions thresholds, which are lower than the life-cycle GHG emissions of conventional gasoline or diesel.[5] The statute requires EPA to account for the direct and indirect life-cycle emissions implications of qualifying biofuel production, considering all stages of fuel and feedstock production and distribution, including those emissions associated with direct and indirect land-use change. EPA has found that there are always life-cycle emissions associated with the production of biofuels. In contrast, AEO assumes that all biofuels are carbon neutral. When quantifying GHG emissions associated with the combustion of fuels, AEO assumes that biofuel emissions are offset by carbon sequestration that occurs during growth of the feedstock and does not consider emissions from land use and land-use change.[6] We did not adjust AEO's treatment of biofuel emissions in developing our base case.

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Diversification of Fuel Mix

Enhanced fuel mix diversity can reduce the average carbon intensity of fuels, thereby reducing GHG emissions associated with transportation. Fuel-mix diversification can be promoted by programs that promote alternative fuel production and/or consumption, or through the development of fueling station infrastructure.

Seven states have already set minimum requirements on the amount of renewable fuel that must be blended into gasoline, diesel, or both. However, these programs do not specify what types of renewable fuels must be used, thus allowing for the use of a wide range of biofuel feedstock, with uncertain net emissions implications. Louisiana and Pennsylvania have blend mandates for ethanol and diesel that will be triggered once state production reaches specified levels.[8]

To date, twenty-eight states offer biofuel tax incentives for ethanol, biodiesel, or both.[9] Idaho, North Dakota, South Dakota, and Wisconsin are among several states that offer tax incentives for development of biofuel infrastructure.[10] In addition, Louisiana, Minnesota, Nebraska, North Dakota, and Virginia have already begun to offer programs supporting research and development of advanced biofuels.[11] Rhode Island is

TABLE A-2.1 Low-carbon Transportation Fuel Scenarios

ACTION	POLICIES AND PROGRAMS DRIVING ACTION	SCENARIOS		
		Lackluster	Middle-of-the-Road	Go-Getter
Diversity in fuel mix resulting in lower average carbon content of fuels	• Low-carbon fuel standard • Clean fuel standard • Advanced biofuels standard • Infrastructure incentives	States that account for 15 percent of energy consumption from transportation fuels reduce carbon intensity of fuels by 1 percent per year beginning in 2015 through 2035.	States that account for 25 percent of energy consumption from transportation fuels reduce carbon intensity of fuels by 1 percent per year beginning in 2015 through 2035.	States that account for 35 percent of energy consumption from transportation fuels reduce carbon intensity of fuels by 1 percent per year beginning in 2015 through 2035.

actively researching and developing plans to expand advanced biofuel production.

Life-cycle GHG emissions intensity can vary considerably depending on the fuel type, sources, and production methods. In the Renewable Fuel Standard Regulatory Program Analysis completed in February 2010, EPA found that advanced biofuels can reduce life-cycle GHG emissions 40 to 90 percent below conventional gasoline, whereas corn ethanol from typical new facilities can only reduce life-cycle GHG emissions between 0 and 40 percent below conventional gasoline.[12,13]

In order to guarantee a reduction in the carbon intensity of fuels, some states have begun to pursue a clean fuel standard or a low-carbon fuel standard. The first such standard was issued by the California Air Resources Board in 2009. It requires the carbon intensity of fuels sold in California to be reduced 10 percent by 2020.[14] Initiatives under way in the Pacific Northwest and Northeast and Mid-Atlantic are evaluating the implications of implementing similar types of standards.[15]

In our scenarios we assume that states pursue a range of actions such as those described above, and that those policies further reduce the average carbon intensity of transportation fuels by 1 percent per year between 2015 and 2035. This rate is generally consistent with targets being considered in the Northeast, Washington, and Oregon, as well as the targets required under California's Low Carbon Fuel Standard.[16] If a similar target was adopted nationwide, this would reduce the carbon intensity of fuels an additional 6 percent in 2020 and 21 percent in 2035. In the lackluster scenario, we assume this annual reduction is achieved by states accounting for 15 percent of energy consumption from transportation fuels. In the middle-of-the-road and go-getter scenarios, we assume that these policies are pursued by states accounting for 25 percent and 35 percent of fuel consumption, respectively. We assume these state actions affect both gasoline and diesel consumption.

Table A-2.2 is intended to help put these numbers into context. It shows that California alone accounts for 10 percent of U.S. on-road fuel consumption, and that the Northeast and Pacific Northwest account for 17 percent and 3 percent of on-road fuel consumption, respectively. Meanwhile, the top five biofuel producing states (IA, NE, IL, MN, and IN) account for 10 percent of on-road fuel consumption.

TABLE A-2.2 Motor Fuel Consumption, 2010

	PERCENT OF TOTAL U.S. MOTOR FUEL CONSUMPTION
California	10
Northeast (New England, Mid-Atlantic, DE, MD)	17
Pacific Northwest	3
Top 5 Biofuel Producers (IA, NE, IL, MN, IN)	10

Source: State Energy Data System, U.S. EIA, 2012.

The 2007 EISA established a national renewable fuel standard that requires increasing renewable fuel production through 2022, with required production levels in later years to be established by the EPA in a future rulemaking. In the scenarios that we consider, biofuel production does not meet or exceed

those standards through 2022. Under all of the state scenarios, biofuel consumption continues to rise until 2035, and over time even the lackluster scenario could lead to biofuel production levels in excess of the 2022 standards sometime before 2035. Note that the precise date the EISA's 2022 standards are exceeded and the total level of biofuel consumption will depend on assumptions about federal agency actions and the impact of fuel economy standards on biofuel consumption. The EISA 2022 standard represents 22 percent of total fuel consumed by light-, medium-, and heavy-duty vehicles in 2022 under our base case.

3. Modeling Notes for Diversification of Fuel Mix

In our model we assume that all of the GHG reductions from fuel diversification are the result of increased biofuel consumption and are not due to state policies and programs promoting use of PHEVs, EVs, and natural gas vehicles. Deployment of PHEVs, EVs, and natural gas vehicles provide credit for manufacturers to meet their national emissions and CAFE standards. This means that increased deployment of these vehicles in one state can help a manufacturer meet the standards and therefore will not necessarily result in nationwide emission reductions.[17] It is true that the current CAFE standards contain an incentive for biofuel vehicles. However, no such credit is provided under EPA's GHG emissions standards, and thus increased consumption of biofuels is expected to lead to additional reductions in GHG emissions.

Biofuels present a modeling challenge due to the uncertainty about the GHG benefits they provide. EPA's *Renewable Fuel Standard Regulatory Program Analysis* finds that in some cases corn ethanol consumption could be worse than traditional gasoline consumption—for instance, if the ethanol is produced in a dry mill fueled by coal.[18]

It is beyond the scope of our analysis to directly model emissions from the fuel production process. Instead, we avoid modeling these impacts by considering only those state policies that are directly or indirectly responsive to the life-cycle impacts of fuel production (e.g., clean fuel standard, advanced biofuel standard).

We assume that the same states that pursue fuel diversification policies also pursue VMT reduction policies. This results in a conservative estimate of the benefits of these policies, since the relative impact of each policy will be less in the presence of the other policy than it would on its own.

4. Uncertainties for Diversification of Fuel Mix

California's LCFS is currently being challenged in two separate lawsuits brought by ethanol producers, refineries, and truckers.[19] One of the rulings prevented California from enforcing the rule, but this injunction was lifted in April 2012 pending a decision on California's appeal. A three-judge panel of the Ninth Circuit Court of Appeals heard oral arguments in this case in October 2012.

For purposes of this analysis, we assume that state policies drive changes in the fuel mix beyond what is required nationally. If, however, state and federal policies are designed in a way that allows increased state consumption or production to count toward the federal fuel standards, then benefits of those policies would decrease.

B. VMT REDUCTION

1. Base Case for VMT Reduction

In these scenarios we only consider reductions in vehicle miles traveled (VMT) from light-duty vehicles. We use the same baseline for gasoline and diesel consumption for light-duty vehicles as our base case for diversity in fuel mix. The AEO2012 projects VMT to increase from 2,660 billion miles in 2010 to 3,583 billion miles in 2035. This is a slower rate of growth than has been projected in previous AEOs, which can be attributed to rising fuel costs and the effects of the economic recession.[20]

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for VMT Reduction

A variety of growth and land-use strategies can reduce VMT and contribute to GHG emissions savings.[21] These include smart-growth strategies, such as targeting growth near public transportation, favoring infill, limiting sprawl, mixed-use development, and provision of affordable housing options. Growth strategies can be complemented by a variety of other tools to reduce VMT, including improving and expanding public transportation options, bike and pedestrian pathways, and car sharing, as well as through speed limit restrictions, intercity tolls, and strategies to limit driving within urban centers (such as parking restrictions).[22]

States play an important role in encouraging the development of smart-growth and related strategies. They can adopt VMT or GHG reduction targets, direct funding for smart growth, and work with regional

TABLE A-2.3 Vehicle Miles Traveled (VMT) Scenarios

ACTION	POLICIES AND PROGRAMS DRIVING ACTION	SCENARIOS		
		Lackluster	Middle-of-the-Road	Go-Getter
Vehicle miles traveled (VMT) reduction	• Smart growth • Improved public transit • Pedestrian and biking infrastructure • Improved traffic systems operation	States that account for 15 percent of GHG emissions from light-duty vehicles annually reduce VMT 0.5 percent below base case projections beginning in 2016	States that account for 25 percent of GHG emissions from light-duty vehicles annually reduce VMT 0.5 percent below base case projections beginning in 2016	States that account for 35 percent of GHG emissions from light-duty vehicles annually reduce VMT 1 percent below base case projections beginning in 2016

planning organizations to implement strategies that will achieve reduction goals.

Several states are in the process of implementing or developing smart-growth programs and policies. In Maryland, the Greenhouse Gas Reduction Act of 2009 required the Maryland Department of the Environment to develop a plan to reduce GHG emissions 25 percent below 2006 levels by 2020 and to allocate reduction targets to lead agencies by economic sector.[23] The Maryland Department of Transportation then developed a plan to meet its allocated goal by adopting VMT reduction strategies such as improved public transportation, bike and pedestrian infrastructure, and travel demand management. According to analysis by the Maryland Department of Transportation, plans that are already currently funded are expected to reduce VMT by roughly 5 percent by 2020 compared to business-as-usual projections, or just over 0.5 percent per year between 2012 and 2020.[24]

California is pursuing a similar strategy with its Sustainable Communities and Climate Protection Act of 2008. This law directs state agencies to set GHG emissions targets from smart growth and other VMT policies and to work with metropolitan planning organizations (MPOs) to implement strategies expected to help achieve these targets.[25] California's Air Resources Board worked with MPOs to develop regionally appropriate targets. In the MPOs with the greatest population densities, this process resulted in per capita GHG emissions reduction targets of 7 to 8 percent below 2005 levels by 2020 and 13 to 16 percent below 2005 levels by 2035. In lower density MPOs, this process resulted in targets around 5 percent below 2005 levels by 2020 and 10 percent below 2005 levels by 2035. In rural areas, targets are lower, and in some cases VMT growth will be allowed until after 2020. The state lacks the authority to require MPOs to adopt these targets or to require the jurisdictions therein to implement VMT strategies. The MPOs, however, have been able to get jurisdictions to participate by prioritizing transportation funding and streamlining administrative requirements for those jurisdictions implementing VMT reduction plans.[26]

Other states are moving forward as well. In Oregon, legislation directed the state Department of Transportation to set GHG reduction goals consistent with a statewide target of 10 percent below 1990 levels by 2020, and to work with MPOs to enact strategies to meet those goals.[27] Similar legislation in Washington established specific VMT reduction targets of 35 percent below 1990 levels by 2035, although later reevaluation of the target suggested 7 to 10 percent was more realistic.[28] Other states—including New York and Massachusetts—are developing smart-growth and VMT reduction strategies as part of broader climate initiatives.[29]

In our lackluster and middle-of-the-road scenarios, we assume that states implement policies and programs that reduce their VMT an additional 0.5 percent below business-as-usual projections per year beginning in 2016, leading to a 10 percent reduction below business-as-usual projections in 2035.[30] This is on the conservative end of the range found in current state programs. We assume that states accounting for 15 percent and 25 percent of GHG emissions from light-duty vehicles adopt programs or policies that lead to these annual savings in the lackluster and middle-of-the-road scenarios, respectively. In the go-getter

scenario, we assume that states reduce their VMT 1 percent below business-as-usual projections per year beginning in 2016, leading to a 20 percent reduction in 2035.

We assume that such programs or policies are pursued by states accounting for 35 percent of GHG emissions from light-duty vehicles.

A VMT reduction of 1 percent per year is consistent with existing plans in California, Oregon, and New York. An analysis by the Urban Land Institute and Cambridge Systematics that looks at a similar set of policies finds that widespread adoption of land use and public transportation strategies results in GHG reductions of about 17 percent below baseline in 2030.[31] By comparison, if all states pursued go-getter-level ambition, reductions in 2030 would be 15 percent below baseline.

Note that the six states identified as already pursuing mandatory and voluntary policies above account for 22 percent of VMT. None of these state programs are directly included in the AEO2012 reference case. Additional state VMT profiles are provided in Table A-2.4.

TABLE A-2.4 Top 15 States According to Light-Duty Vehicle Miles Traveled (VMT), 2010

STATE	VMT (billions)	PERCENT OF TOTAL U.S. VMT
California*	323	11
Texas	234	8
Florida	196	7
New York*	131	4
Ohio	112	4
Georgia	112	4
Illinois	106	4
North Carolina	102	3
Pennsylvania	100	3
Michigan	98	3
Virginia	82	3
Indiana	76	3
New Jersey	73	3
Missouri	71	2
Tennessee	70	2
Washington*	57	2
Maryland*	56	2
Massachusetts*	54	2
Oregon*	33	1

Source: Bureau of Transportation Statistics, State Transportation Statistics, Table 5-3.
Note: Asterisks indicate states with VMT reduction plans. States shaded gray are not in the top 15 of light-duty VMT but are listed here for reference because they have existing reduction plans.

III. Energy Efficiency

A. ELECTRICITY SAVINGS

I. Base Case for Electricity Savings

Reducing electricity demand through improved end-use efficiency avoids the need to burn fossil fuel to generate electricity, thus reducing GHG emissions. A variety of state policies and programs already drive efficiency improvements, including energy efficiency resource standards, programs funded by system benefit charges, and least-cost procurement.[32] In addition, most states participating in the Northeastern and Mid-Atlantic Regional Greenhouse Gas Initiative (RGGI) also use auction revenue to fund electric efficiency programs.[33]

As described in detail in Appendix I, Sections III.A and IV.A, we utilized U.S. Energy Information Administration's (EIA) data for electricity demand in our base case. AEO2012 does not explicitly model state energy efficiency programs. However, programs in existence in 2011 and earlier are generally thought to be captured through recent regional electricity demand trends. Efficiency savings from new programs or existing programs that increase their incremental targets are generally expected to be additional to those modeled in the AEO reference case.[34]

Because AEO2012 does not model state-specific projections, we had to develop electricity demand projections for each U.S. state and the District of Columbia. This was done using historical electricity demand data for each state from EIA's State Energy Data System[35] and regional annual electricity demand growth rates from the AEO2012 reference case.

TABLE A-2.5 Electricity Savings Scenarios

ACTION	POLICIES AND PROGRAMS DRIVING ACTION	SCENARIOS		
		Lackluster	Middle-of-the-Road	Go-Getter
Electricity savings from states with EE targets	• Energy efficiency resource standards • System benefit charge funds or other funds • Least-cost procurement requirements	States responsible for 75 percent of electricity consumption that have existing annual energy efficiency targets below 1.5 percent achieve annual efficiency savings of 1.5 percent per year beginning in 2015 through 2035.	States responsible for 75 percent of electricity consumption that have existing annual energy efficiency targets below 2 percent achieve annual efficiency savings of 2 percent per year beginning in 2015 through 2035.	States responsible for 75 percent of electricity consumption that have an existing annual energy efficiency target below 2.5 percent achieve annual efficiency savings of 2.5 percent per year beginning in 2015 through 2035.
Electricity savings from states without EE targets		States responsible for 25 percent of electricity consumption achieve efficiency savings of 1 percent per year beginning in 2015 through 2035.	States responsible for 25 percent of electricity consumption achieve efficiency savings of 1.5 percent per year beginning in 2015 through 2035.	States responsible for 50 percent of electricity consumption achieve efficiency savings of 1.5 percent per year beginning in 2015 through 2035.

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Electricity Savings

Twenty-four states covering 60 percent of electricity demand currently have energy savings targets, which range from 0.3 to 2.4 percent savings per year.[36] An ACEEE analysis of twenty states with energy efficiency resource standards (EERS) in place in 2009 and 2010 found that states are generally on track toward meeting their efficiency goals.[37,38]

Under each scenario, we assume that some states without existing energy efficiency targets adopt policies and programs that lead to electricity savings beginning in 2015 (see FigureA-2.2). In the lackluster scenario, we assume that states accounting for 25 percent of electricity consumption not covered by an energy efficiency target achieve savings of 1 percent per year. In our middle-of-the-road scenario, we assume that states accounting for 25 percent of electricity consumption not covered by an energy efficiency target achieve savings of 1.5 percent per year. In our go-getter scenario, we assume that states accounting for 50 percent of electricity consumption not covered by an energy efficiency target adopt policies and programs that lead to electricity savings of 1.5 percent per year.

Under each scenario, we also assume that some states with existing energy efficiency targets adopt policies and programs that lead to additional electricity savings above these targets beginning in 2015. In our lackluster scenario, we assume that 75 percent of states with energy efficiency targets below 1.5 percent achieve electricity savings of 1.5 percent per year. In the middle-of-the-road scenario, we assume that 75 percent of states with energy efficiency targets below 2 percent achieve electricity savings of 2 percent per year. In the go-getter scenario, we assume that 75 percent of states with an energy efficiency target below 2.5 percent achieve electricity savings of 2.5 percent per year.

For additional context for these scenarios, see Table A-2.6, which provides a list of the top electricity consumers by state.

3. Modeling Notes for Electricity Savings

For purposes of our analysis we only examined the incremental benefit of new targets. A list of existing state targets was obtained from ACEEE's *2012 State Energy Efficiency Scorecard*.[39]

Typically, energy efficiency targets do not apply to all electricity sales within a state. In some states, targets apply only to investor-owned utilities (IOUs), in others

FIGURE A-2.2 Existing State Energy Efficiency Resource Standards and Scenario Assumptions (percent)

Source: Figure created using data from American Council for an Energy-Efficiency Economy's The 2012 State Energy Efficiency Scorecard, October 2012.
Note: We do not assume all the states pictured reach the scenario targets. Rather, we assume that only some states will take action. See Table A-2.5 for details. Texas had an electricity efficiency standard at the time of publication, but was treated as a state without a target for modeling purposes because its target is relatively low (about 0.2 percent of demand). This approach results in a more conservative estimate of total electricity savings than if Texas were treated as a state with an existing target.

targets apply only to utilities with large numbers of customers, while other states apply targets to varying combinations of IOUs, municipal utilities, and cooperatives.[40] On average, 13 percent of sales are not included by existing targets. To account for this, we adjusted the electricity savings by the percent of electricity sales covered. In the case of states with existing targets, we applied historical coverage percentages estimated by ACEEE (2012).[41] For those states without existing targets, we assumed that the percent of electricity sales covered was equal to the average percentage covered in states with existing targets.

We summed the incremental electricity savings for all states and incorporated the total savings into our electric demand module, which calculates the resulting greenhouse gas benefits (see Appendix I, Section V for more information).

For purposes of this analysis we assumed that these energy efficiency gains would be incremental to the other policies considered in our state and federal scenarios. Thus we assume that these benefits are in addition to savings from improved building codes and increased deployment of combined heat and power systems. We note that some states count combined heat and power (CHP) toward their energy efficiency standards,[42] and some states may allow other policies and programs to count under their energy efficiency goals. However, we believe our approach helps readers to more clearly identify the potential gains from any particular set of actions than would otherwise be possible.

B. NATURAL GAS EFFICIENCY

1. Base Case for Natural Gas Efficiency

Efficiency improvements in residential, commercial, and industrial systems provide GHG benefits by reducing demand for fossil fuels. As described in greater detail below, a number of states have efficiency programs in place that specifically target natural gas consumption.[43]

Our base case relies on U.S. Energy Information Administration's (EIA) data for natural gas demand. AEO2012 does not explicitly model state energy efficiency programs. However, programs in existence in 2011 and earlier are generally thought to be captured through recent regional natural gas demand trends.[44] Because AEO2012 does not model state-specific projections, we had to develop natural gas demand projections for each U.S. state and the District of Columbia. This was done using historical natural gas demand data for each state from EIA's State Energy Data System[45] and regional annual natural gas demand growth rates from the AEO2012 reference case.

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Natural Gas Efficiency

Eleven states covering 34 percent of natural gas demand currently have natural gas savings targets, most of which range from 0.5 to 1.5 percent savings of total natural gas demand per year (see Figure A-2.3).[46] 1 Under each scenario, we assume that some states

TABLE A-2.6 Largest Electricity Consumers, 2010

COVERED BY AN ELECTRIC EFFICIENCY STANDARD			UNCOVERED BY AN ELECTRIC EFFICIENCY STANDARD		
State	Demand (trillion Btu)	Percent of covered sales	State	Demand (trillion Btu)	Percent of uncovered sales
CA	882	14	TX	1223	19
OH	526	8	FL	789	12
PA	508	8	GA	480	8
IL	494	8	VA	388	6
NY	493	8	TN	353	6
NC	465	7	KY	319	5
IN	362	6	AL	310	5
MI	354	5	MO	294	5
WA	308	5	LA	290	5
AZ	249	4	SC	281	4
WI	235	4	NJ	270	4
MN	231	4	OK	197	3
MD	223	3	MS	170	3
MA	195	3	KS	138	2
CO	181	3	WV	109	2

Source: State Energy Data System, U.S. EIA, 2012.

TABLE A-2.7 Natural Gas Efficiency Scenarios

ACTION	POLICIES AND PROGRAMS DRIVING ACTION	SCENARIOS		
		Lackluster	Middle-of-the-Road	Go-Getter
Natural gas savings from states with EE targets	• Energy efficiency resource standards • System benefit charge funds or other funds	States responsible for 25 percent of natural gas consumption that have energy efficiency targets below 1 percent achieve savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 50 percent of natural gas consumption that have energy efficiency targets below 1 percent achieve savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 75 percent of natural gas consumption that have energy efficiency targets below 1.5 percent achieve savings of 1.5 percent of total demand per year from 2015 to 2035.
Natural gas savings from states without EE targets		States responsible for 10 percent of natural gas consumption achieve natural gas savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 25 percent of natural gas consumption achieve natural gas savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 50 percent of natural gas consumption achieve natural gas savings of 1.5 percent of total demand per year from 2015 to 2035.

without existing energy efficiency targets adopt policies and programs that lead to savings in natural gas demand beginning in 2015. In the lackluster scenario, we assume that states accounting for 10 percent of natural gas consumption not covered by an energy efficiency target achieve savings of 1 percent per year. In our middle-of-the-road scenario, we assume that states accounting for 25 percent of natural gas consumption not covered by an energy efficiency target achieve savings of 1 percent per year. In our go-getter scenario, we assume that states accounting for 50 percent of natural gas consumption not covered by an energy efficiency target adopt policies and programs that lead to savings of 1.5 percent per year.

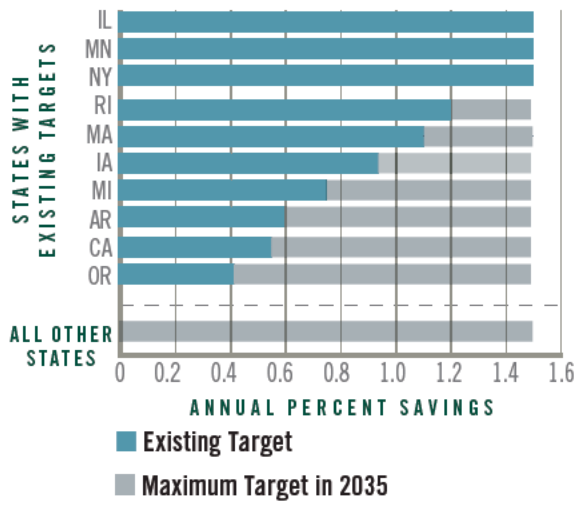
Under each scenario, we also assume that some states with existing energy efficiency targets adopt policies and programs that lead to additional natural gas savings above these targets beginning in 2015. In our lackluster scenario, we assume that 25 percent of states with energy efficiency targets below 1 percent achieve savings of 1 percent beginning in 2015. In the middle-of-the-road scenario, we assume that 50 percent of states with energy efficiency targets below 1 percent achieve savings of 1 percent. In the go-getter Scenario, we assume that 75 percent of states with an energy efficiency target below 1.5 percent achieve savings of 1.5 percent.

For additional context for these scenarios, see Table A-2.8, which provides a list of the top natural gas consumers by state.

3. Modeling Notes for Natural Gas Efficiency

While AEO2012 does not explicitly model state energy efficiency programs, programs in existence in 2011 and earlier are generally thought to be captured through recent regional natural gas demand trends. Efficiency savings from new programs or existing programs that increase their incremental targets are generally expected to be additional to those modeled in the AEO reference case.Therefore, we only modeled incremental benefits from new targets. We obtained the list of existing state targets from ACEEE's *2012 State Energy Efficiency Scorecard.*[48]

FIGURE A-2.3 Existing Natural Gas Efficiency Targets and Scenario Assumptions



Source: Figure created using data from American Council for an Energy-Efficiency Economy's *The 2012 State Energy Efficiency Scorecard,* October 2012.
Note: We do not assume all the states pictured reach the scenario targets. Rather we assume that only some states will take action. See Table A-2.7 for details. Wisconsin and Colorado had natural gas savings targets at the time of publication, but were treated as states without targets in order to generate more conservative modeling results. Wisconsin's targets were defunded in 2011. Colorado sets annual targets commensurate with funding levels and these targets have been historically low (approximately 0.1 percent of demand).

Typically, natural gas targets apply to all commercial, residential, and industrial sales within a state.[49] However, in our middle-of-the-road and go-getter scenarios, we already account for industrial efficiency gains through industrial standards. To avoid double counting of these benefits, we do not include natural gas savings from the industrial sector in either of these two scenarios. Rather, we apply the efficiency gains described in these scenarios to commercial and residential sales only, and assume that the programs will affect virtually all of those sales. The lackluster scenario for industrial policies only targets boiler efficiency improvements, and results in considerably less efficiency gains. Therefore we assume it would be possible to achieve additional efficiency improvements at industrial sources through natural gas efficiency programs in our lackluster scenario. We assume that the targets will affect nearly 100 percent of sales in the applicable customer class (i.e., residential, commercial, and in some cases industrial).

TABLE A-2.8 Largest Consumers of Natural Gas in Commercial, Residential, and Industrial Sectors, 2010

COVERED BY A NATURAL GAS EFFICIENCY TARGET			NOT COVERED BY A NATURAL GAS EFFICIENCY TARGET		
	Demand (trillion Btu)	Percent of sales covered by a target		Demand (trillion Btu)	Percent of sales not covered by a target
California	1546	31	Texas	2000	18
Illinois	869	17	Louisiana	1143	10
New York	772	15	Ohio	733	7
Michigan	618	12	Pennsylvania	587	5
Minnesota	375	8	Indiana	495	5
Iowa	256	5	New Jersey	460	4
Massachusetts	248	5	Colorado	397	3
Arkansas	167	3	Oklahoma	367	3
Oregon	125	3	Georgia	352	3
Rhode Island	36	1	Wisconsin	330	3

Source: State Energy Data System, U.S. EIA, 2012.

Note: Although Colorado and Wisconsin have natural gas savings targets in place, we treat them as though they do not have targets in order to generate more conservative modeling results. Wisconsin's targets were defunded in 2011. Colorado sets annual targets commensurate with funding levels and these targets have been historically low (approximately 0.1 percent of demand).

C. REDUCED ENERGY CONSUMPTION IN BUILDINGS

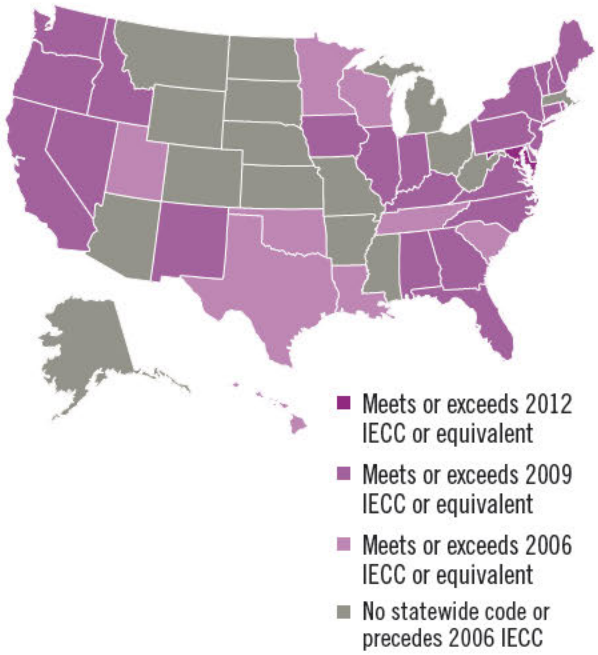
1. Base Case for Reduced Energy Consumption in Buildings

Our base case relies on the AEO2012 reference case. AEO2012 estimated that residential and commercial buildings accounted for 40 percent of total U.S. energy consumption and 73 percent of U.S. electricity use in 2010. These percentages rise to 41 percent of total U.S. energy consumption and 78 percent of U.S. electricity consumption in 2035. The majority of GHG emissions associated with buildings are the result of electricity use, which accounts for 78 percent of emissions in the commercial sector, and 74 percent of emissions in the residential sector. AEO2012 projects that even though population will increase 25 percent by 2035, energy use from buildings will only increase by 9 percent due to improvements in appliance and building shell efficiency.

Building codes provide a vehicle for establishing minimum efficiency standards for new buildings and major renovations. Building codes have historically been controlled by U.S. states and municipalities. As a result, the stringency of commercial and residential building codes they have adopted varies considerably (see Figures A-2.4 and A-2.5). It is also worth noting that the benefit of building codes varies to some extent from state to state depending on enforcement.[50]

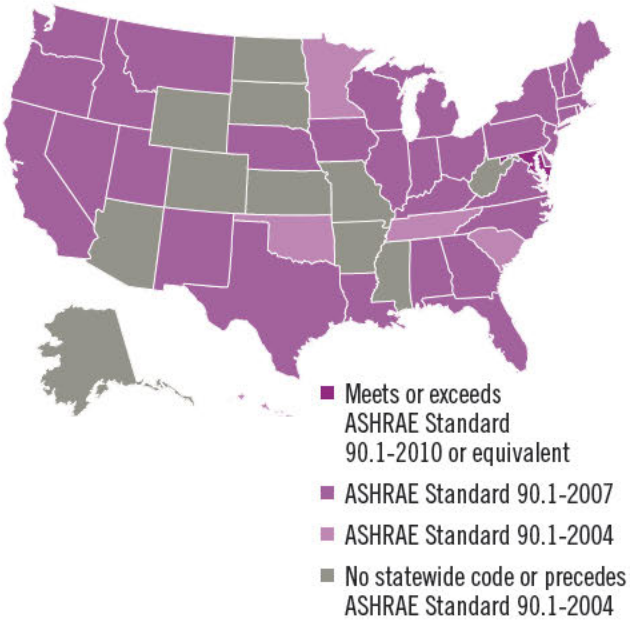
The American Recovery and Reinvestment Act of 2009 attempted to raise the level of standards across the United States by making state funding for the State Energy Program contingent upon states adopting the IECC 2009 codes for new residential buildings and ASHRAE 90.1-2007 for new commercial buildings. However, a number of states have not yet adopted these new codes. AEO2012 assumes that all states will adopt these new codes by 2017. The AEO2012 reference case does not model explicit adoption of additional building codes, although other economic and policy drivers (such as appliance standards) may lead to additional efficiency improvements.

FIGURE A-2.4 Residential Building Codes



Note: Building Code Maps adapted from the Online Code and Advocacy Network (OCEAN) (http://energycodesocean.org/code-status as of November 9, 2012).

FIGURE A-2.5 Commercial Building Codes



Note: Building Code Maps adapted from the Online Code and Advocacy Network (OCEAN) (http://energycodesocean.org/code-status as of November 9, 2012).

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Reduced Energy Consumption in Buildings

In our lackluster scenario, we assume that 10 percent of the electricity consumed by the building sector is covered by more ambitious building codes. In our middle-of-the-road and go-getter scenarios, we assume that 30 and 50 percent of the electricity consumed by the building sector is covered by more ambitious building codes.

Those building codes and the assumed electric energy savings achievable through their adoption are based on the Institute for Electric Efficiency's (IEE's) *Assessment of Electricity Savings in the U.S. Achievable through New Appliance/Equipment Efficiency Standards and Building Efficiency Codes (2010-2025).*[51] This paper quantifies reductions associated with "moderate" and "aggressive" scenarios of new building code adoption. Those scenarios are as follows:

- Residential buildings: The moderate scenario assumes that IECC 2012 goes into effect in 2015, followed by IECC 2015 in 2019, with savings of 25 percent and 45 percent compared to IECC 2006. The aggressive scenario uses the same assumptions as the moderate case until 2024, when it is assumed that a new code, with energy savings of 60 percent, goes into effect.

- Commercial buildings: The moderate scenario assumes the 2007 ASHRAE standards go into effect in 2013, followed by the 2010 ASHRAE in 2015, and 2013 ASHRAE in 2018, with savings of 15 percent, 20 percent, and 40 percent compared to the 2004 ASHRAE standards. The aggressive scenario uses the same assumptions until 2024, when it is assumed that a new ASHRAE standard with savings of 50 percent goes into effect.

Since IEE does not consider natural gas savings, we use the natural gas savings projected from building codes in the AEO2011 expanded standards and codes case. This equates to 210 trillion Btu of energy savings in 2025 (1 percent of total building consumption) and 450 trillion Btu of energy savings (2 percent of consumption) in 2035. The building code adoption

TABLE A-2.9 Building Code Scenarios

ACTION	POLICIES AND PROGRAMS DRIVING ACTION	SCENARIOS		
		Lackluster	Middle-of-the-Road	Go-Getter
Reduced energy consumption in buildings	• Commercial and residential building codes • Financial incentives	States that account for 10 percent of energy consumption in residential and commercial buildings phase in increasingly ambitious building codes through 2035. Generally, residential codes increase from IECC2009 to IECC2015 and commercial codes increase from 2004 ASHRAE 90.1 to 2013 ASHRAE 90.1.	States that account for 30 percent of energy consumption in residential and commercial buildings phase in increasingly ambitious building codes through 2035.	States that account for 50 percent of energy consumption in residential and commercial buildings phase in increasingly ambitious building codes through 2035.

schedule and associated energy savings in our analysis are considerably more ambitious than the AEO2011 expanded standards[52] and codes side case, driving roughly double the level of electricity savings.[53] This suggests that actual natural gas savings associated with adoption of the building code improvements assumed in our scenario would likely be considerably larger than we estimate here. We assume that there is minimal overlap between the natural gas savings due to improved building codes and energy efficiency programs for natural gas. This is because building codes affect new buildings and major renovations, while efficiency programs typically affect only existing buildings.

3. Modeling Notes for Reduced Energy Consumption in Buildings

The IEE report only provides electricity savings for 2025. We therefore estimated savings by assuming a linear rate of growth from 2015 through 2025. For years 2026–35, we extrapolated the national annual electricity savings by applying an assumed incremental benefit, based on the results of the moderate and aggressive scenarios of the IEE paper.[54]

We calculated electricity savings for each scenario by discounting the annual totals according to the percentage of states adopting the IEE building code schedule as described in Table A-2.9. We incorporated the total savings into our electric demand module, which incorporates changes in electricity demand resulting from a variety of federal regulations and state actions (see Appendix I, Section V, for more information).

D. INCREASED COMMERCIAL AND INDUSTRIAL COMBINED HEAT AND POWER (CHP) CAPACITY

1. Base Case for Increased Commercial and Industrial Combined Heat and Power (CHP)

Conventional electricity generation wastes one-half to two-thirds of the embodied energy of fuel, by releasing it as unused heat.[55] Combined heat and power (CHP) systems put that wasted heat energy to work, by simultaneously generating electricity and steam in a single system. This allows for considerable energy savings, thus reducing GHG emissions.[56]

Our base case relies on total electricity demand and energy CO_2 emissions projections from the AEO2012 reference case. AEO2012 projects 13 GW of new CHP capacity by 2020 and 36 GW of new capacity by 2035. This represents a growth of 144 percent from the 25 GW of CHP projected to be installed in 2012.

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Increased Commercial and Industrial Combined Heat and Power (CHP)

Annual additions of CHP have slowed since 2006 in part because of market uncertainty and the financial crisis, among other factors. However, there is emerging recognition of the environmental and economic benefits of CHP at the federal and state levels.[57] For instance, a recent executive order set an ambitious (but non-binding) national goal to deploy 40 GW of new CHP capacity by the end 2020.[58] The Department of Energy is currently working with states to realize this goal.

TABLE A-2.10 Combined Heat and Power (CHP) Scenarios

ACTION	POLICIES AND PROGRAMS DRIVING ACTION	SCENARIOS		
		Lackluster	Middle-of-the-Road	Go-Getter
Increased installation of industrial and commercial combined heat and power (CHP) systems	• Financial incentives, such as tax credits, loans, and loan guarantees • Standard interconnection rules • Reduced stand-by rates • Net metering policies • Output-based emissions regulations	State action results in deployment of an additional 10 GW of new CHP by 2025.	State action results in deployment of an additional 20 GW of new CHP by 2025.	State action results in deployment of an additional 40 GW of new CHP by 2025. When coupled with the new CHP modeled in AEO2012 (13 GW by 2020), this results in CHP deployment consistent with the Executive Order target of 40 GW of new CHP by 2020.

State policies and programs that can facilitate CHP deployment include standard interconnection rules, reduced stand-by rates, net metering policies, friendly air quality regulations such as output-based emissions regulations, feed-in tariffs, and technical assistance programs. Financial incentives—including tax credits, loans, and loan guarantees—can help ease financial uncertainty and encourage investment in CHP. These programs and incentives tend to be most effective, however, when paired with mechanisms that help overcome grid access issues such as developing interconnection standards for CHP.[59]

In a number of states, regulatory policies have not yet been revised to support distributed generation. High standby rates, which power consumers must pay in order to remain connected to the grid when they are not drawing power, offset otherwise positive economics for CHP systems. Net-metering policies that allow CHP operators to sell excess generation back to the grid can be very helpful, but are not yet widespread. In addition, utility acceptance of CHP interconnection varies widely across the states.

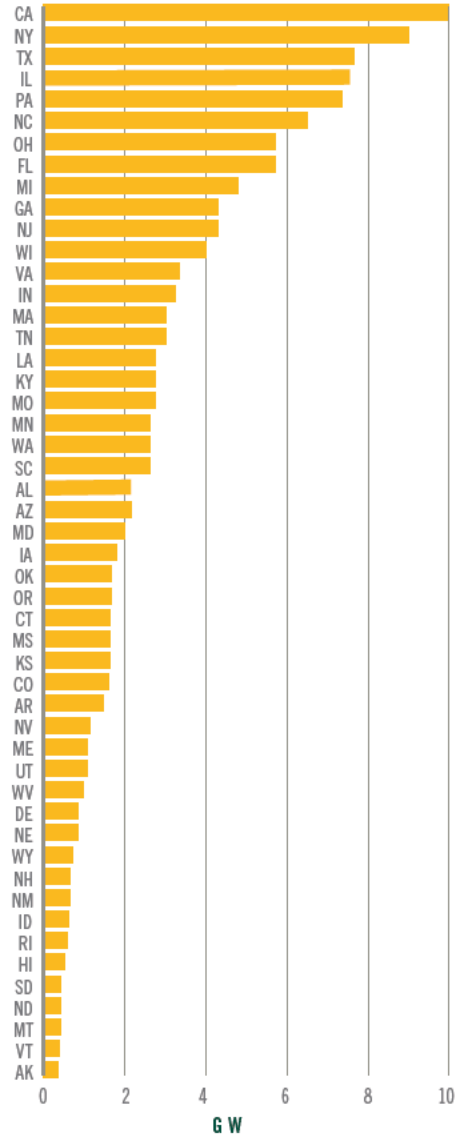
ICF International's *Effect of a 30 Percent Tax Credit on the Economic Potential for Combined Heat and Power* provides the most robust state-level assessment of the technical potential for CHP for all 50 states, and thus serves as the basis for all three of our scenarios. In generating these estimates, ICF limits CHP system size to the site's average electric demand, thus avoiding the need to deal with the challenges of selling electricity onto the grid.

In our lackluster, middle-of-the-road, and go-getter scenarios, we assume that state action results in deployment of an additional 10, 20, and 40 GW of new CHP by 2025. This is roughly 7.5, 15, and 30 percent of the technical potential identified by ICF. Such improvements could be achieved if states accounting for 15, 30, and 60 percent of total technical potential adopted policies that led them to develop new CHP units (above and beyond those modeled in AEO2012) that represent half of their technical potential. In the lackluster and middle-of-the-road scenarios, we assume that policies are implemented in 2015 and that CHP deployment phases in linearly through 2025. Thereafter it plateaus, so that no additional CHP is deployed between 2026 and 2035. In the go-getter scenario, we assume that this ramp-up occurs more rapidly so that 27 of the 40 GW are built by 2020. When coupled with the 13 GW of new CHP already predicted to be built in AEO2012, this enables the U.S. to meet the 40 GW target established by the August 2012 executive order. Figure A-2.6 shows technical potential by state, and is intended to help provide some context for these assumptions.

3. Modeling Notes for Increased Commercial and Industrial Combined Heat and Power (CHP)

We assume that all of the new CHP detailed in the scenarios above is in addition to what is modeled in the AEO2012 reference case. We note that even in our go-getter scenario we build 40 GW of additional CHP. When coupled with the 36 GW of new capacity AEO2012 predicts in 2035, this equates to 58 percent of the technical potential identified by ICF. However, we note that the AEO currently falls far short of recent ICF estimates of existing CHP capacity, estimating

FIGURE A-2.6 Combined Heat and Power Technical Potential



Source: *Effect of a 30 Percent Tax Credit on the Economic Potential for Combined Heat and Power,* ICF International, October 2010.

only 30 GW of capacity in 2011, compared to the 82 GW of CHP capacity estimated in the ICF study.[60]

CHP leads to electricity savings by providing on-site electric generation and displacing electricity that would otherwise be obtained from the grid. The impact of displacing that electricity is calculated by our electricity demand module, described in detail in Appendix I, Section V. Consistent with the ICF study, we assume that CHP units that produce cooling, heating, and power use half of their thermal output to displace electricity production for cooling and half to displace onsite fuel consumption.

CHP deployment tends to result in increased on-site fuel consumption. We estimate both the electricity savings and net increase in onsite fuel consumption using the documented assumptions and findings from ICF International's *Effect of a 30 Percent Tax Credit on the Economic Potential for Combined Heat and Power.*[61] We assume that all new CHP units and retired or refurbished units use 100 percent natural gas.[62] While a few industries are expected to increase use of coal and coal-to-liquid fuel, this will likely be offset by the greater amount of biomass, waste heat, and renewables used in other key industries.[63]

IV. Increased Generation from Renewable Sources

A. BASE CASE FOR INCREASED GENERATION FROM RENEWABLE SOURCES

Increased renewable generation can result from a variety of state programs, such as renewable portfolio standards, alternative energy standards, feed-in or other special tariffs, and other types of financial incentives. Renewable portfolio standards (RPS) specify a percentage of electricity generation (or sales) that must be met by renewable or other alternative sources. Such standards are in place in twenty-nine states and the District of Columbia, which together account for approximately 64 percent of electricity demand.

RPSs have successfully driven renewable development in those states that have adopted them. Analysis by Lawrence Berkeley National Laboratory found that all but three states were within 90 percent of their targets in 2009 and 2010.[64] Most states—including those without RPSs—encourage renewable development through tax incentives, grants and loans, and technical assistance programs.[65]

Our electricity demand projections rely on EIA's AEO2012, which includes all existing mandatory renewable electricity targets. AEO2012 projects that 340 TWh of new renewable electric generation will be built between 2009 and 2035, with an average growth rate of 2 percent in renewables per year, so that renewables account for approximately 14 percent of generation in 2020.

TABLE A-2.11 Renewable Uptake Scenarios

ACTION	POLICIES AND PROGRAMS DRIVING ACTIONS	SCENARIOS		
		Lackluster	Middle-of-the-Road	Go-Getter
Increased renewables from states with renewables targets	• Renewable portfolio standards • Alternative energy standards • Feed-in tariffs • Financial incentives	States responsible for 25 percent of electricity consumption increase their renewable generation by 1 percent annually after the last year for which a standard is set.	States responsible for 50 percent of electricity consumption increase their renewable generation by 1 percent annually after the last year for which a standard is set.	States responsible for 75 percent of electricity consumption increase their renewable generation by 1 percent annually after the last year for which a standard is set.
Increased renewables from states without renewables targets		States responsible for 10 percent of electricity consumption increase their renewable generation 0.5 percent annually beginning in 2015.	States responsible for 25 percent of electricity consumption increase their renewable generation 0.5 percent annually beginning in 2015.	States responsible for 50 percent of electricity consumption increase their renewable generation 0.5 percent annually beginning in 2015.

B. LACKLUSTER, MIDDLE-OF-THE-ROAD, AND GO-GETTER SCENARIOS FOR INCREASED GENERATION FROM RENEWABLE SOURCES

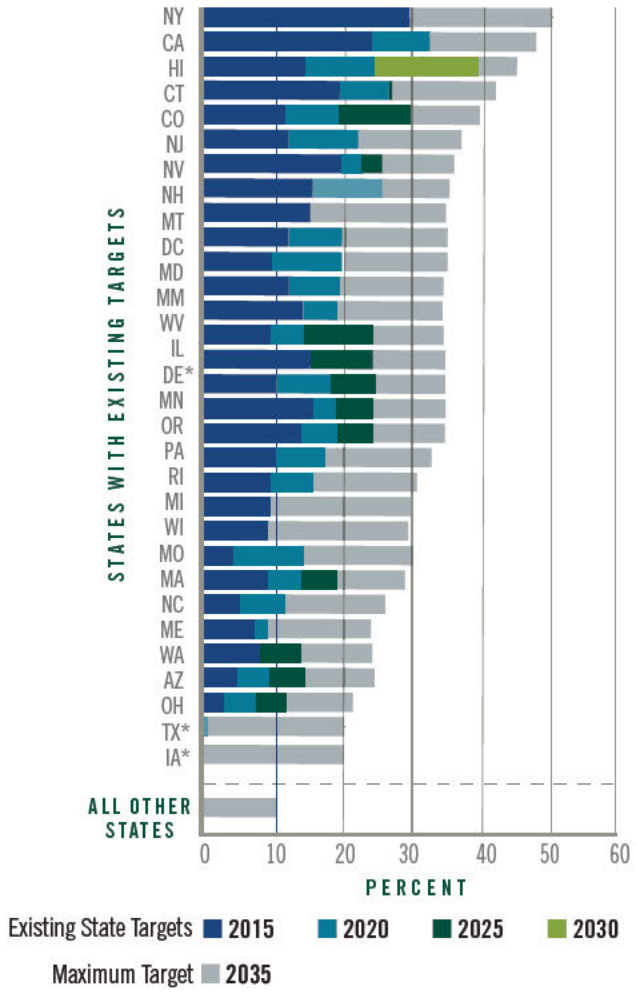
Under each scenario, we assume that some states with existing renewable standards increase these targets by 1 percent per year beginning the year after the target is reached. We choose a 1 percent annual gain because it represents the most common annual gain required by mature state programs (see Figure A-2.7).

Under each scenario, we also assume that some states without existing renewable targets increase renewable generation by 0.5 percent annually beginning in 2015. This is one-half the rate of change we model for states that already have renewable standards in place. In the lackluster scenario, we assume that this improvement occurs in states that account for 10 percent of electricity consumption in the cohort of states without existing renewable standards. In the middle-of-the-

TABLE A-2.12 Largest Electricity Consumers, 2010

COVERED BY A RENEWABLE TARGET			NOT COVERED BY A RENEWABLE TARGET		
State	Demand (trillion Btu)	Percent of sales covered by a target	State	Demand (trillion Btu)	Percent of sales covered by a target
TX	1223	15	FL	789	17
CA	882	11	GA	480	10
OH	526	6	VA	388	8
PA	508	6	IN	362	8
IL	494	6	TN	353	8
NY	493	6	KY	319	7
NC	465	6	AL	310	7
MI	354	4	LA	290	6
WA	308	4	SC	281	6
MO	294	4	OK	197	4

FIGURE A-2.7 Existing State Renewable Targets and Scenario Assumptions



Source: Figure created using data from the Database of State Incentives for Renewables and Efficiency (DSIRE), downloaded September 2012.
Note: Solid bars represent existing renewable targets and hashed bars represent the maximum new renewable energy that could be deployed in any particular state in 2035 if they increase their renewables at the designated rate (i.e., 1 percent or 0.5 percent). As discussed above, we do not assume that each state experiences this level of incremental renewable generation, but instead assume that a fraction of the states achieve this level of incremental renewable generation. Further note that Texas and Iowa have absolute rather than percent targets. Texas' 5,880 MW by 2015 target is calculated as an approximate percentage of electricity demand for ease of display. Iowa's 105 MW target is not displayed here because the target date (2000) is earlier than what is considered here.

road and go-getter scenarios, we assume that increases to 25 percent and 50 percent, respectively. Note that the same level of benefit achieved by states without a current standard can be achieved if half the number of states pursues the same level of ambition as we assume in states that already have renewable standards (i.e., increase renewable generation by 1 percent per year). For context, see Table A-2.12, which provides a list of the top electricity consumers.

To confirm that the assumptions in our scenarios are technically achievable, we compared the maximum (undiscounted) renewables penetration for each state with its technical potential as calculated by the National Renewable Energy Laboratory (NREL). In most states, the maximum level of renewables penetration does not exceed 2 percent of the state's technical potential.

C. MODELING NOTES FOR INCREASED GENERATION FROM RENEWABLE SOURCES

AEO aggregates renewable electricity targets by North American Electric Reliability Corporation region, and does not provide individual state targets.[67] Therefore, we estimated incremental renewable generation state-by-state due to their renewable standards, using our estimated electricity demand baseline for each state (see Section II.C. of Appendix II above for details),[68] and annual RPS targets by state for the years 2005–35 from the DSIRE Renewables Database.[69]

Since our scenarios do not choose what states take action, when modeling we assumed each state took action, but discounted the incremental renewable gains by the assumed implementation level. In some states, renewable targets can be met in part through energy efficiency improvements. Due to the significant energy efficiency increases across all three of our scenarios, we assumed that those energy efficiency limits would be met, thereby reducing the level of renewable energy obtained due to programs in those states.

Most existing renewable targets, and those established in our scenarios, are tied to demand (e.g., Colorado requires that 30 percent of electricity sales will be met with renewables by 2020). Therefore, estimates of the GHG benefits from renewable programs must take into account the impacts of reduced electricity consumption from energy efficiency programs. Incremental renewable generation for each of our scenarios was calculated by comparing the total projected new renewable generation to the original renewable uptake projected under our base case scenario. The greenhouse gas benefits from the new renewable development were calculated using our electric demand module. For more information see Appendix I, Section V.

V. States Implement Policies Modeled for Federal Action

States have broad authority to regulate energy sources and emissions within their boundaries. States may therefore implement many of the same policies that we ascribe to the federal government in the federal analysis, with some exceptions. In this approach we assume that states pursue the same "lackluster," "middle-of-the-road," and "go-getter" policies that are considered in the federal scenarios. Consistent with our other state policies, we do not assume, however, that all states pursue such action. Instead, we assume that these policies are pursued by states accounting for 10, 25, and 50 percent of GHG emissions from those sources. These approaches include state action for all sectors discussed in the federal action section, except for those policies that are ill-suited for state implementation. We deemed policies that eliminate HFCs, regulate off-highway vehicles, adopt appliance and equipment efficiency standards where federal standards already exist, or regulate aviation to be ill-suited to state implementation because they are preempted by federal law. It is important to note that one implication of modeling state-level ambition off of federal ambition for these sectors is that the state scenarios provide the greatest incremental benefit when they are coupled with a less ambitious federal policy.

Endnotes

1. *Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program; Final Rule.* Federal Register, Vol. 75, No. 58, Part II, March 26, 2010.

2. *Regulation of Fuels and Fuel Additives: 2011 Renewable Fuel Standards; Final Rule.* Federal Register, Vol. 75, No. 236, Part II, December 9, 2010.

3. *Regulation of Fuels and Fuel Additives: 2012 Renewable Fuel Standards; Final Rule.* Federal Register, Vol. 77, No. 5, Part V, January 9, 2012.

4. *Annual Energy Outlook 2012.* U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/archive/aeo12/index.cfm>.

5. Thresholds for specific fuel types are as follows: 20 percent for corn ethanol, 50 percent for biomass-based diesel or advanced biofuel, and 60 percent for cellulosic biofuel.

6. *Assumptions to the AEO2012.* U.S. Energy Information Administration, June 25 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/assumptions/pdf/0554(2012).pdf>.

7. To date, these states are Florida, Hawaii, Minnesota, Missouri, Oregon, New Mexico, and Washington. Massachusetts suspended its biodiesel blend mandate and implemented a voluntary program.

8. U.S. Department of Energy Alternative Fuels Data Center. Accessible at: <http://www.afdc.energy.gov>.

9. To date, these states are Alabama, Florida, Georgia, Hawaii, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Montana, New Mexico, New York, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Rhode Island, South Dakota, Virginia, Washington, and Wisconsin. For the most recent information on state biofuels policies, see U.S. Department of Energy Alternative Fuels Data Center at <http://www.afdc.energy.gov>.

10. *Advanced Transportation Fuels Advisory Group Recommendations and Supporting Fact Sheets, Midwestern Governors Association.* For more information, see: <http://www.midwesterngovernors.org/fuels.htm>.

11. *Overview of State Biofuel Policies, Incentives, and Opportunities.* Association of State Energy Research and Technology Transfer Institutions, July 2012.

12. *Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis.* EPA (EPA-420-R-10-006), February 2010.

13. These estimates are based on 100-year global warming potential estimates as published in the IPCC Fourth Assessment Report.

14. *Low Carbon Fuel Standard 2011 Program Review Report.* Advisory Panel, December 2011. For more information, see: <http://www.arb.ca.gov/fuels/lcfs/lcfs.htm>.

15. For more information on these plans, see the following resources:
Washington: <http://www.ecy.wa.gov/climatechange/fuelstandards.htm>.
Oregon: <http://www.deq.state.or.us/aq/committees/advcomLowCarbonFuel.htm>.
Mid-Atlantic/Northeast: <http://www.nescaum.org/topics/clean-fuels-standard>.
Introducing a Low Carbon Fuel Standard in the Northeast: Technical and Policy Considerations. Northeast States Center for a Clean Air Future, July 2009.

16. California's Low Carbon Fuel Standard and similar fuel standards under consideration in other states are not included in the AEO2012 reference case.

17. State programs to promote these vehicles are still valuable. In fact, a case can be made that widespread deployment of PHEVs and EVs, in particular, is essential to meet our long-term emissions trajectory, and that states have an integral role to play in deploying the infrastructure needed to make this possible.

18. *Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis.* EPA (EPA-420-R-10-006), February 2010.

19. For more information, see: <http://www.arb.ca.gov/fuels/lcfs/lcfs.htm>. The California LCFS was ruled unconstitutional by a federal district court judge in *Rocky Mountain Farmer's Union v. Goldstene*, 719 F. Supp.2d 1170 (E. Dist. Cal. 2010), and the case is currently on appeal with the Federal Circuit Court of Appeals for the 9th Circuit. The appeal was heard on oral arguments and on deliberation by the three-judge panel when one of the judges died. Parties to the case are awaiting reassignment of the case to a new third judge. Timing of an ultimate decision is unknown but expected at the end of 2013 or early 2014.

20. *Annual Energy Outlook 2012.* U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/archive/aeo12/index.cfm>.

21. For example, see:
Growing Cooler: The Evidence on Urban Development and Climate Change. Urban Land Institute, Washington, DC, 2009.
Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions. Urban Land Institute, Washington, DC, 2009.

22. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions.* Urban Land Institute, Washington, DC, 2009.

23. *Greenhouse Gas Reduction Act of 2009 (HB 315).* For more information, see: <http://www.mde.state.md.us/assets/document/Air/ClimateChange/GreenHouse_Gas_Reduction_Act_Bill_2009_Summary.pdf>.

24. *Maryland Climate Action Plan, Maryland Department of Transportation Draft Implementation Plan.* Maryland Department of Transportation, April 2011.

25. Sustainable Communities and Protection Act of 2008 (SB 375). For more information, see: <http://www.arb.ca.gov/cc/sb375/sb375.htm>.

26. For more details, see: <http://www.arb.ca.gov/cc/sb375/sb375.htm>.

27. *Draft Oregon Statewide Transportation Strategy.* Oregon Department of Transportation, May 2012.

28. *Sustainable Communities and Climate Protection Act of 2008 (SB 375).* Statutes of 2008. For more information, see: <http://www.arb.ca.gov/cc/sb375/sb375.htm>.

29. *Climate Action Plan Interim Report.* New York State Climate Action Council, November 2010. *Massachusetts Clean Energy and Climate Plan for 2020.* Executive Office of Energy and Environmental Affairs, December 2010.

30. We start the VMT policies one year later than the other policies we consider because of the extra time typically needed to implement local planning policies and programs.

31. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions.* Prepared by Cambridge Systematics for the Urban Land Institute, July 2009.

32. *The 2012 State Energy Efficiency Scorecard.* American Council for an Energy-Efficiency Economy (ACEEE), Report Number E12C, October 2012.

33. As of December 31, 2010, about $400 million—52 percent of RGGI auction revenue—had been used to support energy efficiency programs in the ten states participating at the time.

34. Personal communication with Erin Boedecker, EIA, December 2012.

35. *U.S. Energy Information Administration's State Energy Data System, 2012.* Accessible at: <http://www.eia.gov/state/seds/>.

36. *The 2012 State Energy Efficiency Scorecard.* American Council for an Energy-Efficiency Economy (ACEEE), Report Number E12C, October 2012.

37. *Energy Efficiency Resource Standards: A Progress Report on State Experience.* American Council for an Energy-Efficiency Economy (ACEEE), Report Number U112, June 2011.

38. Specifically, they found that thirteen states had reached or exceeded their goals, three achieved over 90 percent of their goals, and three had reached 80 percent or less of their goals. They found, however, that several of the states that missed their goals have programs that are still ramping up, and predict that those programs will deliver greater savings in the coming years.

39. *The 2012 State Energy Efficiency Scorecard.* American Council for an Energy-Efficiency Economy (ACEEE), Report Number E12C, October 2012.

40. In Colorado, Arkansas, California, Ohio, New Mexico, Nevada, and Texas, targets apply only to investor-owned utilities (IOUs) and not to municipal utilities or cooperatives. Illinois and Pennsylvania set targets only on utilities with large numbers of customers. Arizona, Massachusetts, Rhode Island, Indiana, and Washington set targets on some combination of IOUs, municipal utilities, and cooperatives, but not on all utilities. Hawaii, Maryland, Minnesota, New York, Vermont, Iowa, Michigan, Oregon, Wisconsin, and North Carolina have targets covering all sales.

41. Estimated percent coverage in existing states obtained from *The 2012 State Energy Efficiency Scorecard*, American Council for an Energy-Efficiency Economy (ACEE), Report Number E12C, October 2012.

42. At present, these states include Connecticut, Ohio, Texas, Massachusetts, North Carolina, Pennsylvania, Maine, Washington, Vermont, Arizona, Hawaii, and Nevada.

43. *The 2012 State Energy Efficiency Scorecard*. American Council for an Energy-Efficiency Economy (ACEEE), Report Number E12C, October 2012.

44. Personal communication with Erin Boedecker, EIA, December 2012.

45. *U.S. Energy Information Administration's State Energy Data System, 2012.* Accessible at: <http://www.eia.gov/state/seds/>.

46. *The 2012 State Energy Efficiency Scorecard*. American Council for an Energy-Efficiency Economy (ACEEE), Report Number E12C, October 2012.

47. Personal communication with Erin Boedecker, EIA, December 2012.

48. *The 2012 State Energy Efficiency Scorecard.* American Council for an Energy-Efficiency Economy (ACEEE), Report Number E12C, October 2012.

49. *Energy Efficiency Resource Standards: State and Utility Strategies for Higher Energy Savings*. ACEEE Report Number U113, June 2011.

50. *The 2012 State Energy Efficiency Scorecard*. American Council for an Energy-Efficiency Economy (ACEEE), Report Number E12C, October 2012.

51. *Assessment of Electricity Savings in the U.S. Achievable through New Appliance/Equipment Efficiency Standards and Building Efficiency Codes (2010-2025).* IEE Whitepaper, May 2011.

52. The AEO expanded standards and codes side case assumes that the AEO added three rounds of codes: a 30 percent improvement over IECC 2006 in the residential sector and a 30 percent improvement over ASHRAE 90.1-2004 in the commercial sector by 2020, then two subsequent incremental 5 percent increases in 2023 and 2026.

53. *Annual Energy Outlook 2011.* EIA, June 2011.

54. The only difference between the aggressive and moderate scenarios in the IEE paper is that the aggressive scenario adds a new code in 2024. Therefore, we assumed that the rate of change is identical in both scenarios until 2023 and the incremental difference between the two occurs in years 2024–25. We extrapolate using the sum of the incremental benefit from this code and the incremental benefit from the moderate scenario since benefits of the new code will continue to accrue through 2035.

55. *Efficiency Benefits*. Combined Heat and Power Partnership, U.S. EPA. Accessible at: <http://www.epa.gov/chp/basic/efficiency.html>.

56. *Combined Heat and Power: Markets and Challenges.* ICF International, June 2012.

57. *Combined Heat and Power: Markets and Challenges.* ICF International, June 2012.

58. Executive Order: "Accelerating Investment in Industrial Energy Efficiency." August 30, 2012. Accessible at: <http://www.whitehouse.gov/the-press-office/2012/08/30/executive-order-accelerating-investment-industrial-energy-efficiency>.

59. *Challenges Facing Combined Heat and Power Today: A State-by-State Assessment.* ACEEE Report Number IE111, September 2011.

60. ICF uses a more comprehensive data collection system compared to EIA. For example, EIA does not collect data for systems less than 1 MW in size. For medium and large sites, there may be underreporting where surveys are not sent to sites with CHP installations.

61. *Effect of a 30 Percent Tax Credit on the Economic Potential for Combined Heat and Power.* ICF International, October 2010.

62. *Effect of a 30 Percent Tax Credit on the Economic Potential for Combined Heat and Power.* ICF International, October 2010.

63. *Annual Energy Outlook 2012.* U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/archive/aeo12/index.cfm>.

64. *The State of the States: Update on the Implementation of U.S. Renewable Portfolio Standards.* Ryan Wiser and Galen Barbose, Lawrence Berkeley National Laboratory, 2011 National Summit on RPS, October 26, 2011.

65. For a summary of state incentives for renewable energy, see: <http://www.dsireusa.org/summarytables/finre.cfm>.

66. NREL defines technical potential as "the achievable energy generation of a particular technology given system performance, topographic limitations, environmental, and land-use constraints." For more details see: *U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis.* NREL Technical Report NREL/TP-6A20-51946, July 2012.

67. *Assumptions to the AEO2012.* U.S. Energy Information Administration, June 25 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/assumptions/pdf/0554(2012).pdf>.

68. For those states with absolute targets rather than percent targets (Iowa, New Jersey, and Texas), we assume the absolute targets are met and add the amount of renewable generation into our electricity demand module.

69. Database of State Incentives for Renewables and Efficiency (DSIRE), RPS Database downloaded from dsireusa.org in September 2012.

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WORLD
RESOURCES
INSTITUTE

10 G Street, NE (Suite 800)
Washington, DC 20002
USA
Tel: (1 202) 729 76 00
Fax: (1 202) 729 76 10
www.wri.org

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SUMMARY FOR POLICYMAKERS

Can The U.S. Get There From Here?

Using Existing Federal Laws and State Action to Reduce Greenhouse Gas Emissions

NICHOLAS M. BIANCO
FRANZ T. LITZ
KRISTIN IGUSKY MEEK
REBECCA GASPER

About the Authors

Nicholas Bianco leads WRI's efforts with U.S. states and U.S. federal agencies as they work together and in parallel to develop programs to reduce greenhouse gas emissions. His areas of research include the role of states in future federal climate programs; the regulation of greenhouse gas emissions via existing regulatory authorities; market-based pollution control programs; and stacking of payments for ecosystem services (e.g., greenhouse gas offsets). Nicholas previously worked with the Massachusetts Department of Environmental Protection on climate change and air quality programs. While there, he worked on several market-based air quality and climate change programs, including the Regional Greenhouse Gas Initiative (RGGI), a regional carbon dioxide cap-and-trade program for the power sector. Contact: nbianco@wri.org.

Kristin Meek is an Associate in the Climate and Energy Program at the World Resources Institute. She supports WRI's efforts with U.S. states and U.S. federal agencies as they work together and in parallel to develop programs to reduce greenhouse gas emissions. Prior to joining WRI, Kristin worked with SAIC's climate change services team, where she focused on a wide range of GHG management projects for federal government agencies, local governments, and private sector entities. Projects included supporting the U.S. Energy Information Administration's national inventory of greenhouse gases, EPA's Greenhouse Gas Reporting Program and Climate Leaders Program, researching issues related to new and existing carbon offset project types, and developing community-level GHG inventories for cities and counties across the country. Contact: kmeek@wri.org.

Rebecca Gasper is a Research Assistant in WRI's Climate and Energy Program. She supports WRI's efforts with U.S. states and U.S. federal agencies as they work together and in parallel to develop programs to reduce greenhouse gas emissions. Before joining WRI, Rebecca worked at the Center for Integrative Research (CIER) at the University of Maryland. She worked primarily on climate change mitigation and adaptation at the regional and international levels. She also has experience supporting state efforts to develop water quality markets. Contact: rgasper@wri.org.

Franz Litz is the Executive Director of the Pace Energy & Climate Center, a legal and policy think tank, and Professor of Energy and Climate Change Law in Pace Law School's top-ranked environmental law program. Franz leads his Center's work at the state, regional, national, and international levels on climate change, energy efficiency, renewable energy, transportation, and community energy. Franz is an expert on the federal Clean Air Act, state-level climate and energy policies, and emissions trading. Franz actively convenes officials from U.S. states and Canadian provinces cooperating on energy and climate change policy issues. He also frequently brings stakeholders from diverse viewpoints together to engage policy makers on difficult energy and climate policy issues. Before assuming his leadership role at the Pace Energy & Climate Center in 2011, Franz was a senior fellow at the World Resources Institute in Washington, DC. He led WRI's state and regional climate change initiatives, as well as WRI's engagement with the U.S. EPA. Contact: flitz@law.pace.edu.

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Summary for Policymakers

I. Introduction

CLIMATE CHANGE IMPACTS IN THE UNITED States are increasingly evident and come with steep economic and social costs. The frequency and intensity of extreme weather events has increased in recent years, bringing record-breaking heat, heavy precipitation, coastal flooding, severe droughts, and damaging wildfires.[1] According to the National Oceanic and Atmospheric Administration (NOAA), weather-related damages in the United States were $60 billion in 2011, and are expected to be significantly greater in 2012.[2]

The mounting costs convey an unmistakable urgency to address climate change by reducing greenhouse gas emissions (GHGs). This report examines pathways for GHG reductions in the United States through actions taken at the federal and state levels without the need for new legislation from the U.S. Congress.

This report answers a number of key questions:

- What are current U.S. GHG emissions? Without further action to reduce emissions, what are they projected to be in 2020 and 2035?
- What legal and policy tools exist under current federal law to achieve emissions reductions? What additional actions can states pursue to contribute to emissions reductions?
- Which legal and policy tools at the state and federal levels offer the greatest potential for achieving emissions reductions in the near- and mid-term?
- Can the U.S. meet its international commitment to reduce emissions 17 percent below 2005 levels by 2020 without new federal legislation?
- Can the U.S. put itself on a trajectory to meet or exceed its long-term commitment of reducing emissions by more than 80 percent below 2005 levels by 2050, without new legislation from Congress?

The answers to these questions are set out in detail in the body of this report. Two significant findings stand out. First, it is clear the U.S. is not currently on track to meet its 2020 reduction pledge, however, this target is achievable through implementation of strong new federal measures to reduce emissions using existing legal authorities. Second, the mid-century goal of reducing emissions by 80 percent or more appears unattainable using existing authorities. New legislation will eventually be needed.

BOX 1 Key Conclusions and Recommendations

1. Without new action by the U.S. Administration, greenhouse gas (GHG) emissions will increase over time. The U.S. will fail to make the deep emissions reductions needed in coming decades, and will not meet its international commitment to reduce GHG emissions by 17 percent below 2005 levels by 2020.
2. The U.S. EPA should immediately pursue "go-getter" emissions reductions from power plants and natural gas systems using its authority under the Clean Air Act. These two sectors represent two of the top opportunities for substantial GHG reductions between now and 2035.
3. The U.S. Administration should pursue hydrofluorocarbon (HFC) reductions through both the Montreal Protocol process and under its independent Clean Air Act authority. Eliminating HFCs represents the biggest opportunity for GHG emissions reductions behind power plants.
4. U.S. states should complement federal actions to reduce emissions through state energy efficiency, renewables, transportation, and other actions. States can augment federal reductions.
5. New federal legislation will eventually be needed, because even go-getter action by federal and state governments will probably fail to achieve the more than 80 percent GHG emissions reductions necessary to fend off the most deleterious impacts of climate change.

Potential reductions in the United Stated were assessed in a 2010 WRI Report entitled *Reducing Greenhouse Gas Emissions in the United States Using Existing Federal Authorities and State Action.*[3] This updated report revisits these questions, taking into account the latest GHG emissions information and recent actions taken at the federal and state levels. Since the publication of the last report, notable factors influencing U.S. GHG emissions include:

- Reduced global economic growth, including slower growth of economic output in the United States;
- Increased fuel switching from coal to natural gas in the generation of electricity; and
- Reduced demand for transportation fuel, partly as a result of higher petroleum prices, lower miles traveled, and more efficient vehicles.

These factors and others, including the issuance of new motor vehicle emissions and fuel efficiency standards for cars and trucks, will reduce greenhouse gas emissions. However, even with these factors, we project that total U.S. emissions will experience relatively modest growth over the coming decades.

At the 2009 Conference of the Parties of the United Nations Framework Convention on Climate Change in Copenhagen, Denmark, President Obama made a commitment to reduce U.S. greenhouse gas emissions in the range of 17 percent below 2005 levels by 2020. Despite the inability of Congress to pass comprehensive climate change legislation, the Administration has re-committed to the Copenhagen pledge and taken some steps to reduce emissions using authority under existing laws.[4] While the Administration has reaffirmed its commitment to this target, it has not yet matched that commitment with adequate action. Though significant progress has been made in some areas since our 2010 analysis, most notably with the vehicle rules, key opportunities, such as reductions from power plants, remain untapped. The fact that the U.S. remains far from the "go-getter" emissions trajectory laid out in our 2010 report reinforces the urgency for taking strong action now.

Although the U.S. emissions reduction commitment for 2020 represents an important step toward reducing GHG emissions, much greater reductions are necessary. According to the Intergovernmental Panel on Climate Change, industrialized countries need to collectively reduce emissions between 25 and 40 percent below 1990 levels by 2020 and 80 to 95 percent below 1990 levels by 2050 in order to keep global average temperatures from increasing more than 2 degrees Celsius above preindustrial levels. This report evaluates the potential for meeting the 17 percent commitment and the deeper longer-term reduction pathway necessary to avoid the worst impacts of climate change.

BOX 2 Ambition Matters

Within the bounds of what is legally and technically possible, the single most important factor influencing emissions reductions is political and policy ambition. This analysis considers three levels of ambition:

- **Lackluster.** This is low ambition and represents the results of actions of lowest cost or least optimistic technical achievement.
- **Middle-of-the-Road.** This is mid-level ambition and represents the results of actions of moderate cost and moderately optimistic technical achievement.
- **Go-Getter.** This is the highest ambition achievable without new congressional action. It represents the results of actions of higher cost or most optimistic technical achievement.

The term "go-getter" is not meant to suggest the actions are adequate to achieve U.S. reduction targets or reductions the science suggests are necessary to ward off the worst effects of climate change.

1. *America's Climate Choices: Panel on Advancing the Science of Climate Change.* National Research Council, 2010.ISBN 978-0-309-14588-6. Accessible at: <http://www.nap.edu/catalog.php?record_id=12782>.
2. *Preliminary Info on 2012 U.S. Billion-Dollar Extreme Weather/ Climate Events.* National Oceanic and Atmospheric Administration. Accessible at: <http://www.ncdc.noaa.gov/news/preliminary-info-2012-us-billion-dollar-extreme-weatherclimate-events>. (Last accessed January 15, 2013)
3. Accessible at: <http://www.wri.org/publication/reducing-ghg-emissions-using-existing-federal-authorities-and-state-action>.
4. Most recently, the U.S. delegation to the Conference of the Parties of the UN Framework Convention on Climate Change in Doha, Qatar, made it clear that the 17 percent pledge is not contingent on new legislation from Congress.

Attaining even the 17 percent reduction goal will require new and ambitious action from the U.S. Administration—ambitious action that must survive court challenges. Real progress depends on numerous actions not yet taken by the U.S. Administration—especially for stationary emissions sources like power plants, natural gas systems, and industry. U.S. states may also need to take action to fill any emissions gaps left by the federal government. Achieving the necessary mid-century reductions will almost certainly require the U.S. Congress to act to achieve the needed reductions.

Section II summarizes the report's key findings, including the range of reductions that are possible and a brief description of the analytical approach. An examination of current emissions in the United States and projected emissions without new actions follows in Section III. Section IV summarizes the sector-by-sector actions the federal government might take under existing laws. Section V summarizes potential state actions. Section VI sets out summary conclusions. Two detailed appendixes set out the assumptions and methodologies for the federal and state analyses. The picture revealed is one of significant potential greenhouse gas emissions reductions, provided there is sufficient political will to take strong action.

II. Charting a Path Forward in the U.S.: Summary of Key Findings

This report identifies significant potential for GHG emissions reductions by the U.S. Administration under current laws and through state-level actions, as well as the limitations of current tools. The reductions actually achieved will depend on the level of ambition brought to the effort by the U.S. Administration, including executive agencies such as the U.S. Environmental Protection Agency. At the state level, outcomes will depend on the number of states that choose to support renewable energy, energy efficiency, and transportation measures, and to pursue policies that the federal government opts not to pursue or that go beyond the minimum stringency set by the federal government. Key findings are set out below for federal and state actions.[5]

A. FEDERAL GHG REDUCTIONS POSSIBLE WITHOUT NEW LEGISLATION

- Only with "go-getter" ambition by the U.S. Administration can the United States achieve emissions reductions using current law that meet or exceed the Copenhagen commitment to reduce global warming pollution by at least 17 percent below 2005 levels by 2020.[6] With middle-of-the-road ambition, the United States will fall well short of its 17 percent commitment, unless supplemented by go-getter actions by the states.

- Even with go-getter ambition, long-term emissions reductions fall short of the level of reductions necessary to put the United States on pace to reach its long-term reduction goal of reducing emissions 83 percent below 2005 levels by 2050. New congressional legislation is therefore necessary to achieve reductions in line with what the international scientific community agrees is necessary by mid-century in order to stabilize global average temperatures and avert the worst impacts of climate change.

- After taking action to significantly improve motor vehicle fuel efficiency, the U.S. Administration should now apply similar ambition to reducing emissions from a wider range of sources, such as existing power plants, if it is to achieve the needed reductions.

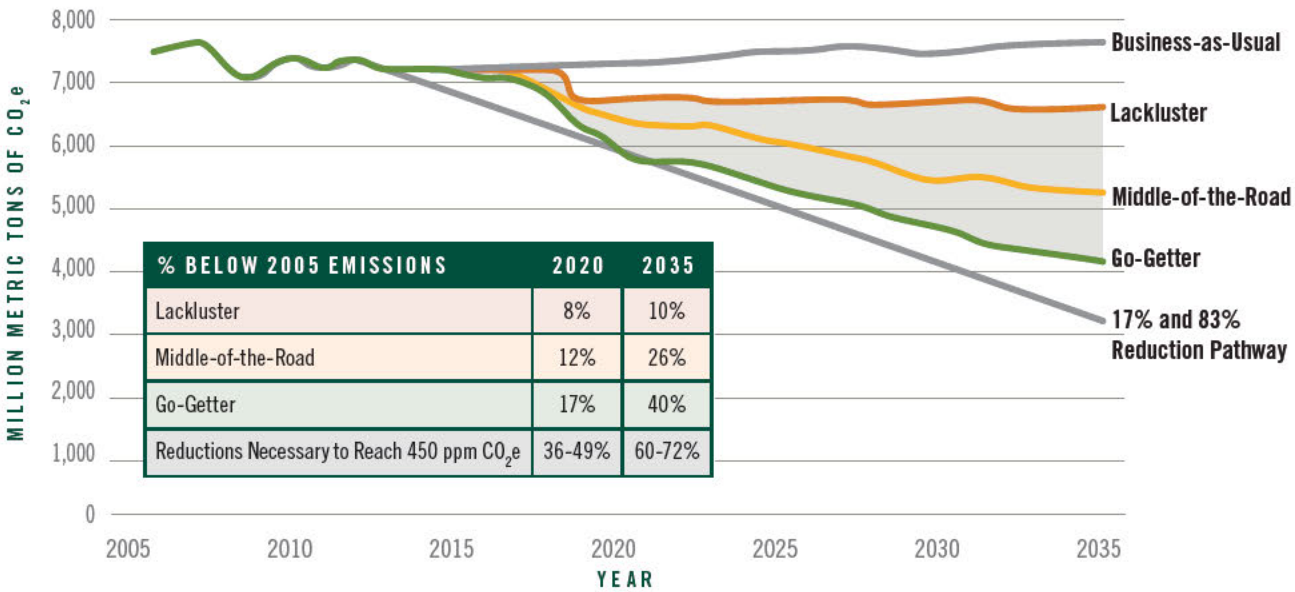
- The greatest projected emissions reduction opportunities by 2020 and beyond come from four federal policy measures. The Administration will need to pursue these opportunities if the United States is to achieve the 17 percent reduction target. Those policies are:

  - standards to reduce carbon pollution from existing power plants (48 percent of total emissions gap between business-as-usual (BAU) and 2020 target);

5. For data sources and an explanation of how expected emissions trends were compiled, please consult the appendixes. For the sake of clarity and brevity, sources are not provided in this summary.

6. The U.S. commitment in Copenhagen calls for reductions in 2020 "in the range of 17 percent [below 2005 levels], in conformity with anticipated U.S. energy and climate legislation." The U.S. submission notes that the ultimate goal of legislation pending at the time was to reduce emissions by 83 percent below 2005 levels in 2050.

FIGURE 1 Projected U.S. Emissions under Different Federal Regulatory Scenarios



% BELOW 2005 EMISSIONS	2020	2035
Lackluster	8%	10%
Middle-of-the-Road	12%	26%
Go-Getter	17%	40%
Reductions Necessary to Reach 450 ppm CO_2e	36-49%	60-72%

Note: The Intergovernmental Panel on Climate Change's (IPCC's) *Fourth Assessment Report* (2007) indicates that industrialized countries need to collectively reduce emissions between 25 and 40 percent below 1990 levels by 2020 and 80 to 95 percent below 1990 levels by 2050 to keep atmospheric concentrations of greenhouse gases from exceeding 450 parts per million of CO_2e and to keep global average temperatures from increasing more than 2 degrees Celsius above pre-industrial levels. This target does not necessarily represent any particular country's share. Due to modeling limitations, this figure depicts HFC consumption, which is generally thought to be equivalent to life-cycle emissions. For this and all other figures, we use the global warming potentials provided in IPCC's *Fourth Assessment Report*. There are some limited exceptions. See Appendix I for more details.

- requirements to phase out the use of certain hydrofluorocarbons (HFCs) (23 percent of total emissions gap between BAU and 2020 target);
- standards to reduce methane emissions from natural gas systems (11 percent of total emissions gap between BAU and 2020 target);[7] and
- actions to improve energy efficiency in the residential, commercial, and industrial sectors (8 percent of total emissions gap between BAU and 2020 target).

B. STATE ACTION COULD HELP THE U.S. MEET NEAR-TERM PLEDGE

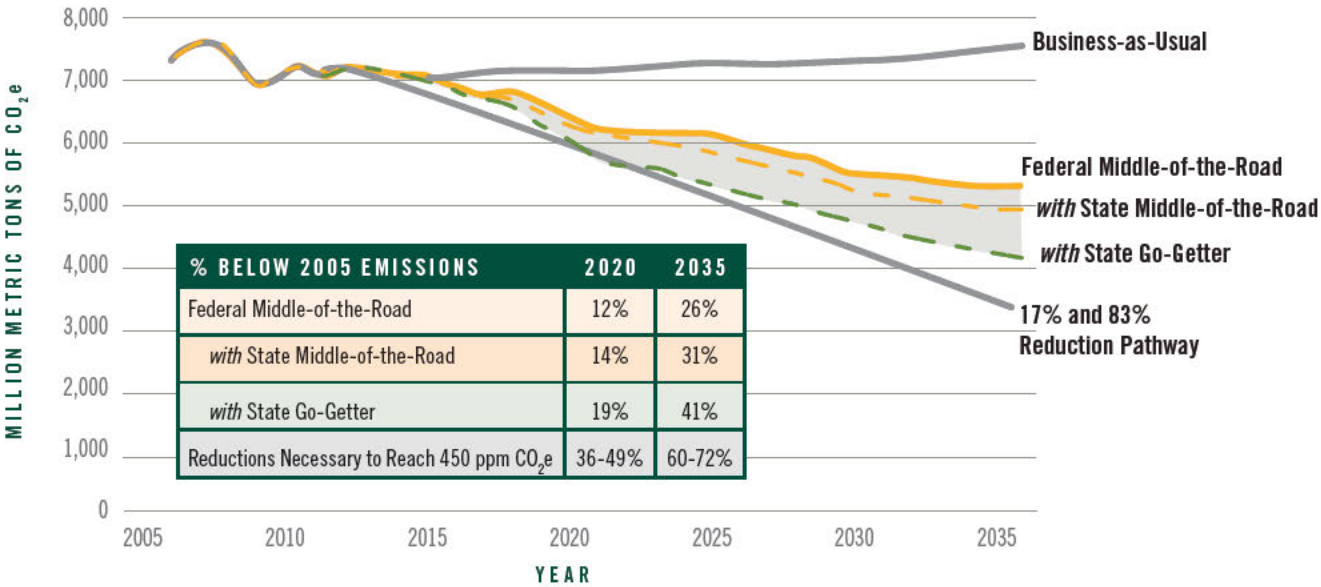
- States can be important contributors to efforts to reduce GHG emissions. If the U.S. Administration were to pursue policies with middle-of-the-road ambition, for example, states could pick up the slack and help the United States reach its goal of reducing emissions 17 percent below 2005 levels by 2020.
- If the federal government pursues a lackluster effort, even a go-getter effort by states is unlikely to achieve the U.S. Administration's 2020 reduction goal.
- Beyond 2020, go-getter state action combined with middle-of-the-road federal action falls short of putting the United States on track to make the mid-century reduction target. This suggests that strong new federal legislative action will be needed.

C. THE STUDY IN BRIEF

This updated report represents the authors' projections of the range of greenhouse gas emissions reductions possible if federal agencies and certain states implement measures to reduce GHG emissions. The report projects the range of reductions possible under current federal law based on a review of published analyses of technical feasibility. The report characterizes three emissions scenarios based on different levels of effort by federal and state actors: "lackluster," "middle-of-the-road," and "go-getter."

7. There is considerable uncertainty with regard to emissions for natural gas systems. The absolute magnitude of abatement opportunities is thus also uncertain. Nevertheless, our analysis suggests that there are important opportunities to reduce emissions from this sector. Those reductions are some of the lowest cost opportunities identified in this analysis.

FIGURE 2 Projected U.S Emissions with State Action Coupled with Middle-of-the-Road Federal Action



% BELOW 2005 EMISSIONS	2020	2035
Federal Middle-of-the-Road	12%	26%
with State Middle-of-the-Road	14%	31%
with State Go-Getter	19%	41%
Reductions Necessary to Reach 450 ppm CO_2e	36-49%	60-72%

Note: Due to modeling limitations, this figure depicts HFC consumption, which is generally thought to be equivalent to life-cycle emissions.

1. Analysis of Federal Actions

The analysis of federal actions is based on a legal assessment of the measures the U.S. Administration, including key federal agencies like EPA, may take under existing federal laws. The federal analysis assumes no new legislation is adopted. Technical studies were used to identify the range of reductions possible within a given sector or subsector. The legally and technically feasible range of reductions was then evaluated based on the level of ambition necessary to achieve a particular point in the range. Where available, we relied more heavily on studies that provided a consideration of the costs needed to achieve a particular outcome to provide a sense of the federal regulatory resolve necessary to achieve those reductions.

Where only a low level of ambition is necessary to achieve a particular technically and legally feasible outcome within a specific sector or subsector, the outcome was judged to be "lackluster." If a high level of ambition is necessary to achieve a particular reduction outcome deemed technically and legally possible, the effort necessary was deemed "go-getter" in our scenarios. "Middle-of-the-road" outcomes were those judged possible with moderate ambition and usually at the middle of the range deemed technically and legally possible.

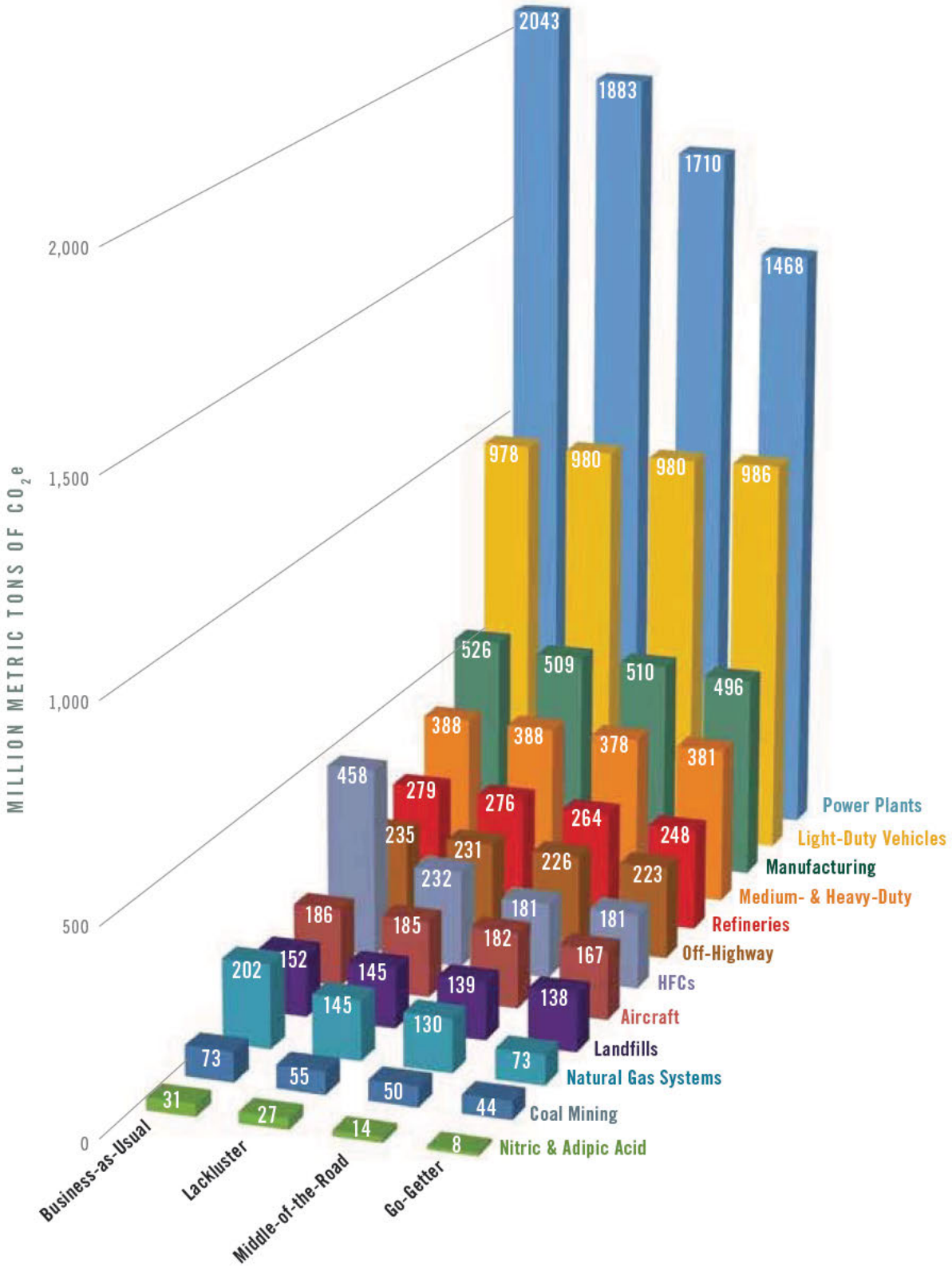
Lackluster emissions reductions from all sectors and subsectors analyzed were aggregated to determine the lackluster emissions pathway through 2035. The same approach was taken for middle-of-the-road and go-getter reductions.

2. Analysis of State Actions

The state analysis has two components: the first considers the impact of states taking action in the absence of federal action; the second considers the impact of states taking action in the presence of varying levels of federal action. In both components we examine the implication of states implementing the same types of policies modeled for the federal government, as well as complementary state-level actions in the transportation, energy efficiency, and renewables areas.

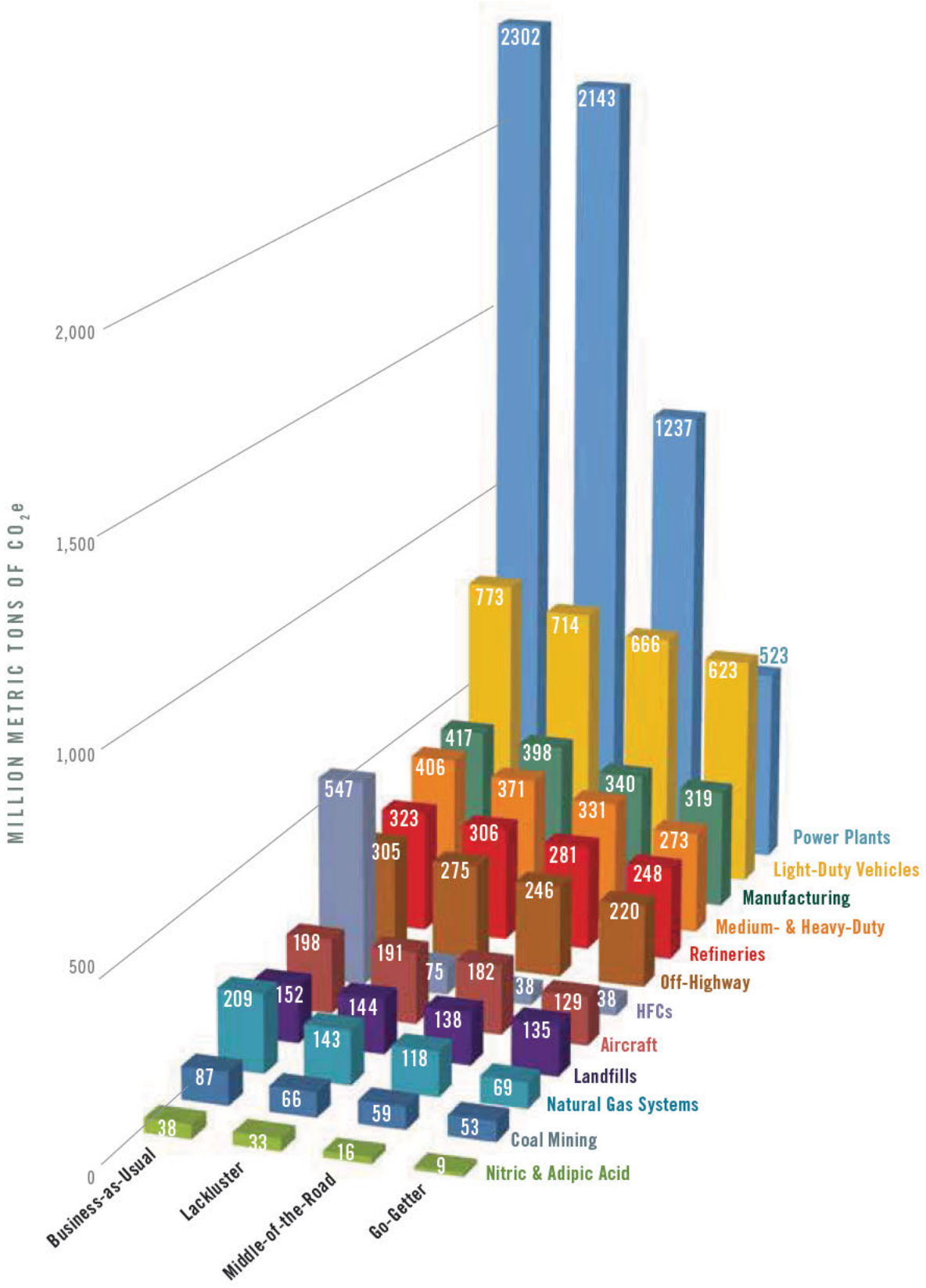
For transportation, the state scenarios consider measures to encourage low carbon fuels and reduce vehicle miles traveled. In the energy efficiency area, measures examined include increased electric end-use energy efficiency, improved building performance, and increased deployment of combined heat and power. For renewables, the analysis adds new and additional renewable energy policies across a certain number of states.

FIGURE 3 Projected U.S. Emissions in 2020 by Sector under Different Federal Regulatory Scenarios



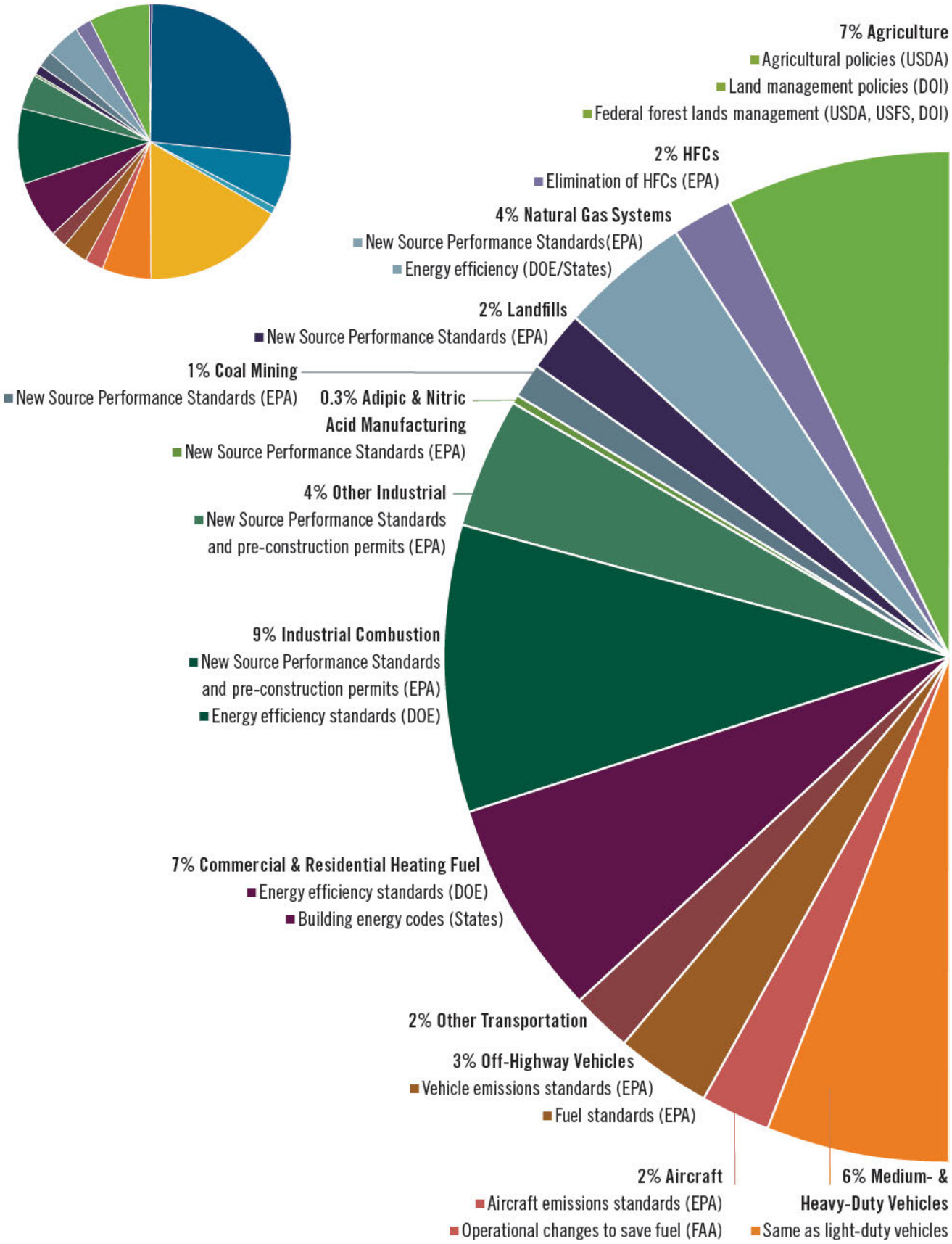
Note: Figure 3 depicts the emissions under the three federal regulatory scenarios by sector or category of sources in 2020. The bars on the left represent business-as-usual emissions. Emissions under the lackluster, middle-of-the-road, and go-getter scenarios are then shown moving from left to right of the business-as-usual emissions. Light-duty vehicle emissions initially increase in our scenarios due to assumptions about vehicle electrification and crediting rates. As shown in Figure 4, these trends reverse in later years. See Appendix I for more information. Due to modeling limitations, this figure depicts HFC consumption, which is generally thought to be equivalent to life-cycle emissions.

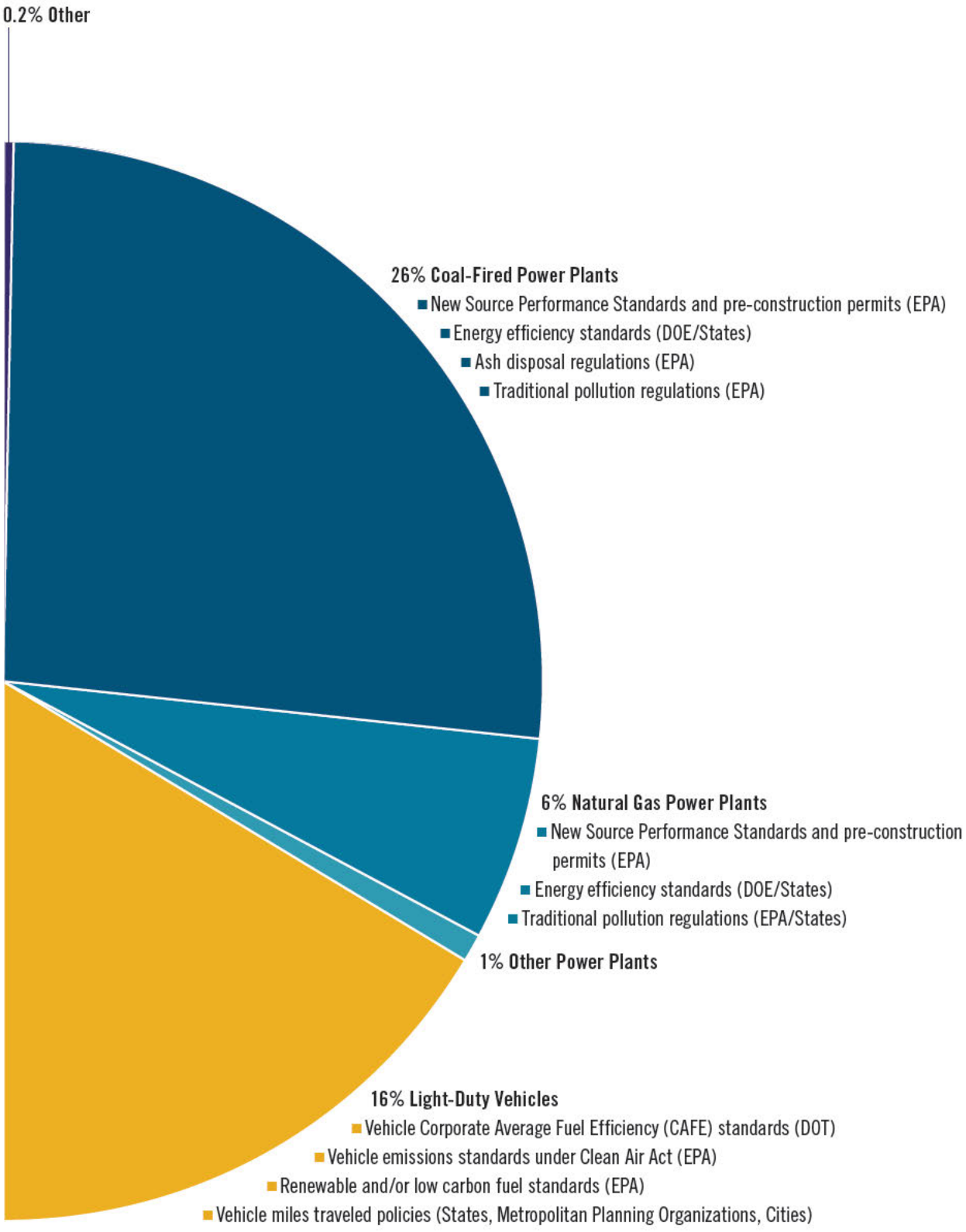
FIGURE 4 Projected U.S. Emissions in 2035 by Sector under Different Federal Regulatory Scenarios



Note: Figure 4 depicts the emissions under the three federal regulatory scenarios by sector or category of sources in 2035. The bars on the left represent the business-as-usual emissions. Emissions under the lackluster, middle-of-the-road, and go-getter scenarios are then shown moving from left to right of the business-as-usual emissions. Due to modeling limitations, this figure depicts HFC consumption, which is generally thought to be equivalent to life-cycle emissions.

FIGURE 5 U.S. Greenhouse Gas Emissions by Sector and Corresponding Federal Authorities, 2010





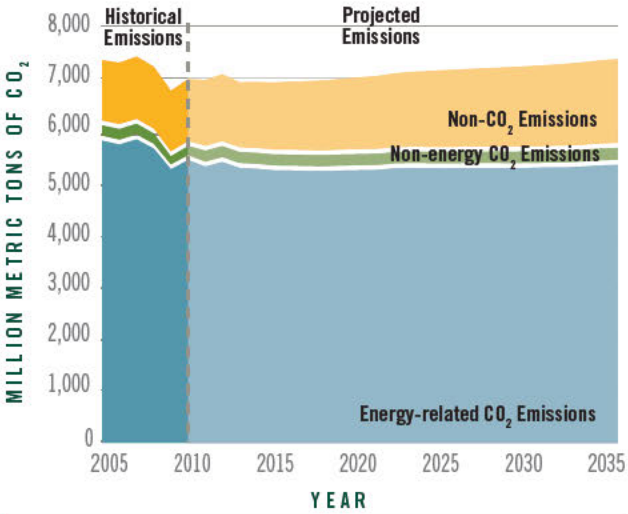
Source: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010*. U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>; *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas*. James Bradbury, Michael Obelter, Laura Draucker, Wen Wang, and Amanda Stevens. World Resources Institute, Working Paper, forthcoming.

Unlike the federal analysis, many of the state measures modeled would require new legislation at the state level. Also unlike the federal scenario, whether state action is "lackluster", "middle-of-the-road" or "go-getter" is a function of how many states adopt the measures modeled, and in some cases the ambition of the policies pursued.

3. Analysis of Federal and State Actions Together

Given that it is unlikely that federal action will occur without state action or that state action will occur without federal action, we analyzed emissions scenarios with both federal and state action. States can be expected to continue to be active in areas of traditional state purview such as energy resource planning and energy efficiency, while also compensating for weak federal action. To capture this dynamic, we modeled varying levels of action for federal and state action.

FIGURE 6 Projected U.S. Greenhouse Gas Emissions if no New State or Federal Action is Taken



Source: See sources listed under Figures 7 and 8 below.

III. The Road the U.S. is on Now: Business as Usual

The reduction pathways presented in this report are best considered in light of current U.S. emissions, along with recent and future emissions trends. A snapshot of U.S. emissions using the most recent data available is presented below, together with a summary of U.S. emissions by key sectors and recent actions to reduce them by federal agencies.

A. CURRENT U.S. EMISSIONS

In 2010 the United States emitted almost 7 billion metric tons of carbon dioxide equivalents (CO_2e), which represents a decrease of about 6 percent below 2005 levels and a 10 percent increase over 1990 levels. Fossil-fuel combustion was responsible for nearly 80 percent of U.S. emissions, with power plants accounting for about 40 percent of combustion emissions, or one-third of the total U.S. GHG inventory, according to EPA. The second largest contributor to total GHG emissions is the transportation sector, with approximately 30 percent of U.S. emissions. Non-CO_2 emissions and CO_2 emissions that result from industrial processes (as opposed to combustion) represented approximately 22 percent of U.S. total GHG emissions.

Figure 5 shows the 2010 U.S. emissions inventory by sector and subsector, together with the corresponding federal regulatory tools available to achieve reductions in the sector.

B. WHAT HAPPENS WITH NO NEW POLICIES? UNDERSTANDING CURRENT U.S. EMISSIONS TRENDS

Before discussing the reduction pathways projected for this report, it is important to describe the major emissions trends that are part of the business-as-usual projections. Business-as-usual emissions trends have shifted downward since the 2010 version of this report. While energy-related CO_2 emissions are projected to rise slowly but remain below 2010 levels through 2035, non-CO_2 emissions are projected to steadily increase over the same time period. The primary trends are noted here:

- **Current Energy-related Carbon Dioxide Emissions Down from 2005 Levels.** In 2011 carbon dioxide emissions from energy sources, which account for nearly 80 percent of U.S. GHG emissions, were 8.7 percent below 2005 levels. Nearly half of those reductions (48 percent) came from the power sector. The rest of the reductions came from transportation (28 percent), industry (18 percent), and buildings (6 percent).[8]

- **Future Energy-CO_2 Emissions Expected to be Relatively Flat.** Our projections suggest that if no future policy actions are taken, then energy-CO_2 emissions will remain approximately 10 percent

8. *Closer than You Think: Latest U.S. CO_2 Pollution Data and Forecasts Show Target Within Reach.* NRDC Issue Brief. Dan Lashof. July 2012.

below 2005 levels in 2020, and will increase slightly through 2035 to levels that are about 8 percent below 2005 levels (Figure 7).

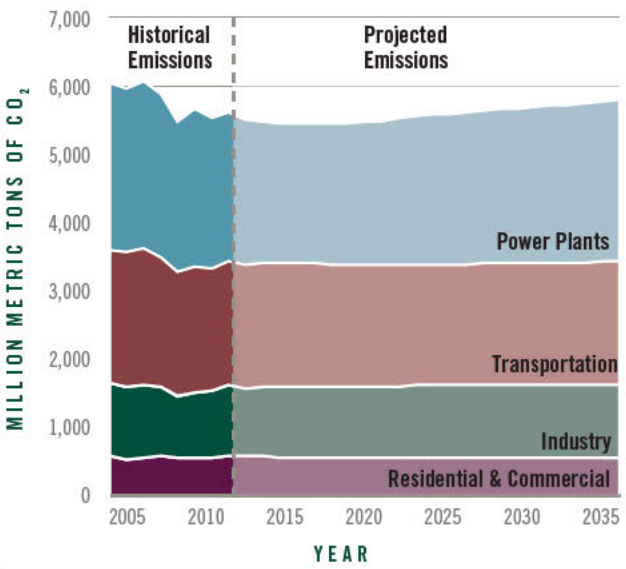
- Those trends are driven by a number of factors, including:

  - **Falling Energy Demand.** The economic slowdown experienced by the United States and other parts of the world over the period from 2008 to 2012 has led to decreased demand for goods and services and reduced energy consumption.[9] Over time, this trend is expected to reverse as economic growth picks up. In addition, the industrial sector was affected significantly by the recent economic turndown and saw a decrease in both production and emissions. This decline is projected to be temporary. Manufacturing output is expected to accelerate from 2010 through 2020, and emissions are projected to increase by 4 percent over this time.[10]

  - **Rise of Natural Gas and Renewables.** The power sector is shifting from coal-fired generation toward natural gas-fired and renewable generation. This trend is driven in part by increases in natural gas extraction, low natural gas prices, increasing coal prices, and new (non-GHG) regulations for the power sector. Increases in renewable generation are driven by state renewable standards, voluntary purchases of "green" energy, and decreasing renewable energy costs. However, gas prices are expected to slowly rise from current levels and demand for electricity is expected to rise 18 percent by 2035 from 2010 levels.[11]

  - **New Vehicle Rules.** The transportation sector is expected to become less carbon-intensive, due in large part to high petroleum prices and new federal GHG emissions and fuel efficiency standards covering light-, medium- and heavy-duty vehicles. These gains will be partially offset by continued increases in vehicle miles traveled.[12] Transportation emissions are projected to increase 1 percent below 2011 levels by 2035.

FIGURE 7 Projected U.S. Energy-Related Carbon Dioxide Emissions if no New State or Federal Action is Taken



Source: U.S. Energy Information Administration, Annual Energy Review (Years 2005-2011); U.S. Energy Information Administration, Annual Energy Outlook (Years 2012-2035)

- **Non-Energy Emissions on the Rise.** Trends for non-energy and non-CO_2 emissions, such as natural gas systems, refrigerants, and landfills, show a likely rise. In 2010, non-energy and non-CO_2 sources accounted for about 22 percent of total U.S. emissions. We project that these emissions will increase roughly 18 percent above 2005 levels by 2020 and 36 percent above 2005 levels by 2035, even after accounting for 2012 regulations that affect portions of natural gas systems and HFCs from vehicles. Those trends are driven by several factors, including:

  - **CFCs Phased Out, HFCs Phased In.** HFC emissions are increasing due to the phaseout of chlorofluorocarbons (CFCs) and other ozone-depleting substances under the Montreal Protocol, which is intended to

9. *Annual Energy Review 2012.* Figure 1.1, Primary Energy Overview (Consumption). EIA, September 2012. Accessible at: <http://www.eia.gov/totalenergy/data/annual/pdf/aer.pdf>.
10. *Annual Energy Outlook 2012 with Projections to 2035. EIA, June 2012.* Accessible at: <http://www.eia.gov/forecasts/aeo/pdf/0383(2012).pdf>.
11. *Annual Energy Outlook 2012 with Projections to 2035.* EIA, June 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/pdf/0383(2012).pdf>.
12. *Annual Energy Outlook 2012 with Projections to 2035.* EIA, June 2012.

BOX 3 Recent Federal Action 2010–12

Since the 2010 report, federal agencies have taken a number of actions that are reducing GHG emissions. The most significant actions from a GHG reduction perspective are summarized below. These are all incorporated into our new business-as-usual projections.

- **Passenger cars and light-duty trucks.** In August 2012 EPA and the National Highway Traffic Safety Administration (NHTSA) finalized new fuel economy and GHG standards for passenger cars and light-duty trucks for model years 2017–2025. These standards equate to a fleet-wide average of 54.5 mpg (101 g CO_2e/km) if they are met solely through fuel economy improvements (as opposed to reductions in HFC emissions from air conditioners). This is approximately double the fuel economy of vehicles sold in 2010. EPA estimates that the rule will save nearly 2 billion tons of CO_2e over the life of the program. This is in addition to the estimated 960 million tons of CO_2e over the life of the prior regulations for model years 2012–2016.

- **Heavy-duty vehicles.** In August 2011 EPA and NHTSA finalized the first-ever fuel efficiency and GHG emission standards for model year 2014 through 2018 medium- and heavy-duty vehicles. EPA estimates that this rule will reduce CO_2 emissions by approximately 270 million metric tons over the life of vehicles sold during the 2014–2018 model years.

- **Natural gas systems.** In April 2012 EPA finalized four regulations that will reduce emissions of volatile organic compounds, sulfur dioxide (SO_2), and air toxics from oil and natural gas systems. EPA estimates that the new standards will have the co-benefit of reducing annual methane emissions by an estimated 19–33 million metric tons of CO_2e.

- **Energy efficiency standards for new appliances.** Between 2009 and 2011, the Department of Energy established 17 new standards. According to analysis by the Appliance Standards Awareness Project and the American Council for an Energy-Efficiency Economy, these standards are expected to save 126.2 TWh in 2025 and 146.8 TWh in 2035.

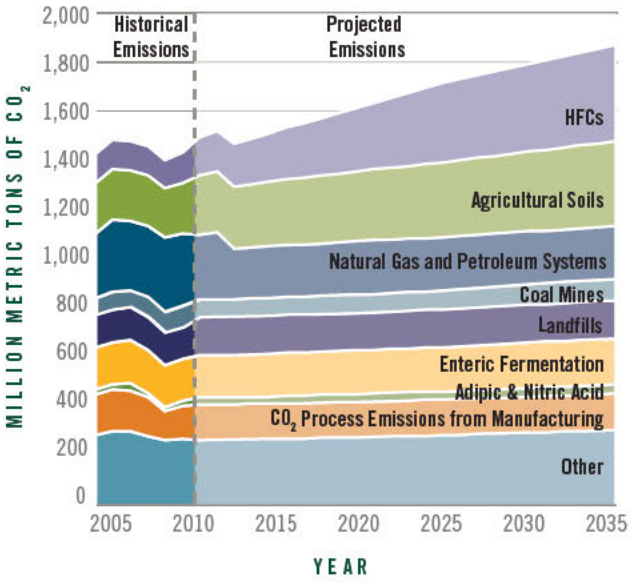
- **Non-GHG regulations for power plants.** EPA has also finalized several other non-GHG-related environmental regulations for power plants, most notably those for mercury and other air toxics. Some modeling has suggested that these rules could lead to the retirement of old, inefficient, coal-fired power plants.

protect and restore the ozone layer in the upper atmosphere, and the Clean Air Act. This trend is expected to continue as the interim substitutes, HCFCs, are also phased out as they are currently being replaced with gases that have a high global warming potential.

- **With the Natural Gas Boon, More Methane Leaks.** Extraction of natural gas in the United States has increased by over 25 percent over the period of 2005 to 2011 due to rapid development of shale gas resources.[13] Increases in natural gas extraction lead to larger fugitive methane emissions from natural gas systems. Fugitive methane emissions are expected to fall significantly, however, due to 2012 EPA regulations that reduce emissions of volatile organic

13. *Monthly Energy Review.* Table 1.2, Primary Energy Production by Source. EIA, December 2012. Accessible at: <http://www.eia.gov/totalenergy/data/monthly/pdf/sec1_5.pdf>.

FIGURE 8 Projected U.S. Non-CO_2 and Non-Energy Emissions if no New State or Federal Action is Taken



Source: U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010 (Years 2005-2010)*; U.S. Environmental Protection Agency, *Draft Global Non-CO_2 Emissions Projections Report 1990-2030 (Non-CO_2 Years 2011-2035)*; RTI, *Applied Dynamic Analysis of the Global Economy Model (Non-energy CO_2 Years 2011-2035)*; *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas.* World Resources Institute. Working Paper. James Bradbury, Michael Obelter, Laura Draucker, Wen Wang, and Amanda Stevens.

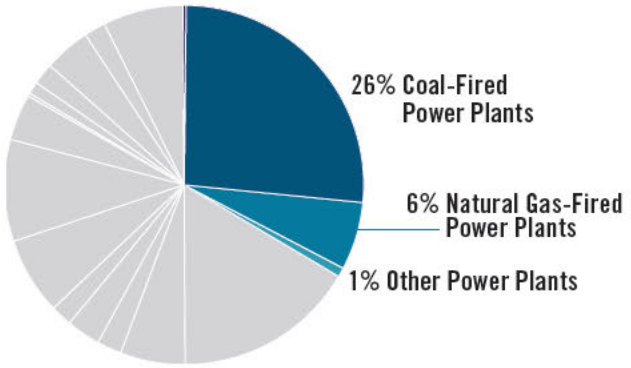
compounds, sulfur dioxide, and air toxics from natural gas systems. Actions to reduce those emissions will also reduce methane emissions (see Box 3 for more details).

IV. Understanding the Federal Reduction Pathways

A. ABOUT THE SECTOR-BY-SECTOR APPROACH

This analysis is a bottom-up assessment of the policies and regulatory tools available to the U.S. Administration, through the federal executive agencies tasked with implementing such regulations—to reduce GHG emissions. The analysis began with an examination of the makeup of U.S. emissions in 2010, followed by research and analysis into existing laws on authority to reduce emissions. We reviewed available literature to determine the range of emissions reductions technically feasible for each sector or subsector. Lastly, we considered legal authority, technical feasibility, cost and political will in constructing lackluster, middle-of-the-road, and go-getter scenarios for each sector or subsector. We briefly describe the scenarios for each sector or subsector below, beginning with the sectors that our analysis indicates offer the greatest potential for reductions. A more detailed discussion of our federal methods is provided in Appendix I.

FIGURE 9 Power Plant Emissions



As a Share of U.S. Emissions in 2010

B. ELECTRIC POWER

The electric sector is the largest single source of GHG emissions in the United States. In 2010 it made up 33 percent of total U.S. GHG emissions, and about 40 percent of all carbon pollution from the combustion of fossil fuels. This sector also represents the single biggest opportunity for emissions reductions using existing legal and regulatory tools.

1. Power plants

Carbon pollution from power plants can be reduced through the following federal regulatory authorities:

TABLE 1 Projecting New Source Performance Standards for Power Plants

	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Existing plants	Emissions reductions consistent with a 5 percent improvement in efficiency starting in 2018.	Aggregate emissions reductions across all electric generators equal to an 18 percent reduction in emissions in 2021 compared to 2012 emission levels, and a 33 percent reduction in 2035.	Aggregate emissions reduction across all electric generators equal to a 38 percent reduction in emissions in 2021 compared to 2012 emission levels, and a 74 percent reduction in 2035.
New plants	Standards initially consistent with EPA's proposal (1,000 pounds of CO_2 per megawatt-hour of output). Beginning in 2020, new unit performance improves to 570 pounds of CO_2 per megawatt-hour by 2030.	Standards initially consistent with the lackluster scenario. Beginning in 2028, new units achieve emissions rates equivalent to carbon capture and storage (CCS) with a 90 percent capture rate.	Standards initially consistent with the lackluster scenario. Beginning in 2020, new units achieve emissions rates equivalent to CCS with a 90 percent capture rate.

TABLE 2 Appliance and Equipment Efficiency Standards (Electric)

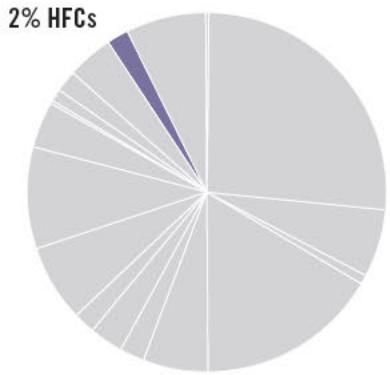
LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
192 TWh savings in 2025 from the residential and commercial sectors, plus additional savings from the industrial sector. Annual savings remain constant through 2035.	212 TWh savings in 2025 and 306 TWh savings in 2035 from the residential and commercial sectors, plus additional savings from the industrial sector.	364 TWh savings in 2025 and 525 TWh savings in 2035 from the residential and commercial sectors, plus additional savings from the industrial sector.

a. **Performance standards for new and existing sources under section 111 of the federal Clean Air Act**
Under section 111 of the Clean Air Act, EPA may prescribe emissions limitations based on the "best system of emission reduction" for new and modified existing sources within source categories EPA determines cause or contribute significantly to air pollution that may reasonably be anticipated to endanger human health or welfare.[14] To determine the "best system of emission reduction," EPA considers technological feasibility, cost, lead time, and energy and non-air environmental impacts.[15] In the spring of 2012 EPA proposed new source performance standards (NSPS) for new power plants.

In addition, for any source category EPA regulates on the federal level, EPA must also promulgate guidelines to states to use in developing requirements for existing sources under section 111(d). In regulating existing sources, states must determine the "best system of emission reduction" for existing sources while taking into account the same factors EPA uses to set limitations for new sources, and also the remaining useful life of existing sources.[16] The form of regulations imposed on existing sources is not tightly prescribed in the statute, and EPA has previously taken the position that states could implement flexible, market-based approaches in setting standards from existing sources. Table I specifies our three scenarios for new and existing power plants under section 111.

b. **Appliance and equipment efficiency standards under Department of Energy authority**
The Department of Energy (DOE) may promulgate efficiency standards for consumer appliances and non-consumer equipment under authority already granted DOE in current law. Based on available studies, the three scenarios analyzed assume progressively greater reductions through appliance and equipment standards, ranging up to 364 TWh of annual savings from residential and commercial consumers in 2025 and 525 TWh annual savings in 2035, with additional savings from industrial consumers.

FIGURE 10 HFC Emissions



As a Share of U.S. Emissions in 2010

C. HYDROFLUOROCARBONS

Hydrofluorocarbons (HFCs), used primarily for refrigeration and air conditioning, represented only 2 percent of all U.S. global warming pollution in 2010. Despite their relatively small share of the U.S. emissions picture today, our analysis finds HFCs can provide some of the greatest reductions by 2020 and through 2035. EPA has existing authority to regulate HFC consumption under Title VI of the Clean Air Act. EPA can phase down the use of HFCs under

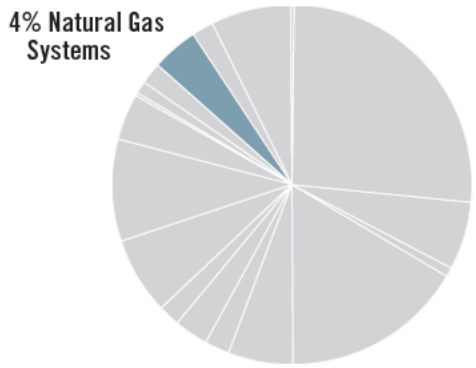
14. 42 U.S.C. §§ 7411(a)(1) & 7411(b)(1)(A).). U.S. Environmental Protection Agency. "Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act." Accessible at: <http://www.gpo.gov/fdsys/pkg/FR-2009-12-15/pdf/E9-29537.pdf>.
15. 42 U.S.C. §§ 7411(a)(1).
16. 42 U.S.C. §§ 7411(d)(1)(B).

TABLE 3 Emissions Reduction Schedule for Hydrofluorocarbons

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Consumption ramp-down occurs three years later than the schedule detailed in the joint North American Proposal.	Consumption is ramped-down in a manner consistent with the joint North American Proposal, which calls for an 85 percent reduction below 2005–2008 levels by 2033.	Consumption is ramped-down more rapidly than in the joint North American Proposal, achieving the 85 percent reduction target in 2028, five years earlier than detailed in the joint North American Proposal.

its Significant New Alternatives Program (SNAP), implementing section 612 of the Clean Air Act. The U.S. Administration has proposed an international ramp-down schedule to achieve reductions worldwide under the Montreal Protocol. Our middle-of-the-road scenarios for HFCs assume this proposed ramp-down schedule is met in the United States. The lackluster scenario assumes that the same ramp-down schedule is implemented, but on a delayed timeline, commencing in 2019 instead of 2016. Meanwhile, the go-getter scenario assumes a more ambitious reduction schedule.[17]

FIGURE 11 Emissions from Natural Gas Systems



As a Share of U.S. Emissions in 2010

D. NATURAL GAS SYSTEMS

Global warming pollution from natural gas systems accounts for approximately 4 percent of U.S. emissions. Yet like HFCs, our analysis suggests that natural gas systems may be among the top emissions reduction opportunities in the near term. Similar to power plants, EPA can regulate natural gas systems by implementing emissions performance standards for methane under section 111 of the Clean Air Act for new and existing natural gas systems. They may also be able to achieve additional GHG emissions reductions

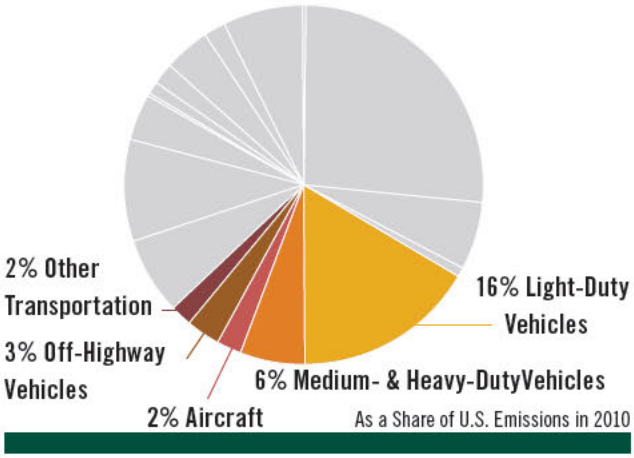
17. Due to modeling limitations, our analysis examines changes in HFC consumption. In the United States, HFC consumption is roughly equivalent to life-cycle emissions due to low rates of capture and destruction. See Appendix I for a more detailed discussion.

TABLE 4 Performance Standards to Reduce Emissions from Natural Gas Systems

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Emissions reductions of 26 percent from business-as-usual starting in 2019. Assumes implementation of plunger lift systems to reduce emissions from liquids unloading at new and existing wells, and leak monitoring and repair to reduce fugitive emissions from production, processing, and compressor stations.	Emissions reductions of 37 percent from business-as-usual starting in 2019. Assumes implementation of measures in lackluster scenario and conversion of existing high-bleed pneumatic controllers to low-bleed or no-bleed controllers to reduce emissions from production, processing, and transmission.	Emissions reductions of 67 percent from business-as-usual starting in 2019. Assumes implementation of measures in middle-of-the-road scenario, as well as desiccant dehydrators to reduce emissions during dehydration of wet gas; improved compressor maintenance to reduce emissions during processing; hot taps in maintenance of pipelines during transmission; and vapor recovery units to reduce emissions during storage.

by tightening standards for other air pollutants, such as volatile organic compounds and air toxics, as they recently did with respect to new equipment in the U.S. oil and gas sector. Through one or more of these regulatory paths, EPA could require equipment changes, upgrades, changes to operational practices, and inspection and leak prevention. Table 4 details the three scenarios analyzed. However, there is a great deal of uncertainty with regard to emissions for natural gas systems. This means that the absolute magnitude of abatement opportunities is uncertain. Nevertheless, our analysis identifies important opportunities to reduce emissions from this sector. Those reductions are some of the lowest cost opportunities identified in this analysis. See the appendix for a more detailed discussion of uncertainties and opportunities.

FIGURE 12 Transportation Emissions



E. TRANSPORT VEHICLES

Transportation is one of the largest sources of global warming pollution in the United States, accounting for 30 percent of the 2010 inventory. Improving the efficiency of motor vehicles has been a priority for the Obama Administration, which promulgated new standards to reduce emissions and raise the fuel efficiency of light-, medium- and heavy-duty vehicles. Our analysis finds that it is possible to achieve additional reductions from light-, medium-, and heavy-duty vehicles. In addition, there are opportunities to reduce emissions of global warming pollution from aircraft and off-highway vehicles.

1. Passenger vehicles

Under Title II of the Clean Air Act, EPA has the authority to regulate greenhouse gas emissions from new light-duty cars and trucks, and has done so already in two consecutive rulemakings covering vehicles sold through model year 2025. In conjunction with EPA's rulemaking, the Department of Transportation's National Highway Traffic Safety Administration (NHTSA) may promulgate corporate average fuel economy (CAFE) standards regulating the average fuel efficiency of new vehicles. Because standards have already been issued covering light-duty vehicles through model year 2025, our analysis focuses on the time period after 2025. Table 5 outlines the three scenarios, with the lackluster scenario projecting improvements at half the rate of the previous standards, middle-of-the-road projecting continuation of the same rate of improvement, and go-getter increasing the rate of improvement significantly.

2. Medium- and heavy-duty vehicles

For medium- and heavy-duty vehicles, EPA has established emissions standards and NHTSA has established fuel economy standards for model years 2014 through 2018. These standards are included in our business-as-usual emissions trajectory. Our emissions reduction scenarios pick up in model year 2020 using the same legal authority, but making different assumptions about the stringency of the next set of standards. As shown in Table 5, our lackluster scenario assumes a rate of improvement that is just half that of the current standards through 2035, middle-of-the-road projects a continuation of the current standards through 2035, and the go-getter scenario considerably increases new standards to meet the maximum level of efficiency currently thought to be technically achievable in that time frame.

3. Off-Highway engines

EPA may also regulate off-highway sources of global warming pollution under Title II of the Clean Air Act. For the lackluster, middle-of-the-road, and go-getter scenarios, respectively, the analysis assumes new standards can achieve 0.9 percent, 1.8 percent, and 2.4 percent annual improvement in the emissions rate for new equipment and engines from 2018 to 2035.

4. Aviation and aircraft

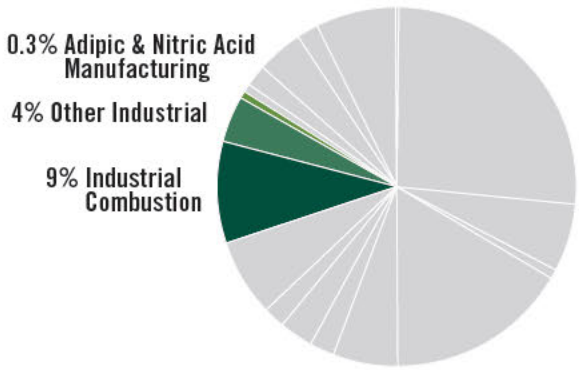
The Federal Aviation Administration (FAA) may make operational improvements in the air traffic control system that could achieve significant carbon pollution reductions over time. We draw our assumptions about operational improvements from an EPA analysis of the reductions possible and the FAA's comments on that analysis. Our scenarios, shown in Table 5, bound the range of reductions estimated by EPA and FAA.

TABLE 5 Vehicle Emissions Standards, Efficiency Standards, and Operational Improvements

	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Light-duty vehicles	Vehicle standards continue to improve from 2026–2035 at roughly half the rate of the 2017–2025 standards (2 percent per year). This results in a 131 grams per mile emissions standard and a 61 mpg CAFE standard in 2035.	Vehicle standards continue to improve from 2026–2035 at roughly the same rate as the 2017–2025 standards (4 percent per year). This results in a 104 gram per mile emissions standard and a 75 mpg CAFE standard in 2035.	Vehicle standards continue to improve from 2026–2035 at 6 percent annually. This results in a 81 grams per mile and a 92 mpg CAFE standard in 2035.
Medium- & heavy-duty vehicles	Standards continue to improve through 2035 at half the rate of the 2013–2018 standards by vehicle category—about a 1.3 percent annual improvement.	Standards continue to improve through 2035 at the same rate as the 2013–2018 standards by vehicle category—about a 2.6 percent annual improvement.	By 2020–2022, the medium- and heavy-duty fleet reduces its emissions rate by an average 26 percent and by 42 percent in 2023–2025 compared to 2010. Standards continue to improve annually by 1 percent through 2035.
Off-highway	From 2018 to 2035, a 0.9 percent annual improvement in the emissions rate for new equipment and engines.	From 2018 to 2035, a 1.8 percent annual improvement in the emissions rate for new equipment and engines.	From 2018 to 2035, a 2.4 percent annual improvement in the emissions rate for new equipment and engines.
Aviation	Through 2035, a 0.17 percent annual emissions reduction from operational improvements via FAA's NextGen Program.	Through 2035, a 0.4 percent annual emissions reduction from operational improvements via FAA's NextGen Program.	Through 2035, a 1.4 percent annual emissions reduction from operational improvements via FAA's NextGen Program, plus a 2.3 percent annual improvement in the performance of new aircraft and engines.

EPA has statutory authority under Title II of the Clean Air Act to promulgate standards to reduce emissions from new and existing aircraft engines. To date, EPA has never exercised that authority to require aircraft engine manufacturers to meet standards that the industry association has not previously adopted voluntarily. Nevertheless, our go-getter scenario, shown in Table 5, projects the emissions reductions that could be achieved if EPA were to pursue this regulatory course of action.

FIGURE 13 Industrial Emissions



As a Share of U.S. Emissions in 2010

F. INDUSTRY

Emissions from industrial facilities comprised 13 percent of U.S. global warming pollution in 2010. Fossil fuel combustion at industrial facilities accounts for 9 percent of U.S. emissions, while non-combustion industrial processes account for 4 percent of emissions. When accounting for upstream, indirect CO_2 emissions from power plants, the industrial sector is responsible for 23 percent of total U.S. GHG emissions.

EPA may regulate industrial stationary sources of emissions through performance standards under section 111 of the Clean Air Act. As with power

TABLE 6 Performance Standards to Reduce Industry Emissions

	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Fossil-fuel combustion in manufacturing and cement kilns	Emissions reductions consistent with a 10 percent improvement in combustion efficiency by boilers.	Emissions reductions consistent with harnessing all cost-effective energy efficiency across all processes and energy uses at manufacturing facilities. Emissions standards also drive reductions in process emissions from cement kilns.	Emissions reductions consistent with harnessing all cost-effective energy efficiency across the entire manufacturing facility. All new units must meet emissions rate equivalent to natural gas combustion. Emissions standards also drive reductions in process emissions from cement kilns.
Refineries	Emissions reductions consistent with a 1 percent improvement in efficiency beyond business-as-usual projections.	Emissions reductions consistent with a 5 percent improvement in efficiency beyond business-as-usual projections.	Emissions reductions consistent with a 10 percent improvement in efficiency beyond business-as-usual projections.
Nitric and adipic acid manufacturing	A 13 percent reduction in emissions.	A 56 percent reduction in emissions.	A 75 percent reduction in emissions.

plants, this is accomplished through EPA's setting of standards for new sources and issuing regulations that provide states with guidelines for covering existing sources. New source requirements typically take the form of a simple emissions rate, while regulation of existing sources can be more flexible.

1. Fossil fuel combustion in manufacturing and cement kilns

As with fossil-fuel burning power plants, reducing the GHG emissions profile of the industrial sector can be accomplished through improvements to the efficiency of boilers, fuel switching, and use of renewable energy such as biomass or geothermal, among other methods. Additional reductions are possible if regulations require a manufacturing facility to capture all cost-effective process efficiencies across an entire operation, beyond the boiler. Table 6 details the three scenarios analyzed for projecting possible reductions from the industrial sector. In addition, for the middle-of-the-road and go-getter scenarios for cement kilns, we assume emissions standards are used to drive reductions in process emissions through greater use of blended cements, and potentially carbon capture and storage, achieving reductions in process emissions of 2 percent in 2020 and 13 percent in 2035.

2. Petroleum refineries

EPA's advanced notice of proposed rulemaking, *Regulating Greenhouse Gas Emissions Under the Clean Air Act,* indicated that efficiency improvements in refineries are possible in the range of 10 to 20 percent. Some efficiency improvements are included in our business-as-usual projections, however. Therefore, in order to generate conservative estimates of emissions reductions, starting in 2018 we model lackluster, middle-of-the-road, and go-getter scenarios with reductions in annual GHG emissions of 1, 5, and 10 percent reductions beyond business-as-usual projections, respectively.

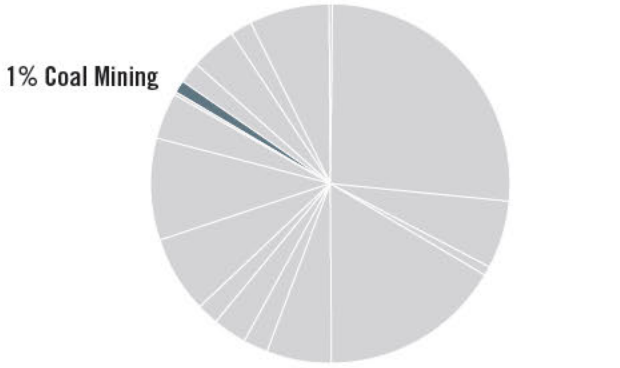
3. Nitric and adipic acid manufacturing

Nitric acid is primarily used as a feedstock for synthetic fertilizer, and also used to produce adipic acid and explosives. Adipic acid is used in the production of nylon and is a flavor enhancer in foods. The production of both compounds leads to emissions of nitrous oxide, a potent greenhouse gas. Though nitric and adipic acid manufacturing makes up less than 0.5 percent of total U.S. global warming pollution, there are opportunities to achieve dramatic reductions at low cost, making it a good target for policy.

To reduce emissions from acid manufacturing, EPA can use its authority under section 111 of the Clean Air Act to set standards for new manufacturing plants and issue guidelines to states to cover existing sources. Our

lackluster, middle-of-the-road and go-getter scenarios project reductions of annual GHG emissions of 13 percent, 56 percent, and 75 percent, respectively, compared to the business-as-usual projections.

FIGURE 14 Coal Mine Emissions

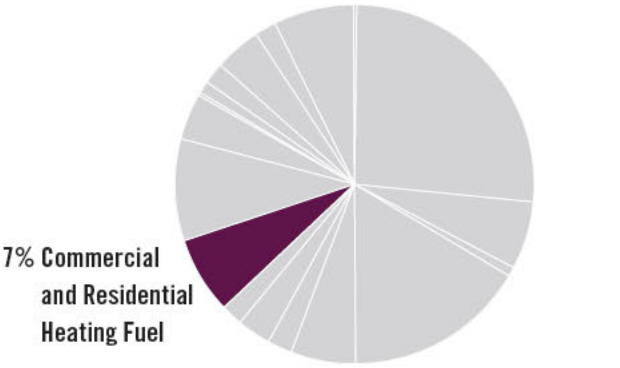


As a Share of U.S. Emissions in 2010

G. COAL MINES

Methane emissions from coal mines represented 1 percent of total U.S. global warming pollution in 2010. EPA may regulate coal mines as a source category under section 111 of the Clean Air Act. As discussed above for power plants and industry, this would entail EPA issuing performance standards for new coal mines and regulations to guide states in their regulation of existing coal mines. The statute does not prescribe the specific form of regulations applied to existing sources. For the lackluster, middle-of-the-road, and go-getter scenarios, we projected reductions from coal mines of 24 percent, 32 percent, and 39 percent, respectively, compared to business-as-usual projections.

FIGURE 15 Commercial & Residential Heating Emissions

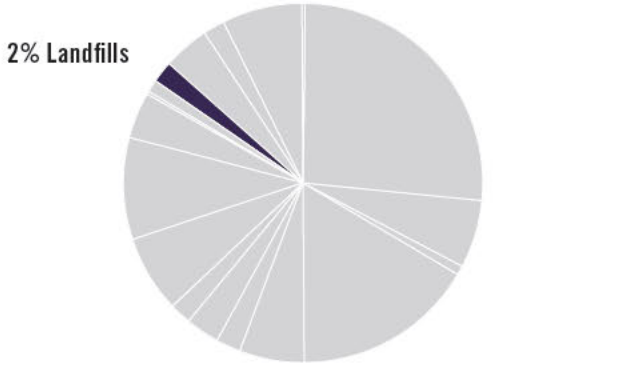


As a Share of U.S. Emissions in 2010

H. COMMERCIAL AND RESIDENTIAL HEATING

Carbon pollution from commercial and residential heating, mostly through natural gas combustion, accounted for 7 percent of U.S. emissions in 2010. This includes things such as home heating, cooking, and water heating. The most effective way to decrease emissions in this sector is to improve the building envelope—a path traditionally the province of state and local governments in the United States. However, the federal government can promulgate efficiency standards for appliances and equipment used to heat buildings. Based on our survey of the available literature, we conclude that efficiency standards implemented in 2015 could reduce natural gas demand by 126 Trillion British thermal units (TBtu) in 2025 and 235 TBtu in 2035, reducing GHG emissions by 6.7 million tons of CO_2 in 2025 and 12.5 million tons CO_2 in 2035 compared to business-as-usual projections. Due to limitations in the available literature, we project the same reductions level for all three scenarios.

FIGURE 16 Landfill Emissions



As a Share of U.S. Emissions in 2010

I. LANDFILLS

Methane emissions from landfills represented 2 percent of total U.S. global warming pollution in 2010. EPA already regulates emissions of volatile organic compounds from landfills under section 111 of the Clean Air Act. These standards provide the co-benefit of reducing methane emissions. EPA could either strengthen those standards or establish new standards for GHG emissions. The statute does not prescribe the form of regulations applied to existing sources. For the lackluster, middle-of-the-road, and go-getter scenarios, we projected reductions of 5 percent, 9 percent, and 9 percent, respectively, compared to our business-as-usual projections. The reductions we

project for landfills in this report are substantially smaller than the reductions projected in the 2010 report. These differences are attributable to changes in the EPA data used in the analysis.

V. Understanding the State Reduction Pathways

Policy action to address environmental challenges frequently begins at the state level, and greenhouse gases are no exception. States were the first to push ambitious emissions standards for vehicles, adopt greenhouse gas regulations for the power sector, and establish economy-wide reduction targets. Many states already have programs that reduce emissions from transportation, improve energy efficiency, and promote renewable generation. In the state scenarios, we examine what would happen if states continue to adopt policies that reduce their GHG footprint.

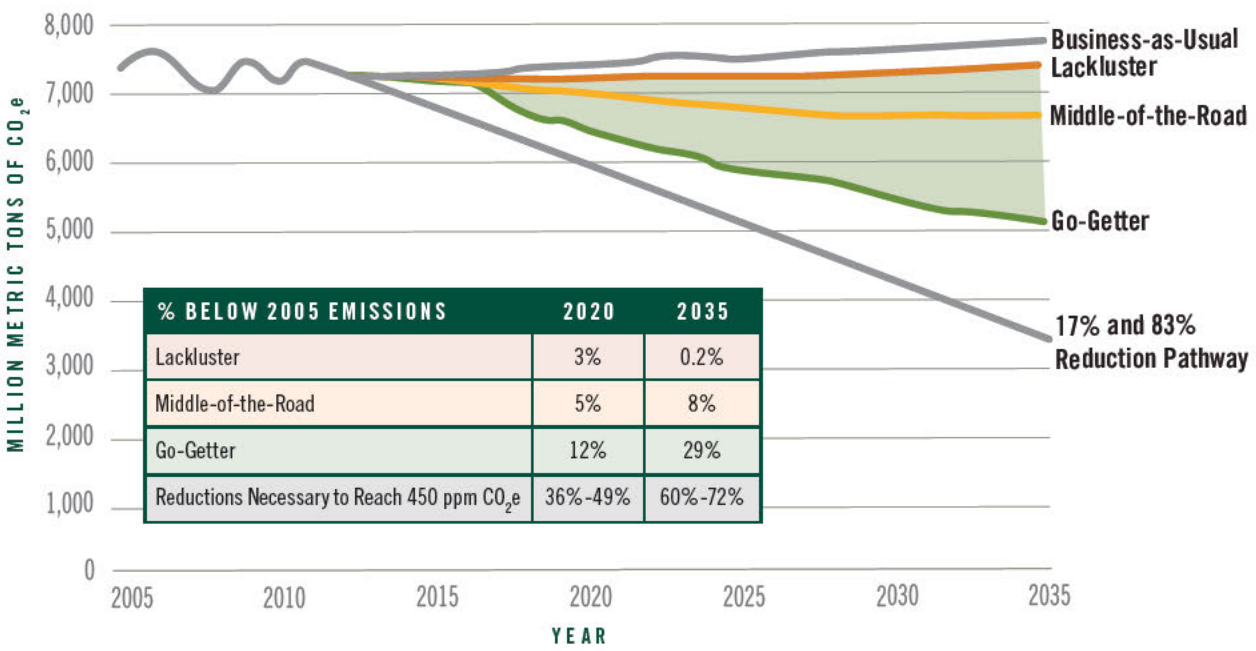
A. ABOUT THE STATES APPROACH

The state analysis takes a two-pronged approach. First, we project the potential greenhouse gas emissions reductions from transportation, end-use energy efficiency, and renewable electricity policies typically undertaken by states. Second, we consider the potential for state action in areas we also consider for the federal government, such as emissions standards for power plants and industry. This is based on the observation that the Constitution grants states broad authority to regulate their energy sources and emissions. States thus have the ability to implement many of the same policies as federal agencies.

In this analysis, the difference between lackluster and go-getter action at the state level is a function of the number and size of the states that adopt the measures modeled, and in some cases the ambition of the policies pursued. Unlike the federal analysis, in some cases state action would require new state legislation. However, we did not attempt to determine which states would require new legislation to implement the state measures and which states could implement without new legislation. A detailed discussion of our state methods is provided in Appendix II.

In addition to the direct emission reduction opportunities modeled here, state-level action can help trigger more ambitious action at the federal level. In the words of Justice Brandeis, states can serve as "laboratories of democracy," testing out approaches that provide possible models for federal action. Action at the state level can also lead to broader support for federal action, with the most ambitious states helping establish a floor for federal ambition.

FIGURE 17 Projected U.S Emissions when States Pursue the Full Range of Policies within their Authority (No Federal Action)



% BELOW 2005 EMISSIONS	2020	2035
Lackluster	3%	0.2%
Middle-of-the-Road	5%	8%
Go-Getter	12%	29%
Reductions Necessary to Reach 450 ppm CO_2e	36%-49%	60%-72%

Note: Due to modeling limitations, this figure depicts HFC consumption, which is generally thought to be equivalent to life-cycle emissions.

B. TRANSPORTATION

As noted above, the transport sector is responsible for about 30 percent of GHG emissions in the United States, making it the second largest emitting sector behind power plants. State and local policies have traditionally played a significant role in transportation, and as a result we project reductions that states might be able to achieve in this area, including through policies to encourage the use of lower carbon fuels and reduce vehicle miles traveled.

1. Lower Carbon Fuels

States may establish requirements for the fuels delivered in their jurisdictions to reduce the carbon profile of those fuels. To project potential reductions through state policies that reduce the life-cycle emissions of transportation fuels, we do not select specific policies in specific states. Rather, we model percent improvements in the carbon profile of fuels generally. These general improvements in the carbon profile of fuels are a proxy for what is likely to be a diverse set of measures across numerous states.

For modeling purposes, we assume that those policies further reduce the average life-cycle carbon intensity of transportation fuels by 1 percent per year between 2015 and 2035. In the lackluster scenario, we assume this annual reduction is achieved by states accounting for 15 percent of total energy consumption from U.S. transportation fuels. In the middle-of-the-road and go-getter scenarios, we assume that these policies are pursued by states accounting for 25 percent and 35 percent of total U.S. transportation fuel consumption, respectively.[18]

2. Reducing Vehicle Miles Traveled

States play a big role in designing and implementing policies that directly impact the number of vehicle miles traveled. These include smart growth strategies, such as targeting new development near public transportation, favoring infill, limiting sprawl, mixed-use development, and provision of smartly located affordable housing options. These strategies can be complemented by a variety of strategies, including improving and expanding public transportation options, bike and pedestrian pathways, car sharing, and HOV lanes, as well as through speed limit restrictions, intercity tolls, and strategies to limit driving within urban centers (e.g., parking restrictions).

In our lackluster and middle-of-the-road scenarios, we assume that states that implement policies and programs achieve VMT reductions of 0.5 percent per year beginning in 2016, leading to a 10 percent reduction below business-as-usual projections in 2035.

18. See Appendix II for context about what it would take to achieve the state uptake in this and the other state scenarios.

TABLE 7 State Transportation Measures

ACTION	POLICIES AND PROGRAMS DRIVING ACTION	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Reduce carbon content of fuels by 1 percent per year from 2015 to 2035	■ Low-carbon fuel standard ■ Clean fuel standard ■ Advanced biofuels standard ■ Infrastructure incentives	States accounting for 15 percent of transportation fuel consumption implement measures to achieve a reduction.	States accounting for 25 percent of transportation fuel consumption implement measures to achieve a reduction.	States accounting for 35 percent of transportation fuel consumption implement measures to achieve a reduction.
Vehicle miles traveled reductions of 0.5 or 1 percent per year from 2016 to 2035	■ Smart growth ■ Improved public transit ■ Pedestrian and biking infrastructure ■ Improved traffic systems operations	States accounting for 15 percent of GHG emissions from light-duty vehicles implement measures to achieve a reduction of 0.5 percent per year.	States accounting for 25 percent of GHG emissions from light-duty vehicles implement measures to achieve a reduction of 0.5 percent per year.	States accounting for 35 percent of GHG emissions from light-duty vehicles implement measures to achieve a reduction of 1 percent per year.

This is on the conservative end of the range found in the state programs under way. Therefore, in our go-getter scenario we assume that states reduce VMT 1 percent per year. We assume that these policies and programs are implemented by states accounting for 15, 25, and 35 percent of GHG emissions from light-duty vehicles in our lackluster, middle-of-the-road, and go-getter scenarios, respectively.

C. ENERGY EFFICIENCY

Energy efficiency measures avoid the need to use fossil fuels and save consumers money, creating significant economic benefits.[19] States are on the front lines in designing and implementing programs to enhance energy efficiency, both for end-use electricity and heating fuels. Our analysis projects the emissions reductions states may achieve implementing energy efficiency programs, building codes, and the increased penetration of combined heat and power. Each type of measure is outlined below.

1. Electricity Savings

States have been the primary drivers of end-use energy efficiency within their borders. Many states have implemented energy efficiency portfolio standards and/or other ratepayer-funded programs to fund energy efficiency investments. Other states have sought to integrate energy efficiency into the process for procuring new generation resources (e.g., in the context of long-term resource planning), so that energy efficiency can compete as a viable alternative to more traditional generating resources.

To project potential emissions reductions from increased state-level energy efficiency policies, we made different assumptions about states with and without such policies. We assume that some states with and without existing energy efficiency targets adopt policies and programs that lead to electricity savings beginning in 2015. Both the rate of savings and the number of states covered varies across the scenarios, as shown in Table 8.

2. Natural Gas Savings

A number of states have also begun to implement energy efficiency programs targeted at natural gas consumption. These programs can resemble those for electricity savings, taking the form of energy efficiency portfolio standards or system benefit charges. As with the electricity savings scenarios, we assume that some states with targets increase those targets, and that some states without targets implement those targets. The scenarios are shown in Table 8.

3. Improving Building Performance

States and municipalities are generally responsible for adopting and updating state and local building energy codes, which apply to new construction and major renovations. Responsibility for enforcing these codes is part of the states' police powers. In our lackluster scenario, we assume that states accounting for 10 percent of the energy consumed by the building sector implement more ambitious building codes. In our middle-of-the-road and go-getter scenarios, we assume that states accounting for 30 and 50 percent of the energy consumed by the building sector implement more ambitious building codes, respectively.

4. Increased Penetration of Combined Heat and Power

The U.S. electricity system is designed to accommodate large central station power plants located away from the electricity customers. Fossil-fuel generating plants operate at 30 to 60 percent efficiency, wasting significant energy in unused heat from the combustion process. Combined heat and power (CHP), or cogeneration, is a form of distributed generation located at or very near end-use customers that captures and puts waste heat to beneficial use.

States have been at the forefront in driving the spread of CHP. They have done so through a variety of policies, including standard interconnection rules, reduced standby rates, net metering policies, friendly air quality regulations (such as output-based emissions regulations), technical assistance programs, and various financial incentives.[20] In our lackluster, middle-of-the-road, and go-getter scenarios, we assume that state action results in deployment of an additional 10, 20, and 40 GW of new CHP by 2025, respectively, beyond business-as-usual projections.[21]

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19. *The Long-Term Energy Efficiency Potential: What the Evidence Suggests.* American Council for an Energy Efficient Economy, Research Report E121, January 2012. Accessible at: < http://www.aceee.org/research-report/e121>.
20. *Challenges Facing Combined Heat and Power Today: A State-by-State Assessment.* ACEEE Report Number IE111, September 2011.
21. In the go-getter scenario, we assume that state action results in deployment of 27 GW of CHP in 2020, in addition to the 13 GW built into our business-as-usual projections. Combined, they result in CHP deployment consistent with the executive order target of 40 GW of new CHP by 2020.

TABLE 8 State Energy Efficiency Measures

ACTION	POLICIES AND PROGRAMS DRIVING ACTION	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Electricity savings from states with EE targets	■ Energy efficiency resource standards ■ System benefit charge funds or other funds ■ Least-cost procurement requirements	States responsible for 75 percent of electricity consumption that have annual energy efficiency targets below 1.5 percent increase their annual target to 1.5 percent from 2015 to 2035.	States responsible for 75 percent of electricity consumption that have annual energy efficiency targets below 2 percent increase their annual targets to 2 percent from 2015 to 2035.	States responsible for 75 percent of electricity consumption that have annual energy efficiency targets below 2.5 percent increase their annual targets to 2.5 percent from 2015 to 2035.
Electricity savings from states without EE targets		States responsible for 25 percent of electricity consumption achieve electricity savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 25 percent of electricity consumption achieve electricity savings of 1.5 percent of total demand per year from 2015 to 2035.	States responsible for 50 percent of electricity consumption achieve electricity savings of 1.5 percent of total demand per year from 2015 to 2035.
Natural gas savings from states with EE targets	■ Energy efficiency resource standards ■ System benefit charge funds or other funds	States responsible for 25 percent of natural gas consumption that have energy efficiency targets below 1 percent achieve savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 50 percent of natural gas consumption that have energy efficiency targets below 1 percent achieve savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 75 percent of natural gas consumption that have energy efficiency targets below 1.5 percent achieve savings of 1.5 percent of total demand per year from 2015 to 2035.
Natural gas savings from states without EE targets		States responsible for 10 percent of natural gas consumption achieve natural gas savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 25 percent of natural gas consumption achieve natural gas savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 50 percent of natural gas consumption achieve natural gas savings of 1.5 percent of total demand per year from 2015 to 2035.
Reduced energy consumption in buildings	■ Commercial and residential building codes ■ Financial incentives	States accounting for 10 percent of the energy consumed by the building sector implement more ambitious building codes.	States accounting for 30 percent of the energy consumed by the building sector implement more ambitious building codes.	States accounting for 50 percent of the energy consumed by the building sector implement more ambitious building codes.
Increased penetration of combined heat and power	■ Standard interconnection rules ■ Reduced standby rates ■ Net metering policies ■ Output-based emissions regulations	State action results in deployment of an additional 10 GW of new CHP beyond business-as-usual projections by 2025.	State action results in deployment of an additional 20 GW of new CHP beyond business-as-usual projections by 2025.	State action results in deployment of an additional 40 GW of new CHP beyond business-as-usual projections by 2025.

TABLE 9 State Renewable Energy Policies

	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Increased renewables from states with renewables targets	States responsible for 25 percent of electricity consumption increase their renewable generation by 1 percent annually after the last year for which a standard is set.	States responsible for 50 percent of electricity consumption increase their renewable generation by 1 percent annually after the last year for which a standard is set.	States responsible for 75 percent of electricity consumption increase their renewable generation by 1 percent annually after the last year for which a standard is set.
Increased renewables from states without renewables targets	States responsible for 10 percent of electricity consumption increase their renewable generation 0.5 percent annually beginning in 2015.	States responsible for 25 percent of electricity consumption increase their renewable generation 0.5 percent annually beginning in 2015.	States responsible for 50 percent of electricity consumption increase their renewable generation 0.5 percent annually beginning in 2015.

D. RENEWABLE ELECTRICITY GENERATION

Similar to energy efficiency, state policies have been major drivers of renewable electricity generation in the United States. Twenty-nine states and the District of Columbia have renewable energy portfolio standards or advanced energy standards. Numerous states also support distributed or customer-sited renewables as part of their RPS or through other ratepayer-funded programs. In order to capture the reductions possible from states taking new or additional action to increase renewable generation serving their residents, we assumed that a certain number of states without renewable energy targets add 0.5 percent renewables per year beginning in 2015. For those states that already have renewables targets, we assumed they continued to add 1 percent a year to those targets after the target is achieved. Table 9 provides details on differences across the scenarios.

E. WHEN STATES TAKE A MORE EXPANSIVE TACK

States have broad authority to regulate energy sources and emissions within their boundaries. They may therefore implement many of the same policies that we ascribe to the federal government in the federal analysis. In determining what reductions states might make in the future, the analysis considers not only traditional state energy policies, but also scenarios in which states decide to approach carbon pollution more expansively. For example, the states participating in the Northeast and Mid-Atlantic Regional Greenhouse Gas Initiative (RGGI) have chosen to design and implement a multistate cap-and-trade program to reduce carbon pollution from power plants in their states. Other states could join them, or take alternative approaches to reducing carbon pollution from power plants. The most significant example of this is California, which has taken an expansive approach to reducing GHGs in its Global Warming Solutions Act of 2006 and the regulations adopted under that law.

Because it is hard to predict which other states, if any, will pursue ambitious standards for greenhouse gases, we modeled more broad-based action by assuming a portion of total national emissions within each sector would be covered by the reduction measures analyzed for the federal government in section IV above. In the lackluster, middle-of-the-road, and go-getter scenarios, we assume these measures are adopted by states accounting for 10, 25, and 50 percent of GHG emissions from a given sector, respectively.

These approaches include state action for all sectors discussed in the federal action section, except for those policies that are ill-suited for state implementation. We deemed policies that eliminate HFCs, regulate off-highway vehicles, adopt appliance and equipment efficiency standards where federal standards already exist, or regulate aviation to be ill-suited to state implementation because they are preempted by federal law.

It is important to note that we vary both the number of states taking action and the level of ambition they each pursue. In all sectors, the level of ambition pursued is the same as the ambition defined in the federal scenario described in Section IV. Therefore, in our lackluster scenario for power plants, we assume states accounting for 10 percent of GHG emissions from the power sector

implement policies equivalent to the lackluster scenario for federal action. In our go-getter scenario, we assume states accounting for 50 percent of GHG emissions from the power sector implement policies equivalent to the go-getter scenario for federal action.

VI. Conclusion: Finding Our Way to a Low-Carbon Future

The enormous economic and social costs of climate disruption are increasingly evident in the United States. Yet the urgency conveyed by the mounting evidence is not yet reflected in U.S. federal and state actions or climate policies. The United States is not currently on path to meet its international pledge to reduce GHG emissions to 17 percent below 2005 levels by 2020, though it could meet this goal with go-getter action by the U.S. Administration under current laws. In order to achieve adequate mid-century reductions, it appears almost certain that the U.S. Congress will eventually have to enact new legislation aimed at getting deep reductions. Ultimately, a cooperative approach bringing together Congress, states, and the executive branch will be necessary for the United States to do its part.

States can contribute to U.S. emissions reductions, both through state-level transportation, energy efficiency, and renewables programs, as well as through new legislative efforts to initiate a wide array of other policies aimed at reducing GHGs. It appears unlikely that state actions alone will put the United States on the necessary course. However, they can help complement federal action, and can enable the United States to meet its 17 percent target if federal agencies fail to pursue go-getter-level action.

KEY RECOMMENDATIONS

- In the short term, federal agencies and the states should aggressively move forward with a "go-getter" emissions reduction scenario. This will necessitate taking action in the following key areas that present the greatest opportunities for GHG emissions reductions through 2020:
  - EPA and the states should focus on achieving significant reductions in carbon pollution from power plants and natural gas systems.
    - For power plants, EPA should finalize its proposed greenhouse gas emissions standards for new power plants and should move ahead with flexible and ambitious standards for existing power plants. States should move ahead with measures to reduce emissions from the power sector, such as increasing the use of renewable power and cogeneration and reducing electricity demand.
    - For natural gas systems, EPA and the states should propose rules that address methane as a greenhouse gas pollutant, which can result in significant reduction of methane leakage throughout the natural gas life cycle. Such rules would complement the volatile organic compound and air toxics rules established in 2012 for natural gas systems that have the co-benefit of reducing methane leakage.
  - The State Department should continue to seek reductions in hydrofluorocarbons through amendments to the Montreal Protocol. But, in the meantime, EPA should begin reducing consumption in the United States using its authority under the Clean Air Act.
  - EPA and the states should also work to improve energy efficiency in the residential, commercial, and industrial sectors.
- Over time, we will need to see reductions from all sectors, and the Administration should use its existing authorities to achieve go-getter-level reductions across the economy.
- Even with go-getter-level action, however, reductions will fall short of the long-term targets necessary to avoid the worst impacts of climate disruption. As a result, congressional action will be necessary.

BOX 4 Risks and Uncertainties

Uncertainties associated with the methods and results of this analysis include:

- **Uncertainties inherent in the models.** As with any modeling analysis of this sort, there is significant uncertainty in projecting the future. The analysis relies heavily on the Energy Information Administration's *Annual Energy Outlook 2012*, which attempts to project energy and emissions trends into the future based on a number of assumptions, including likely fuel costs, economic activity, and source turnover rates. There are also considerable uncertainties in the estimates of fugitive emissions from natural gas systems. All projections are only as good as the assumptions that go into them and the quality of the data modeled.

- **Regulatory impetus.** As the different scenarios suggest, a major uncertainty in the analysis is whether the federal administration will carry out the regulatory actions in a manner sufficient to achieve the reductions that available studies suggest are technically feasible. The lackluster, middle-of-the-road, and go-getter scenarios stand for different levels of regulatory ambition. The go-getter scenario, it should be emphasized, will require steadfast resolve on the part of the Administration and the states.

- **Congressional action.** Federal agencies depend on the U.S. Congress for their budgets. In order to carry out a series of new regulatory actions, federal agencies will require sufficient resources through the annual budget process. In addition, it should be noted that existing authorities can be curtailed through new legislation.

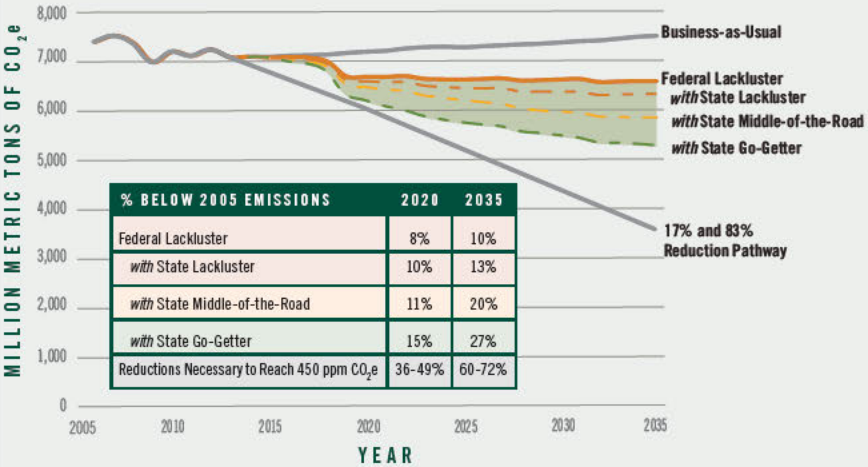
- **Legal risk.** The assumptions made in this analysis were informed by sound legal analysis and vetted with legal experts in the field. Nevertheless, when federal agencies take new actions under existing statutes, the new actions are often challenged in federal court on the grounds that the agency has exceeded the authority originally granted to it in the statute. It is impossible to predict with any precision whether the challenges will be successful.

- **Technological development.** The results modeled depend in part on the development and deployment of new technologies over time. Indeed, many of the regulatory policies are technology-based and must be revised by federal agencies as technology progresses. If technologies emerge rapidly, emissions reductions are more likely. Conversely, if technologies are slow to appear, emissions reductions will slow. This uncertainty is especially important further out into the future.

Supplemental Figures

BOX S-1 Greenhouse Gas Emissions Reductions from State Action Coupled with Lackluster Federal Action

FIGURE S-1 Projected U.S Emissions with State Action Coupled with Lackluster Federal Action



% BELOW 2005 EMISSIONS	2020	2035
Federal Lackluster	8%	10%
with State Lackluster	10%	13%
with State Middle-of-the-Road	11%	20%
with State Go-Getter	15%	27%
Reductions Necessary to Reach 450 ppm CO_2e	36-49%	60-72%

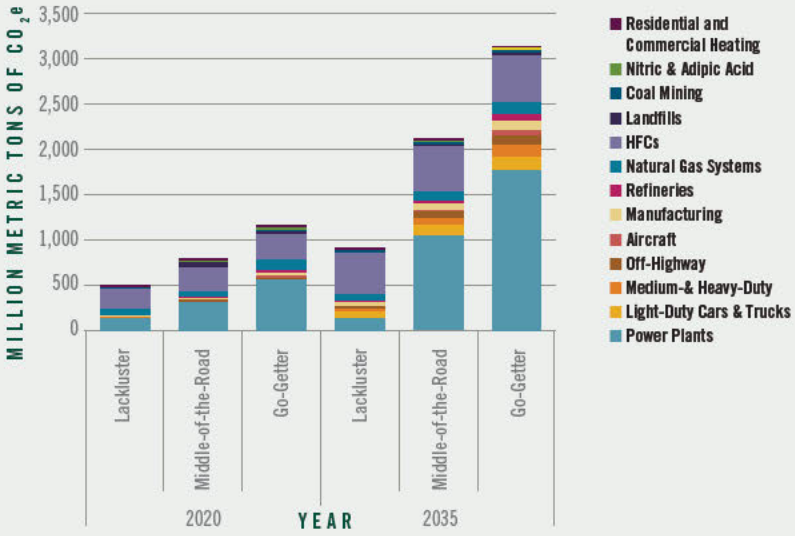
Note: Figure depicts changes in consumption of HFCs.

If the U.S. Administration pursues a lackluster effort, go-getter state action will not be sufficient to make up the emissions gap and reduce GHG emissions 17 percent below 2005 levels by 2020. However, as shown in Figure 2, the 17 percent GHG reduction goal can be achieved with a state go-getter effort along with middle-of-the-road federal action. State action with go-getter federal action is not shown, as it does not provide significant reductions above and beyond other combinations of state and federal action that were considered as a result of the way the scenarios are defined.

BOX S-2 Greenhouse Gas Emissions Reductions from Federal Action

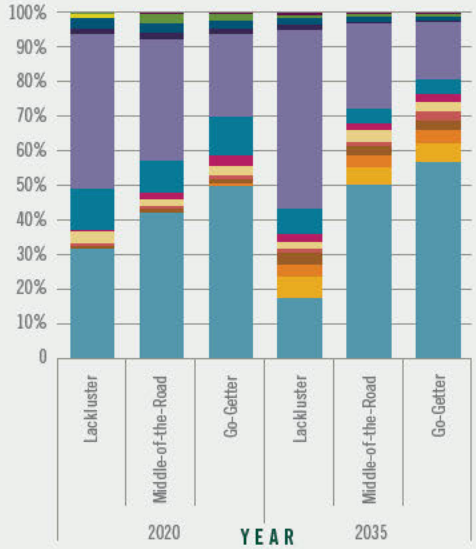
The majority of potential GHG benefits come from actions taken in the power sector, energy efficiency improvements, reducing HFC consumption, and reducing methane emissions from natural gas systems. These actions represent between 80 and 93 percent of potential GHG reductions across all scenarios in 2020 and 2035, and are necessary to achieve a 17 percent reduction below 2005 GHG emissions levels.

FIGURE S-2 Greenhouse Gas Emissions Reductions from Federal Action, in million metric tons



Note: Figure depicts changes in consumption of HFCs.

FIGURE S-3 Greenhouse Gas Emissions Reductions from Federal Action, as a percent of total reductions



Note: Figure depicts changes in consumption of HFCs.

BOX S-3 Greenhouse Gas Emissions Reductions from State Action Only

Improvements in the power sector largely drive reductions in all of the scenarios that examine the impact of state actions without any new federal actions. This is accomplished through a combination of GHG performance standards, renewable and energy efficiency standards, building codes, and policies to promote combined heat and power. In our scenarios those actions can alleviate the demand for up to 1,280 terra watt-hours of conventional sources of electricity in 2035. This is offset to a limited extent through increased vehicle electrification, which increases demand by up to 66 terra watt-hours of electricity in 2035.

States can implement many of the same types of policies as federal agencies. They can also take additional actions that increase electric efficiency, renewable electricity generation, building performance, and combined heat and power penetration.

However, states are less well-equipped to reduce HFC consumption, adopt appliance and equipment efficiency standards where federal standards already exist, and to drive reductions in GHG emissions from off-highway vehicles and aviation. As a result, under our scenarios, state action alone is insufficient to achieve the near-term and long-term GHG reduction targets.

FIGURE S-4 State Actions that Affect Electricity Supply and Demand

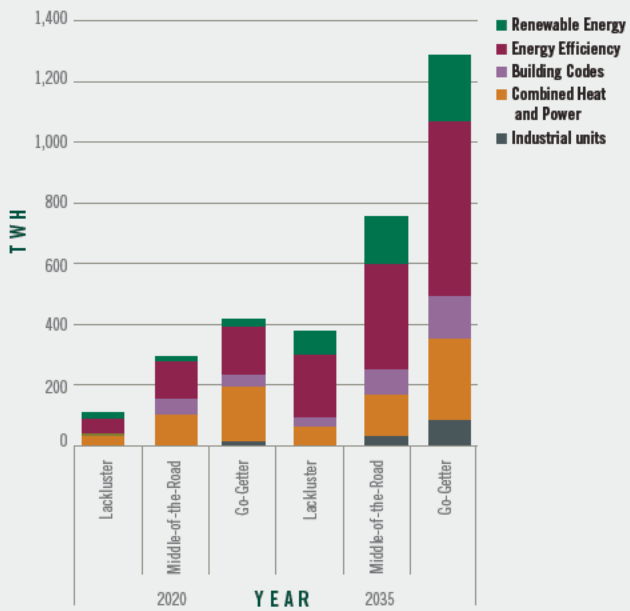


FIGURE S-5 Greenhouse Gas Emissions Reductions from State Action, in million metric tons

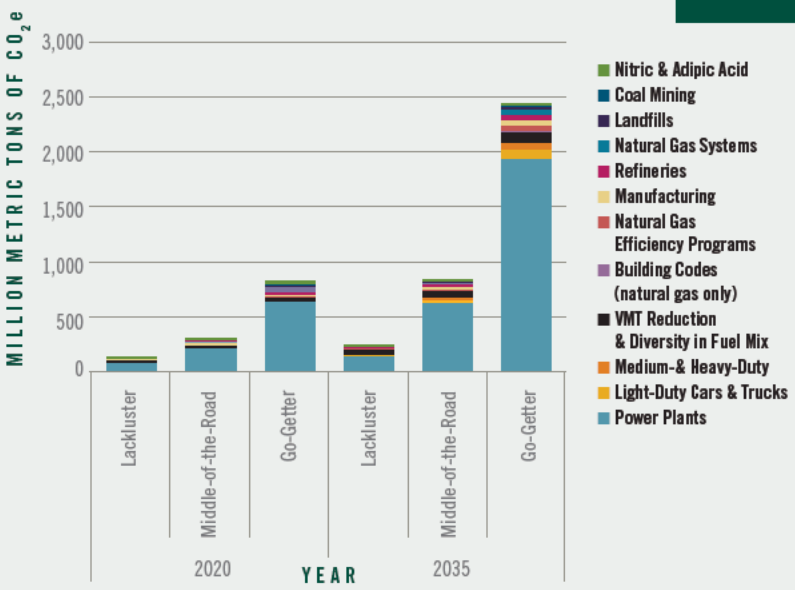
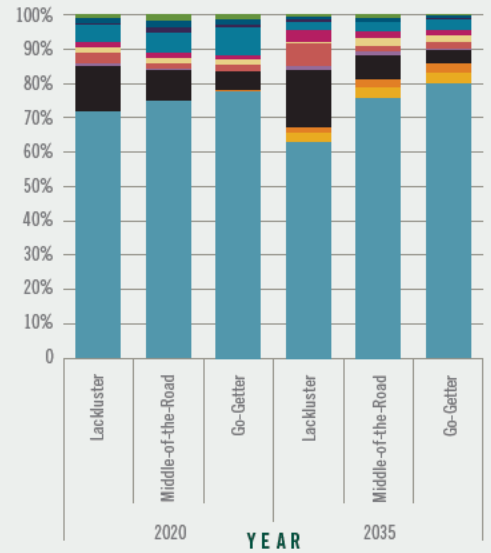


FIGURE S-6 Greenhouse Gas Emissions Reductions from State Action, as a percent of total reductions from state actions



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WORLD
RESOURCES
INSTITUTE

10 G Street, NE (Suite 800)
Washington, DC 20002
USA
Tel: (1 202) 729 76 00
Fax: (1 202) 729 76 10
www.wri.org

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SUMMARY FOR POLICYMAKERS

Can The U.S. Get There From Here?

Using Existing Federal Laws and State Action to Reduce Greenhouse Gas Emissions

NICHOLAS M. BIANCO
FRANZ T. LITZ
KRISTIN IGUSKY MEEK
REBECCA GASPER

About the Authors

Nicholas Bianco leads WRI's efforts with U.S. states and U.S. federal agencies as they work together and in parallel to develop programs to reduce greenhouse gas emissions. His areas of research include the role of states in future federal climate programs; the regulation of greenhouse gas emissions via existing regulatory authorities; market-based pollution control programs; and stacking of payments for ecosystem services (e.g., greenhouse gas offsets). Nicholas previously worked with the Massachusetts Department of Environmental Protection on climate change and air quality programs. While there, he worked on several market-based air quality and climate change programs, including the Regional Greenhouse Gas Initiative (RGGI), a regional carbon dioxide cap-and-trade program for the power sector. Contact: nbianco@wri.org.

Kristin Meek is an Associate in the Climate and Energy Program at the World Resources Institute. She supports WRI's efforts with U.S. states and U.S. federal agencies as they work together and in parallel to develop programs to reduce greenhouse gas emissions. Prior to joining WRI, Kristin worked with SAIC's climate change services team, where she focused on a wide range of GHG management projects for federal government agencies, local governments, and private sector entities. Projects included supporting the U.S. Energy Information Administration's national inventory of greenhouse gases, EPA's Greenhouse Gas Reporting Program and Climate Leaders Program, researching issues related to new and existing carbon offset project types, and developing community-level GHG inventories for cities and counties across the country. Contact: kmeek@wri.org.

Rebecca Gasper is a Research Assistant in WRI's Climate and Energy Program. She supports WRI's efforts with U.S. states and U.S. federal agencies as they work together and in parallel to develop programs to reduce greenhouse gas emissions. Before joining WRI, Rebecca worked at the Center for Integrative Research (CIER) at the University of Maryland. She worked primarily on climate change mitigation and adaptation at the regional and international levels. She also has experience supporting state efforts to develop water quality markets. Contact: rgasper@wri.org.

Franz Litz is the Executive Director of the Pace Energy & Climate Center, a legal and policy think tank, and Professor of Energy and Climate Change Law in Pace Law School's top-ranked environmental law program. Franz leads his Center's work at the state, regional, national, and international levels on climate change, energy efficiency, renewable energy, transportation, and community energy. Franz is an expert on the federal Clean Air Act, state-level climate and energy policies, and emissions trading. Franz actively convenes officials from U.S. states and Canadian provinces cooperating on energy and climate change policy issues. He also frequently brings stakeholders from diverse viewpoints together to engage policy makers on difficult energy and climate policy issues. Before assuming his leadership role at the Pace Energy & Climate Center in 2011, Franz was a senior fellow at the World Resources Institute in Washington, DC. He led WRI's state and regional climate change initiatives, as well as WRI's engagement with the U.S. EPA. Contact: flitz@law.pace.edu.

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Summary for Policymakers

I. Introduction

CLIMATE CHANGE IMPACTS IN THE UNITED States are increasingly evident and come with steep economic and social costs. The frequency and intensity of extreme weather events has increased in recent years, bringing record-breaking heat, heavy precipitation, coastal flooding, severe droughts, and damaging wildfires.[1] According to the National Oceanic and Atmospheric Administration (NOAA), weather-related damages in the United States were $60 billion in 2011, and are expected to be significantly greater in 2012.[2]

The mounting costs convey an unmistakable urgency to address climate change by reducing greenhouse gas emissions (GHGs). This report examines pathways for GHG reductions in the United States through actions taken at the federal and state levels without the need for new legislation from the U.S. Congress.

This report answers a number of key questions:

- What are current U.S. GHG emissions? Without further action to reduce emissions, what are they projected to be in 2020 and 2035?
- What legal and policy tools exist under current federal law to achieve emissions reductions? What additional actions can states pursue to contribute to emissions reductions?
- Which legal and policy tools at the state and federal levels offer the greatest potential for achieving emissions reductions in the near- and mid-term?
- Can the U.S. meet its international commitment to reduce emissions 17 percent below 2005 levels by 2020 without new federal legislation?
- Can the U.S. put itself on a trajectory to meet or exceed its long-term commitment of reducing emissions by more than 80 percent below 2005 levels by 2050, without new legislation from Congress?

The answers to these questions are set out in detail in the body of this report. Two significant findings stand out. First, it is clear the U.S. is not currently on track to meet its 2020 reduction pledge, however, this target is achievable through implementation of strong new federal measures to reduce emissions using existing legal authorities. Second, the mid-century goal of reducing emissions by 80 percent or more appears unattainable using existing authorities. New legislation will eventually be needed.

BOX 1 Key Conclusions and Recommendations

1. Without new action by the U.S. Administration, greenhouse gas (GHG) emissions will increase over time. The U.S. will fail to make the deep emissions reductions needed in coming decades, and will not meet its international commitment to reduce GHG emissions by 17 percent below 2005 levels by 2020.
2. The U.S. EPA should immediately pursue "go-getter" emissions reductions from power plants and natural gas systems using its authority under the Clean Air Act. These two sectors represent two of the top opportunities for substantial GHG reductions between now and 2035.
3. The U.S. Administration should pursue hydrofluorocarbon (HFC) reductions through both the Montreal Protocol process and under its independent Clean Air Act authority. Eliminating HFCs represents the biggest opportunity for GHG emissions reductions behind power plants.
4. U.S. states should complement federal actions to reduce emissions through state energy efficiency, renewables, transportation, and other actions. States can augment federal reductions.
5. New federal legislation will eventually be needed, because even go-getter action by federal and state governments will probably fail to achieve the more than 80 percent GHG emissions reductions necessary to fend off the most deleterious impacts of climate change.

Potential reductions in the United Stated were assessed in a 2010 WRI Report entitled *Reducing Greenhouse Gas Emissions in the United States Using Existing Federal Authorities and State Action.*[3] This updated report revisits these questions, taking into account the latest GHG emissions information and recent actions taken at the federal and state levels. Since the publication of the last report, notable factors influencing U.S. GHG emissions include:

- Reduced global economic growth, including slower growth of economic output in the United States;
- Increased fuel switching from coal to natural gas in the generation of electricity; and
- Reduced demand for transportation fuel, partly as a result of higher petroleum prices, lower miles traveled, and more efficient vehicles.

These factors and others, including the issuance of new motor vehicle emissions and fuel efficiency standards for cars and trucks, will reduce greenhouse gas emissions. However, even with these factors, we project that total U.S. emissions will experience relatively modest growth over the coming decades.

At the 2009 Conference of the Parties of the United Nations Framework Convention on Climate Change in Copenhagen, Denmark, President Obama made a commitment to reduce U.S. greenhouse gas emissions in the range of 17 percent below 2005 levels by 2020. Despite the inability of Congress to pass comprehensive climate change legislation, the Administration has re-committed to the Copenhagen pledge and taken some steps to reduce emissions using authority under existing laws.[4] While the Administration has reaffirmed its commitment to this target, it has not yet matched that commitment with adequate action. Though significant progress has been made in some areas since our 2010 analysis, most notably with the vehicle rules, key opportunities, such as reductions from power plants, remain untapped. The fact that the U.S. remains far from the "go-getter" emissions trajectory laid out in our 2010 report reinforces the urgency for taking strong action now.

Although the U.S. emissions reduction commitment for 2020 represents an important step toward reducing GHG emissions, much greater reductions are necessary. According to the Intergovernmental Panel on Climate Change, industrialized countries need to collectively reduce emissions between 25 and 40 percent below 1990 levels by 2020 and 80 to 95 percent below 1990 levels by 2050 in order to keep global average temperatures from increasing more than 2 degrees Celsius above preindustrial levels. This report evaluates the potential for meeting the 17 percent commitment and the deeper longer-term reduction pathway necessary to avoid the worst impacts of climate change.

BOX 2 Ambition Matters

Within the bounds of what is legally and technically possible, the single most important factor influencing emissions reductions is political and policy ambition. This analysis considers three levels of ambition:

- **Lackluster.** This is low ambition and represents the results of actions of lowest cost or least optimistic technical achievement.
- **Middle-of-the-Road.** This is mid-level ambition and represents the results of actions of moderate cost and moderately optimistic technical achievement.
- **Go-Getter.** This is the highest ambition achievable without new congressional action. It represents the results of actions of higher cost or most optimistic technical achievement.

The term "go-getter" is not meant to suggest the actions are adequate to achieve U.S. reduction targets or reductions the science suggests are necessary to ward off the worst effects of climate change.

1. *America's Climate Choices: Panel on Advancing the Science of Climate Change.* National Research Council, 2010.ISBN 978-0-309-14588-6. Accessible at: <http://www.nap.edu/catalog.php?record_id=12782>.
2. *Preliminary Info on 2012 U.S. Billion-Dollar Extreme Weather/ Climate Events.* National Oceanic and Atmospheric Administration. Accessible at: <http://www.ncdc.noaa.gov/news/preliminary-info-2012-us-billion-dollar-extreme-weatherclimate-events>. (Last accessed January 15, 2013)
3. Accessible at: <http://www.wri.org/publication/reducing-ghg-emissions-using-existing-federal-authorities-and-state-action>.
4. Most recently, the U.S. delegation to the Conference of the Parties of the UN Framework Convention on Climate Change in Doha, Qatar, made it clear that the 17 percent pledge is not contingent on new legislation from Congress.

Attaining even the 17 percent reduction goal will require new and ambitious action from the U.S. Administration—ambitious action that must survive court challenges. Real progress depends on numerous actions not yet taken by the U.S. Administration—especially for stationary emissions sources like power plants, natural gas systems, and industry. U.S. states may also need to take action to fill any emissions gaps left by the federal government. Achieving the necessary mid-century reductions will almost certainly require the U.S. Congress to act to achieve the needed reductions.

Section II summarizes the report's key findings, including the range of reductions that are possible and a brief description of the analytical approach. An examination of current emissions in the United States and projected emissions without new actions follows in Section III. Section IV summarizes the sector-by-sector actions the federal government might take under existing laws. Section V summarizes potential state actions. Section VI sets out summary conclusions. Two detailed appendixes set out the assumptions and methodologies for the federal and state analyses. The picture revealed is one of significant potential greenhouse gas emissions reductions, provided there is sufficient political will to take strong action.

II. Charting a Path Forward in the U.S.: Summary of Key Findings

This report identifies significant potential for GHG emissions reductions by the U.S. Administration under current laws and through state-level actions, as well as the limitations of current tools. The reductions actually achieved will depend on the level of ambition brought to the effort by the U.S. Administration, including executive agencies such as the U.S. Environmental Protection Agency. At the state level, outcomes will depend on the number of states that choose to support renewable energy, energy efficiency, and transportation measures, and to pursue policies that the federal government opts not to pursue or that go beyond the minimum stringency set by the federal government. Key findings are set out below for federal and state actions.[5]

A. FEDERAL GHG REDUCTIONS POSSIBLE WITHOUT NEW LEGISLATION

- Only with "go-getter" ambition by the U.S. Administration can the United States achieve emissions reductions using current law that meet or exceed the Copenhagen commitment to reduce global warming pollution by at least 17 percent below 2005 levels by 2020.[6] With middle-of-the-road ambition, the United States will fall well short of its 17 percent commitment, unless supplemented by go-getter actions by the states.

- Even with go-getter ambition, long-term emissions reductions fall short of the level of reductions necessary to put the United States on pace to reach its long-term reduction goal of reducing emissions 83 percent below 2005 levels by 2050. New congressional legislation is therefore necessary to achieve reductions in line with what the international scientific community agrees is necessary by mid-century in order to stabilize global average temperatures and avert the worst impacts of climate change.

- After taking action to significantly improve motor vehicle fuel efficiency, the U.S. Administration should now apply similar ambition to reducing emissions from a wider range of sources, such as existing power plants, if it is to achieve the needed reductions.

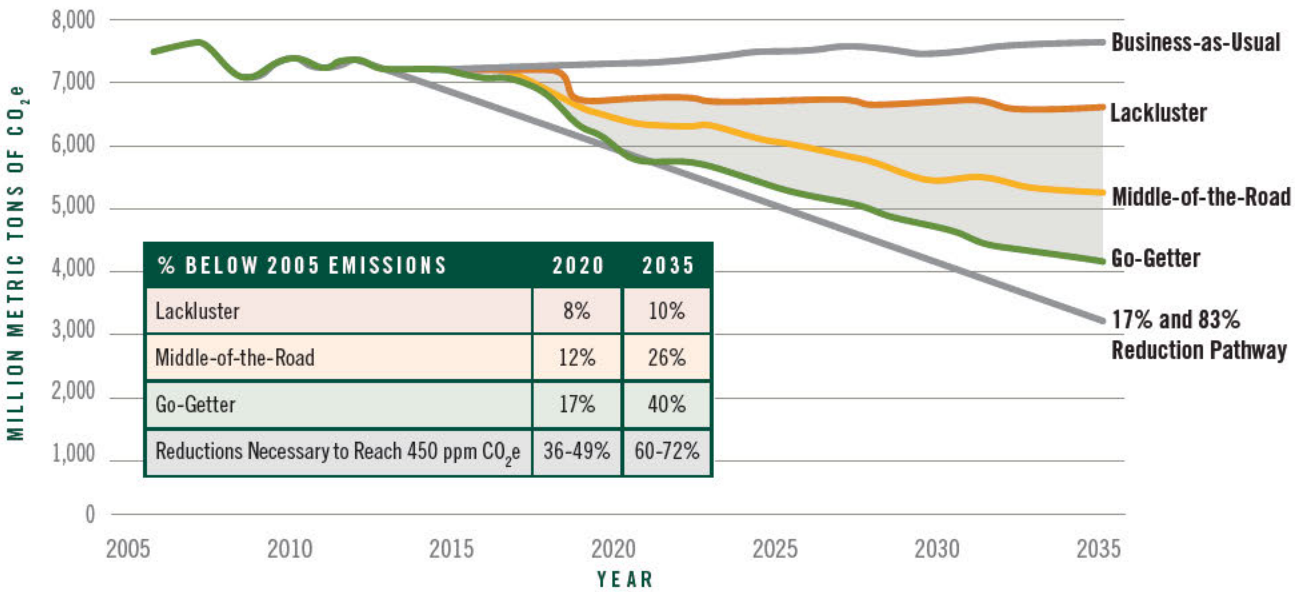
- The greatest projected emissions reduction opportunities by 2020 and beyond come from four federal policy measures. The Administration will need to pursue these opportunities if the United States is to achieve the 17 percent reduction target. Those policies are:

  - standards to reduce carbon pollution from existing power plants (48 percent of total emissions gap between business-as-usual (BAU) and 2020 target);

5. For data sources and an explanation of how expected emissions trends were compiled, please consult the appendixes. For the sake of clarity and brevity, sources are not provided in this summary.

6. The U.S. commitment in Copenhagen calls for reductions in 2020 "in the range of 17 percent [below 2005 levels], in conformity with anticipated U.S. energy and climate legislation." The U.S. submission notes that the ultimate goal of legislation pending at the time was to reduce emissions by 83 percent below 2005 levels in 2050.

FIGURE 1 Projected U.S. Emissions under Different Federal Regulatory Scenarios



% BELOW 2005 EMISSIONS	2020	2035
Lackluster	8%	10%
Middle-of-the-Road	12%	26%
Go-Getter	17%	40%
Reductions Necessary to Reach 450 ppm CO_2e	36-49%	60-72%

Note: The Intergovernmental Panel on Climate Change's (IPCC's) *Fourth Assessment Report* (2007) indicates that industrialized countries need to collectively reduce emissions between 25 and 40 percent below 1990 levels by 2020 and 80 to 95 percent below 1990 levels by 2050 to keep atmospheric concentrations of greenhouse gases from exceeding 450 parts per million of CO_2e and to keep global average temperatures from increasing more than 2 degrees Celsius above pre-industrial levels. This target does not necessarily represent any particular country's share. Due to modeling limitations, this figure depicts HFC consumption, which is generally thought to be equivalent to life-cycle emissions. For this and all other figures, we use the global warming potentials provided in IPCC's *Fourth Assessment Report*. There are some limited exceptions. See Appendix I for more details.

- requirements to phase out the use of certain hydrofluorocarbons (HFCs) (23 percent of total emissions gap between BAU and 2020 target);
- standards to reduce methane emissions from natural gas systems (11 percent of total emissions gap between BAU and 2020 target);[7] and
- actions to improve energy efficiency in the residential, commercial, and industrial sectors (8 percent of total emissions gap between BAU and 2020 target).

B. STATE ACTION COULD HELP THE U.S. MEET NEAR-TERM PLEDGE

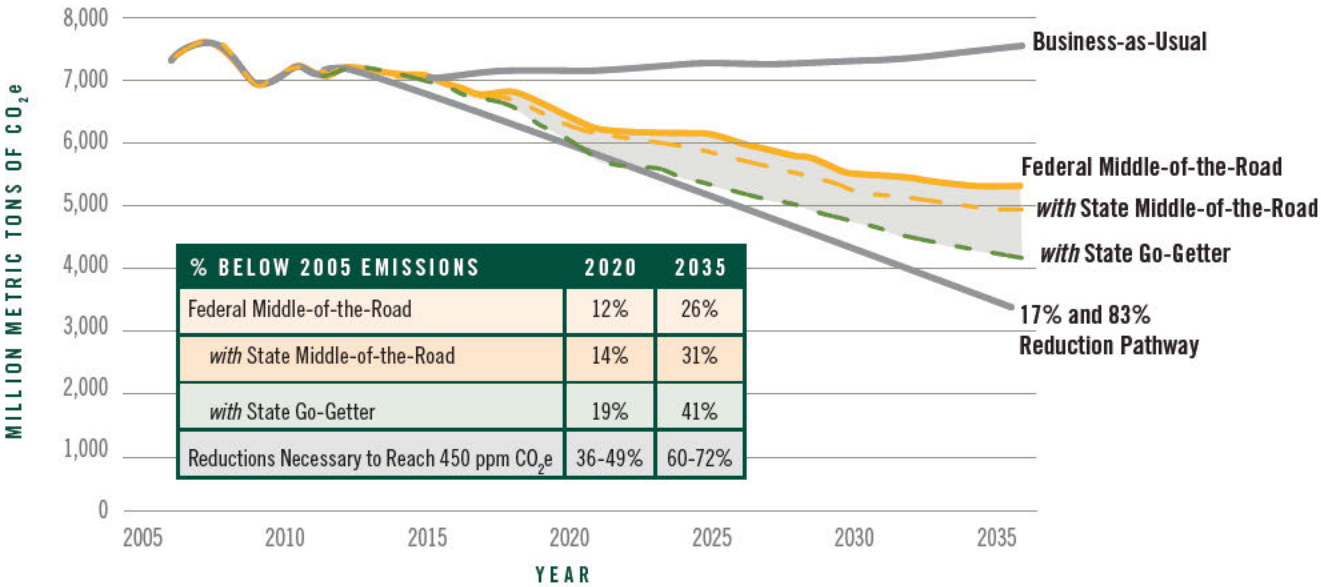
- States can be important contributors to efforts to reduce GHG emissions. If the U.S. Administration were to pursue policies with middle-of-the-road ambition, for example, states could pick up the slack and help the United States reach its goal of reducing emissions 17 percent below 2005 levels by 2020.
- If the federal government pursues a lackluster effort, even a go-getter effort by states is unlikely to achieve the U.S. Administration's 2020 reduction goal.
- Beyond 2020, go-getter state action combined with middle-of-the-road federal action falls short of putting the United States on track to make the mid-century reduction target. This suggests that strong new federal legislative action will be needed.

C. THE STUDY IN BRIEF

This updated report represents the authors' projections of the range of greenhouse gas emissions reductions possible if federal agencies and certain states implement measures to reduce GHG emissions. The report projects the range of reductions possible under current federal law based on a review of published analyses of technical feasibility. The report characterizes three emissions scenarios based on different levels of effort by federal and state actors: "lackluster," "middle-of-the-road," and "go-getter."

7. There is considerable uncertainty with regard to emissions for natural gas systems. The absolute magnitude of abatement opportunities is thus also uncertain. Nevertheless, our analysis suggests that there are important opportunities to reduce emissions from this sector. Those reductions are some of the lowest cost opportunities identified in this analysis.

FIGURE 2 Projected U.S Emissions with State Action Coupled with Middle-of-the-Road Federal Action



% BELOW 2005 EMISSIONS	2020	2035
Federal Middle-of-the-Road	12%	26%
with State Middle-of-the-Road	14%	31%
with State Go-Getter	19%	41%
Reductions Necessary to Reach 450 ppm CO_2e	36-49%	60-72%

Note: Due to modeling limitations, this figure depicts HFC consumption, which is generally thought to be equivalent to life-cycle emissions.

1. Analysis of Federal Actions

The analysis of federal actions is based on a legal assessment of the measures the U.S. Administration, including key federal agencies like EPA, may take under existing federal laws. The federal analysis assumes no new legislation is adopted. Technical studies were used to identify the range of reductions possible within a given sector or subsector. The legally and technically feasible range of reductions was then evaluated based on the level of ambition necessary to achieve a particular point in the range. Where available, we relied more heavily on studies that provided a consideration of the costs needed to achieve a particular outcome to provide a sense of the federal regulatory resolve necessary to achieve those reductions.

Where only a low level of ambition is necessary to achieve a particular technically and legally feasible outcome within a specific sector or subsector, the outcome was judged to be "lackluster." If a high level of ambition is necessary to achieve a particular reduction outcome deemed technically and legally possible, the effort necessary was deemed "go-getter" in our scenarios. "Middle-of-the-road" outcomes were those judged possible with moderate ambition and usually at the middle of the range deemed technically and legally possible.

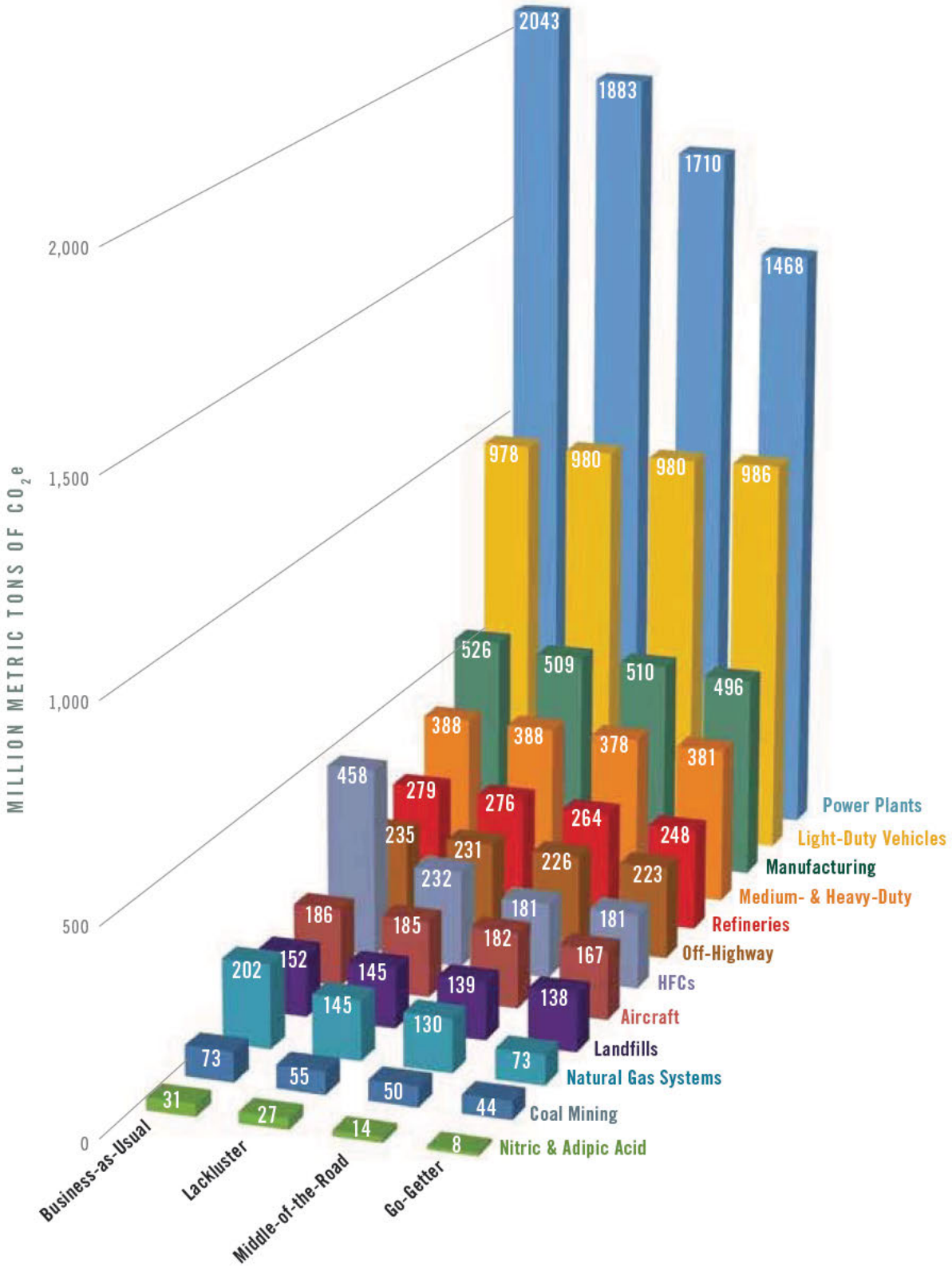
Lackluster emissions reductions from all sectors and subsectors analyzed were aggregated to determine the lackluster emissions pathway through 2035. The same approach was taken for middle-of-the-road and go-getter reductions.

2. Analysis of State Actions

The state analysis has two components: the first considers the impact of states taking action in the absence of federal action; the second considers the impact of states taking action in the presence of varying levels of federal action. In both components we examine the implication of states implementing the same types of policies modeled for the federal government, as well as complementary state-level actions in the transportation, energy efficiency, and renewables areas.

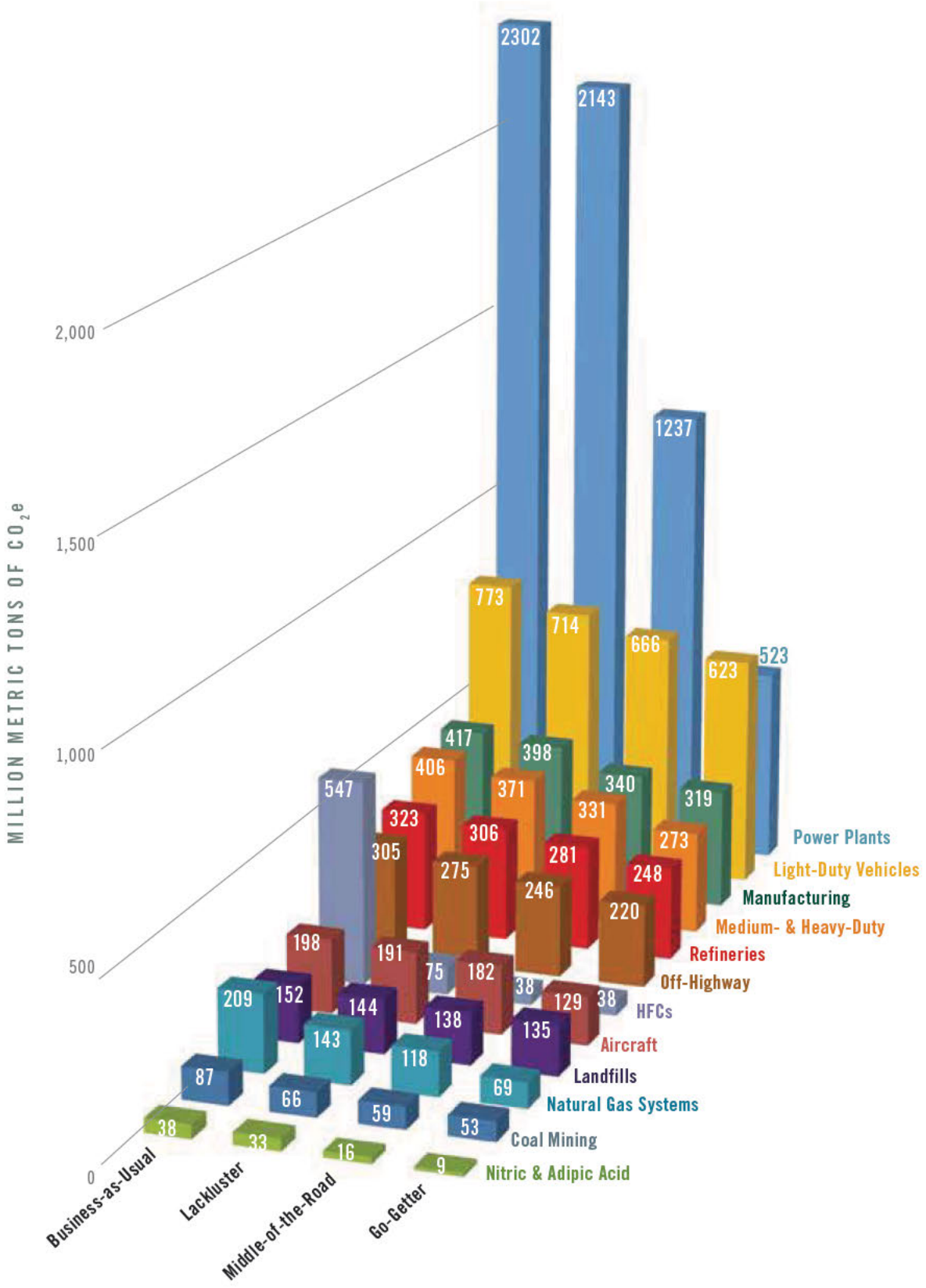
For transportation, the state scenarios consider measures to encourage low carbon fuels and reduce vehicle miles traveled. In the energy efficiency area, measures examined include increased electric end-use energy efficiency, improved building performance, and increased deployment of combined heat and power. For renewables, the analysis adds new and additional renewable energy policies across a certain number of states.

FIGURE 3 Projected U.S. Emissions in 2020 by Sector under Different Federal Regulatory Scenarios



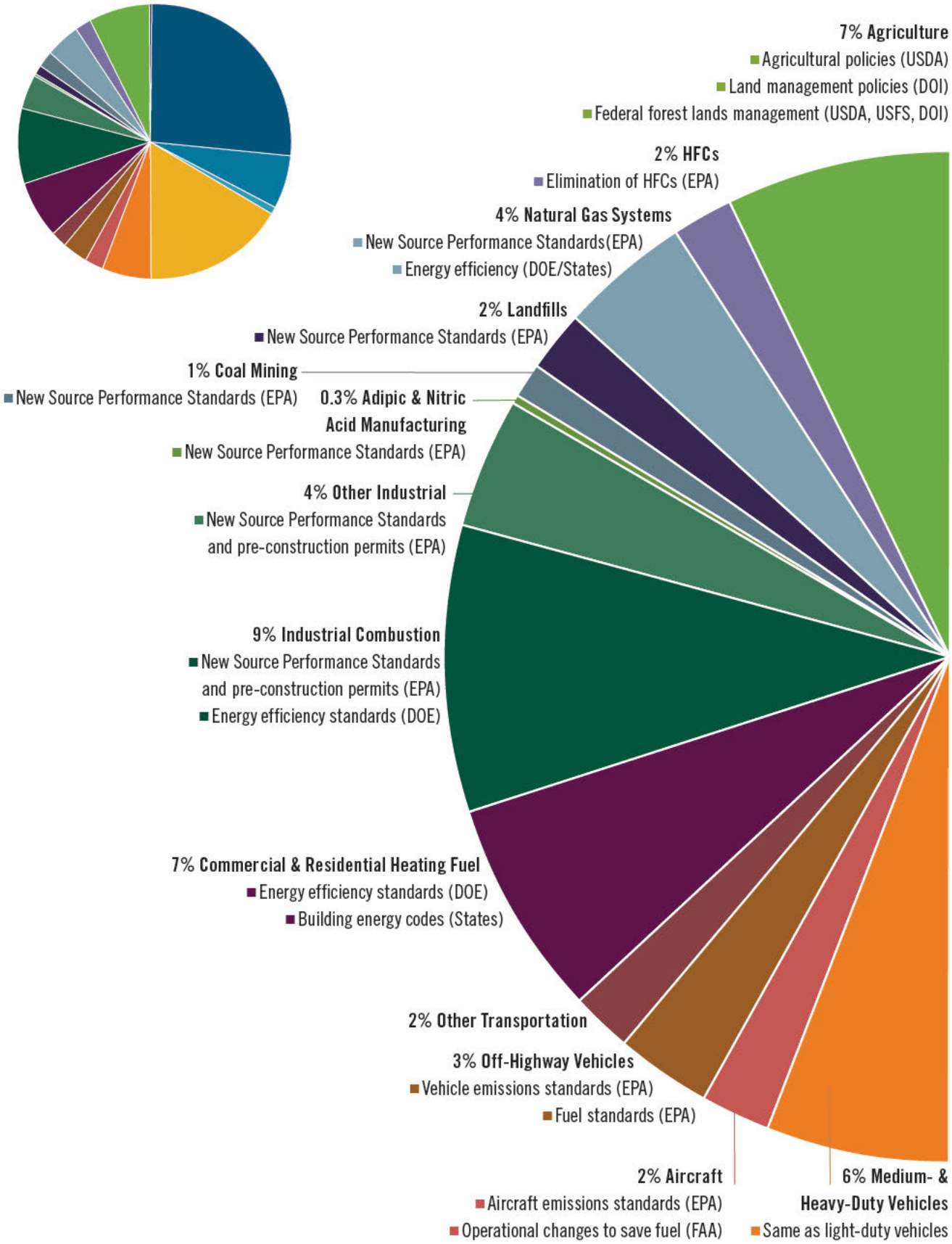
Note: Figure 3 depicts the emissions under the three federal regulatory scenarios by sector or category of sources in 2020. The bars on the left represent business-as-usual emissions. Emissions under the lackluster, middle-of-the-road, and go-getter scenarios are then shown moving from left to right of the business-as-usual emissions. Light-duty vehicle emissions initially increase in our scenarios due to assumptions about vehicle electrification and crediting rates. As shown in Figure 4, these trends reverse in later years. See Appendix I for more information. Due to modeling limitations, this figure depicts HFC consumption, which is generally thought to be equivalent to life-cycle emissions.

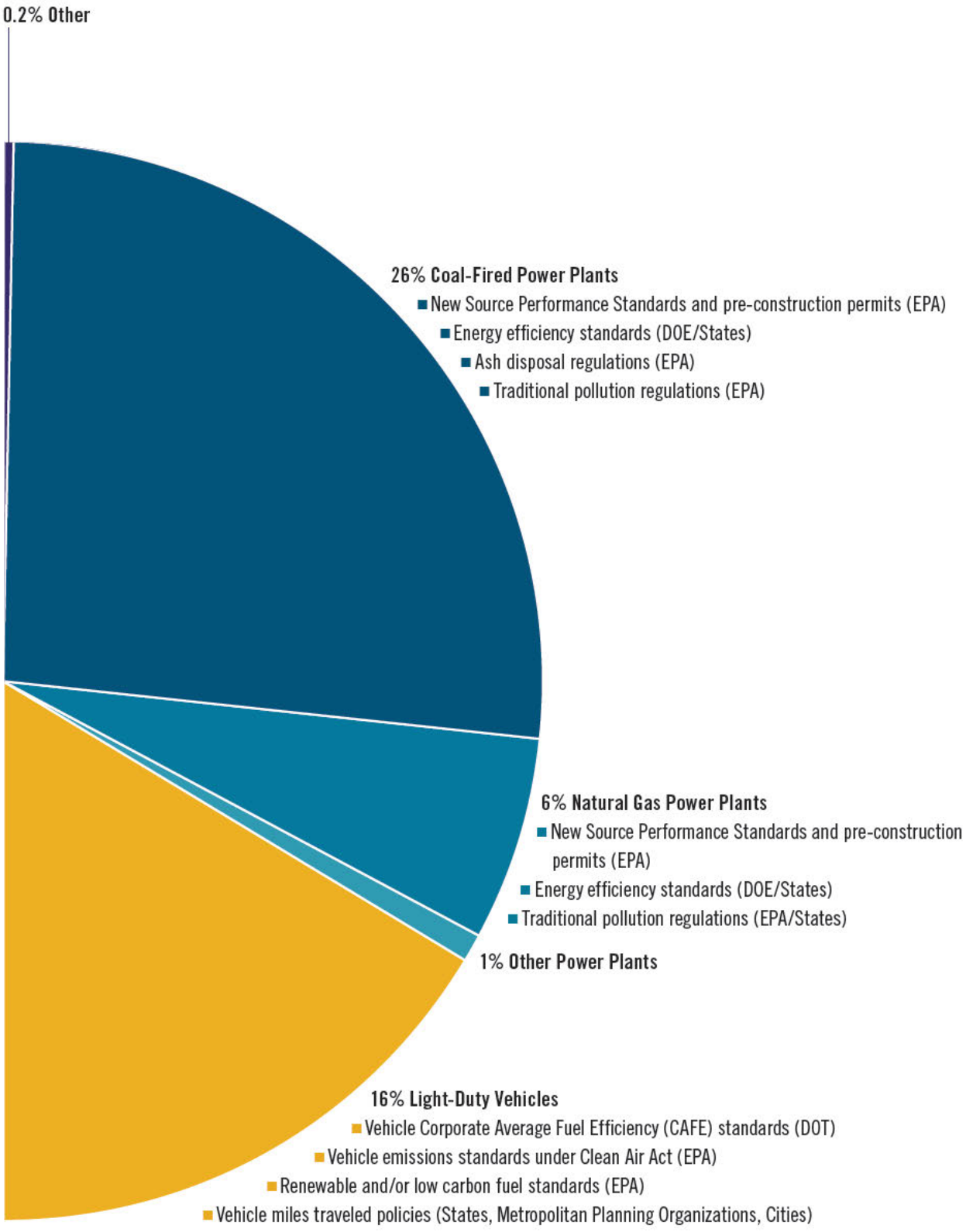
FIGURE 4 Projected U.S. Emissions in 2035 by Sector under Different Federal Regulatory Scenarios



Note: Figure 4 depicts the emissions under the three federal regulatory scenarios by sector or category of sources in 2035. The bars on the left represent the business-as-usual emissions. Emissions under the lackluster, middle-of-the-road, and go-getter scenarios are then shown moving from left to right of the business-as-usual emissions. Due to modeling limitations, this figure depicts HFC consumption, which is generally thought to be equivalent to life-cycle emissions.

FIGURE 5 U.S. Greenhouse Gas Emissions by Sector and Corresponding Federal Authorities, 2010





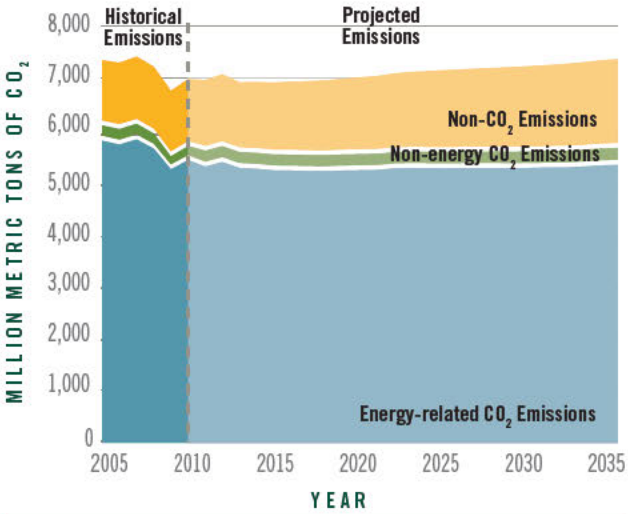
Source: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010*. U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>; *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas*. James Bradbury, Michael Obelter, Laura Draucker, Wen Wang, and Amanda Stevens. World Resources Institute, Working Paper, forthcoming.

Unlike the federal analysis, many of the state measures modeled would require new legislation at the state level. Also unlike the federal scenario, whether state action is "lackluster", "middle-of-the-road" or "go-getter" is a function of how many states adopt the measures modeled, and in some cases the ambition of the policies pursued.

3. Analysis of Federal and State Actions Together

Given that it is unlikely that federal action will occur without state action or that state action will occur without federal action, we analyzed emissions scenarios with both federal and state action. States can be expected to continue to be active in areas of traditional state purview such as energy resource planning and energy efficiency, while also compensating for weak federal action. To capture this dynamic, we modeled varying levels of action for federal and state action.

FIGURE 6 Projected U.S. Greenhouse Gas Emissions if no New State or Federal Action is Taken



Source: See sources listed under Figures 7 and 8 below.

III. The Road the U.S. is on Now: Business as Usual

The reduction pathways presented in this report are best considered in light of current U.S. emissions, along with recent and future emissions trends. A snapshot of U.S. emissions using the most recent data available is presented below, together with a summary of U.S. emissions by key sectors and recent actions to reduce them by federal agencies.

A. CURRENT U.S. EMISSIONS

In 2010 the United States emitted almost 7 billion metric tons of carbon dioxide equivalents (CO_2e), which represents a decrease of about 6 percent below 2005 levels and a 10 percent increase over 1990 levels. Fossil-fuel combustion was responsible for nearly 80 percent of U.S. emissions, with power plants accounting for about 40 percent of combustion emissions, or one-third of the total U.S. GHG inventory, according to EPA. The second largest contributor to total GHG emissions is the transportation sector, with approximately 30 percent of U.S. emissions. Non-CO_2 emissions and CO_2 emissions that result from industrial processes (as opposed to combustion) represented approximately 22 percent of U.S. total GHG emissions.

Figure 5 shows the 2010 U.S. emissions inventory by sector and subsector, together with the corresponding federal regulatory tools available to achieve reductions in the sector.

B. WHAT HAPPENS WITH NO NEW POLICIES? UNDERSTANDING CURRENT U.S. EMISSIONS TRENDS

Before discussing the reduction pathways projected for this report, it is important to describe the major emissions trends that are part of the business-as-usual projections. Business-as-usual emissions trends have shifted downward since the 2010 version of this report. While energy-related CO_2 emissions are projected to rise slowly but remain below 2010 levels through 2035, non-CO_2 emissions are projected to steadily increase over the same time period. The primary trends are noted here:

- **Current Energy-related Carbon Dioxide Emissions Down from 2005 Levels.** In 2011 carbon dioxide emissions from energy sources, which account for nearly 80 percent of U.S. GHG emissions, were 8.7 percent below 2005 levels. Nearly half of those reductions (48 percent) came from the power sector. The rest of the reductions came from transportation (28 percent), industry (18 percent), and buildings (6 percent).[8]

- **Future Energy-CO_2 Emissions Expected to be Relatively Flat.** Our projections suggest that if no future policy actions are taken, then energy-CO_2 emissions will remain approximately 10 percent

8. *Closer than You Think: Latest U.S. CO_2 Pollution Data and Forecasts Show Target Within Reach.* NRDC Issue Brief. Dan Lashof. July 2012.

below 2005 levels in 2020, and will increase slightly through 2035 to levels that are about 8 percent below 2005 levels (Figure 7).

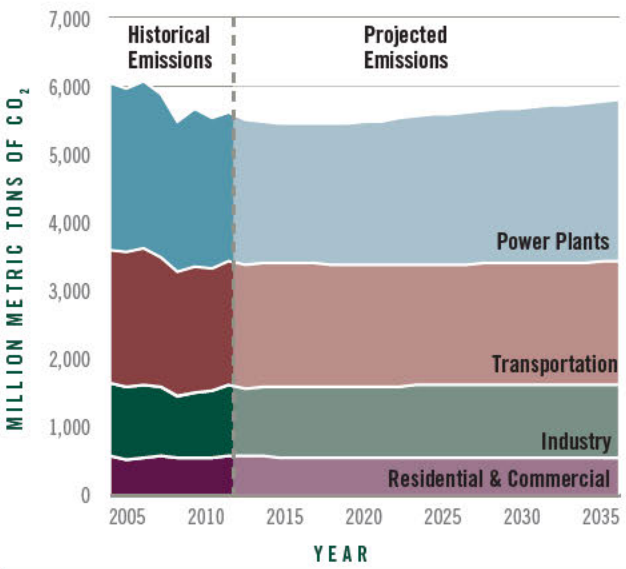
- Those trends are driven by a number of factors, including:

  - **Falling Energy Demand.** The economic slowdown experienced by the United States and other parts of the world over the period from 2008 to 2012 has led to decreased demand for goods and services and reduced energy consumption.[9] Over time, this trend is expected to reverse as economic growth picks up. In addition, the industrial sector was affected significantly by the recent economic turndown and saw a decrease in both production and emissions. This decline is projected to be temporary. Manufacturing output is expected to accelerate from 2010 through 2020, and emissions are projected to increase by 4 percent over this time.[10]

  - **Rise of Natural Gas and Renewables.** The power sector is shifting from coal-fired generation toward natural gas-fired and renewable generation. This trend is driven in part by increases in natural gas extraction, low natural gas prices, increasing coal prices, and new (non-GHG) regulations for the power sector. Increases in renewable generation are driven by state renewable standards, voluntary purchases of "green" energy, and decreasing renewable energy costs. However, gas prices are expected to slowly rise from current levels and demand for electricity is expected to rise 18 percent by 2035 from 2010 levels.[11]

  - **New Vehicle Rules.** The transportation sector is expected to become less carbon-intensive, due in large part to high petroleum prices and new federal GHG emissions and fuel efficiency standards covering light-, medium- and heavy-duty vehicles. These gains will be partially offset by continued increases in vehicle miles traveled.[12] Transportation emissions are projected to increase 1 percent below 2011 levels by 2035.

FIGURE 7 Projected U.S. Energy-Related Carbon Dioxide Emissions if no New State or Federal Action is Taken



Source: U.S. Energy Information Administration, Annual Energy Review (Years 2005-2011); U.S. Energy Information Administration, Annual Energy Outlook (Years 2012-2035)

- **Non-Energy Emissions on the Rise.** Trends for non-energy and non-CO_2 emissions, such as natural gas systems, refrigerants, and landfills, show a likely rise. In 2010, non-energy and non-CO_2 sources accounted for about 22 percent of total U.S. emissions. We project that these emissions will increase roughly 18 percent above 2005 levels by 2020 and 36 percent above 2005 levels by 2035, even after accounting for 2012 regulations that affect portions of natural gas systems and HFCs from vehicles. Those trends are driven by several factors, including:

  - **CFCs Phased Out, HFCs Phased In.** HFC emissions are increasing due to the phaseout of chlorofluorocarbons (CFCs) and other ozone-depleting substances under the Montreal Protocol, which is intended to

9. *Annual Energy Review 2012.* Figure 1.1, Primary Energy Overview (Consumption). EIA, September 2012. Accessible at: <http://www.eia.gov/totalenergy/data/annual/pdf/aer.pdf>.
10. *Annual Energy Outlook 2012 with Projections to 2035. EIA, June 2012.* Accessible at: <http://www.eia.gov/forecasts/aeo/pdf/0383(2012).pdf>.
11. *Annual Energy Outlook 2012 with Projections to 2035.* EIA, June 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/pdf/0383(2012).pdf>.
12. *Annual Energy Outlook 2012 with Projections to 2035.* EIA, June 2012.

BOX 3 Recent Federal Action 2010–12

Since the 2010 report, federal agencies have taken a number of actions that are reducing GHG emissions. The most significant actions from a GHG reduction perspective are summarized below. These are all incorporated into our new business-as-usual projections.

- **Passenger cars and light-duty trucks.** In August 2012 EPA and the National Highway Traffic Safety Administration (NHTSA) finalized new fuel economy and GHG standards for passenger cars and light-duty trucks for model years 2017–2025. These standards equate to a fleet-wide average of 54.5 mpg (101 g CO_2e/km) if they are met solely through fuel economy improvements (as opposed to reductions in HFC emissions from air conditioners). This is approximately double the fuel economy of vehicles sold in 2010. EPA estimates that the rule will save nearly 2 billion tons of CO_2e over the life of the program. This is in addition to the estimated 960 million tons of CO_2e over the life of the prior regulations for model years 2012–2016.

- **Heavy-duty vehicles.** In August 2011 EPA and NHTSA finalized the first-ever fuel efficiency and GHG emission standards for model year 2014 through 2018 medium- and heavy-duty vehicles. EPA estimates that this rule will reduce CO_2 emissions by approximately 270 million metric tons over the life of vehicles sold during the 2014–2018 model years.

- **Natural gas systems.** In April 2012 EPA finalized four regulations that will reduce emissions of volatile organic compounds, sulfur dioxide (SO_2), and air toxics from oil and natural gas systems. EPA estimates that the new standards will have the co-benefit of reducing annual methane emissions by an estimated 19–33 million metric tons of CO_2e.

- **Energy efficiency standards for new appliances.** Between 2009 and 2011, the Department of Energy established 17 new standards. According to analysis by the Appliance Standards Awareness Project and the American Council for an Energy-Efficiency Economy, these standards are expected to save 126.2 TWh in 2025 and 146.8 TWh in 2035.

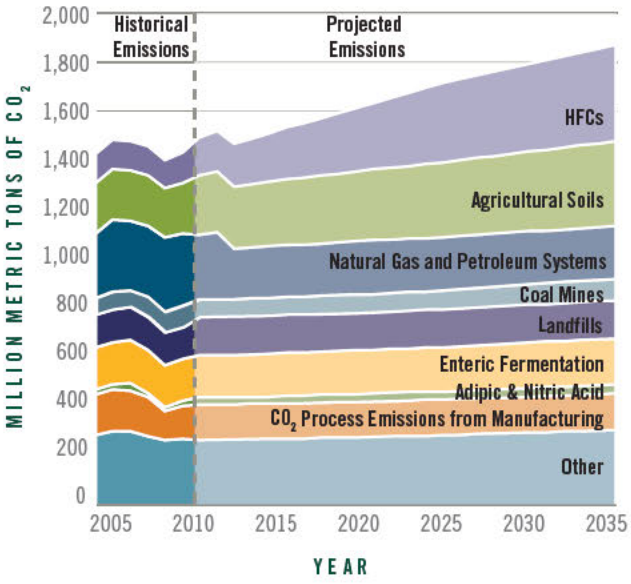
- **Non-GHG regulations for power plants.** EPA has also finalized several other non-GHG-related environmental regulations for power plants, most notably those for mercury and other air toxics. Some modeling has suggested that these rules could lead to the retirement of old, inefficient, coal-fired power plants.

protect and restore the ozone layer in the upper atmosphere, and the Clean Air Act. This trend is expected to continue as the interim substitutes, HCFCs, are also phased out as they are currently being replaced with gases that have a high global warming potential.

- **With the Natural Gas Boon, More Methane Leaks.** Extraction of natural gas in the United States has increased by over 25 percent over the period of 2005 to 2011 due to rapid development of shale gas resources.[13] Increases in natural gas extraction lead to larger fugitive methane emissions from natural gas systems. Fugitive methane emissions are expected to fall significantly, however, due to 2012 EPA regulations that reduce emissions of volatile organic

13. *Monthly Energy Review.* Table 1.2, Primary Energy Production by Source. EIA, December 2012. Accessible at: <http://www.eia.gov/totalenergy/data/monthly/pdf/sec1_5.pdf>.

FIGURE 8 Projected U.S. Non-CO_2 and Non-Energy Emissions if no New State or Federal Action is Taken



Source: U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010 (Years 2005-2010)*; U.S. Environmental Protection Agency, *Draft Global Non-CO_2 Emissions Projections Report 1990-2030 (Non-CO_2 Years 2011-2035)*; RTI, *Applied Dynamic Analysis of the Global Economy Model (Non-energy CO_2 Years 2011-2035)*; *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas.* World Resources Institute. Working Paper. James Bradbury, Michael Obelter, Laura Draucker, Wen Wang, and Amanda Stevens.

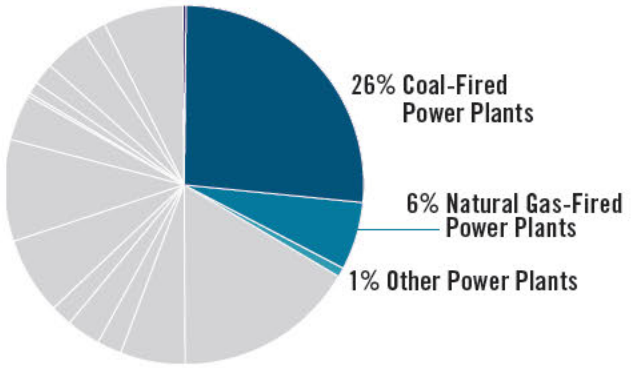
compounds, sulfur dioxide, and air toxics from natural gas systems. Actions to reduce those emissions will also reduce methane emissions (see Box 3 for more details).

IV. Understanding the Federal Reduction Pathways

A. ABOUT THE SECTOR-BY-SECTOR APPROACH

This analysis is a bottom-up assessment of the policies and regulatory tools available to the U.S. Administration, through the federal executive agencies tasked with implementing such regulations—to reduce GHG emissions. The analysis began with an examination of the makeup of U.S. emissions in 2010, followed by research and analysis into existing laws on authority to reduce emissions. We reviewed available literature to determine the range of emissions reductions technically feasible for each sector or subsector. Lastly, we considered legal authority, technical feasibility, cost and political will in constructing lackluster, middle-of-the-road, and go-getter scenarios for each sector or subsector. We briefly describe the scenarios for each sector or subsector below, beginning with the sectors that our analysis indicates offer the greatest potential for reductions. A more detailed discussion of our federal methods is provided in Appendix I.

FIGURE 9 Power Plant Emissions



As a Share of U.S. Emissions in 2010

B. ELECTRIC POWER

The electric sector is the largest single source of GHG emissions in the United States. In 2010 it made up 33 percent of total U.S. GHG emissions, and about 40 percent of all carbon pollution from the combustion of fossil fuels. This sector also represents the single biggest opportunity for emissions reductions using existing legal and regulatory tools.

1. Power plants

Carbon pollution from power plants can be reduced through the following federal regulatory authorities:

TABLE 1 Projecting New Source Performance Standards for Power Plants

	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Existing plants	Emissions reductions consistent with a 5 percent improvement in efficiency starting in 2018.	Aggregate emissions reductions across all electric generators equal to an 18 percent reduction in emissions in 2021 compared to 2012 emission levels, and a 33 percent reduction in 2035.	Aggregate emissions reduction across all electric generators equal to a 38 percent reduction in emissions in 2021 compared to 2012 emission levels, and a 74 percent reduction in 2035.
New plants	Standards initially consistent with EPA's proposal (1,000 pounds of CO_2 per megawatt-hour of output). Beginning in 2020, new unit performance improves to 570 pounds of CO_2 per megawatt-hour by 2030.	Standards initially consistent with the lackluster scenario. Beginning in 2028, new units achieve emissions rates equivalent to carbon capture and storage (CCS) with a 90 percent capture rate.	Standards initially consistent with the lackluster scenario. Beginning in 2020, new units achieve emissions rates equivalent to CCS with a 90 percent capture rate.

TABLE 2 Appliance and Equipment Efficiency Standards (Electric)

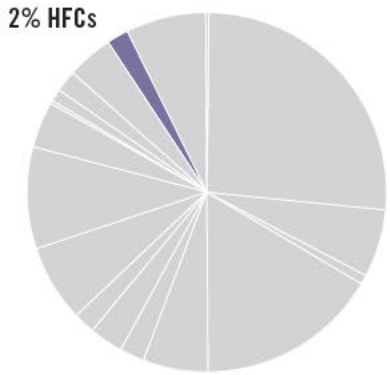
LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
192 TWh savings in 2025 from the residential and commercial sectors, plus additional savings from the industrial sector. Annual savings remain constant through 2035.	212 TWh savings in 2025 and 306 TWh savings in 2035 from the residential and commercial sectors, plus additional savings from the industrial sector.	364 TWh savings in 2025 and 525 TWh savings in 2035 from the residential and commercial sectors, plus additional savings from the industrial sector.

a. **Performance standards for new and existing sources under section 111 of the federal Clean Air Act**
Under section 111 of the Clean Air Act, EPA may prescribe emissions limitations based on the "best system of emission reduction" for new and modified existing sources within source categories EPA determines cause or contribute significantly to air pollution that may reasonably be anticipated to endanger human health or welfare.[14] To determine the "best system of emission reduction," EPA considers technological feasibility, cost, lead time, and energy and non-air environmental impacts.[15] In the spring of 2012 EPA proposed new source performance standards (NSPS) for new power plants.

In addition, for any source category EPA regulates on the federal level, EPA must also promulgate guidelines to states to use in developing requirements for existing sources under section 111(d). In regulating existing sources, states must determine the "best system of emission reduction" for existing sources while taking into account the same factors EPA uses to set limitations for new sources, and also the remaining useful life of existing sources.[16] The form of regulations imposed on existing sources is not tightly prescribed in the statute, and EPA has previously taken the position that states could implement flexible, market-based approaches in setting standards from existing sources. Table I specifies our three scenarios for new and existing power plants under section 111.

b. **Appliance and equipment efficiency standards under Department of Energy authority**
The Department of Energy (DOE) may promulgate efficiency standards for consumer appliances and non-consumer equipment under authority already granted DOE in current law. Based on available studies, the three scenarios analyzed assume progressively greater reductions through appliance and equipment standards, ranging up to 364 TWh of annual savings from residential and commercial consumers in 2025 and 525 TWh annual savings in 2035, with additional savings from industrial consumers.

FIGURE 10 HFC Emissions



As a Share of U.S. Emissions in 2010

C. HYDROFLUOROCARBONS

Hydrofluorocarbons (HFCs), used primarily for refrigeration and air conditioning, represented only 2 percent of all U.S. global warming pollution in 2010. Despite their relatively small share of the U.S. emissions picture today, our analysis finds HFCs can provide some of the greatest reductions by 2020 and through 2035. EPA has existing authority to regulate HFC consumption under Title VI of the Clean Air Act. EPA can phase down the use of HFCs under

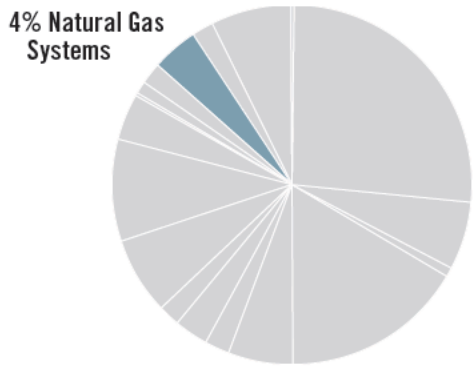
14. 42 U.S.C. §§ 7411(a)(1) & 7411(b)(1)(A).). U.S. Environmental Protection Agency. "Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act." Accessible at: <http://www.gpo.gov/fdsys/pkg/FR-2009-12-15/pdf/E9-29537.pdf>.
15. 42 U.S.C. §§ 7411(a)(1).
16. 42 U.S.C. §§ 7411(d)(1)(B).

TABLE 3 Emissions Reduction Schedule for Hydrofluorocarbons

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Consumption ramp-down occurs three years later than the schedule detailed in the joint North American Proposal.	Consumption is ramped-down in a manner consistent with the joint North American Proposal, which calls for an 85 percent reduction below 2005–2008 levels by 2033.	Consumption is ramped-down more rapidly than in the joint North American Proposal, achieving the 85 percent reduction target in 2028, five years earlier than detailed in the joint North American Proposal.

its Significant New Alternatives Program (SNAP), implementing section 612 of the Clean Air Act. The U.S. Administration has proposed an international ramp-down schedule to achieve reductions worldwide under the Montreal Protocol. Our middle-of-the-road scenarios for HFCs assume this proposed ramp-down schedule is met in the United States. The lackluster scenario assumes that the same ramp-down schedule is implemented, but on a delayed timeline, commencing in 2019 instead of 2016. Meanwhile, the go-getter scenario assumes a more ambitious reduction schedule.[17]

FIGURE 11 Emissions from Natural Gas Systems



As a Share of U.S. Emissions in 2010

D. NATURAL GAS SYSTEMS

Global warming pollution from natural gas systems accounts for approximately 4 percent of U.S. emissions. Yet like HFCs, our analysis suggests that natural gas systems may be among the top emissions reduction opportunities in the near term. Similar to power plants, EPA can regulate natural gas systems by implementing emissions performance standards for methane under section 111 of the Clean Air Act for new and existing natural gas systems. They may also be able to achieve additional GHG emissions reductions

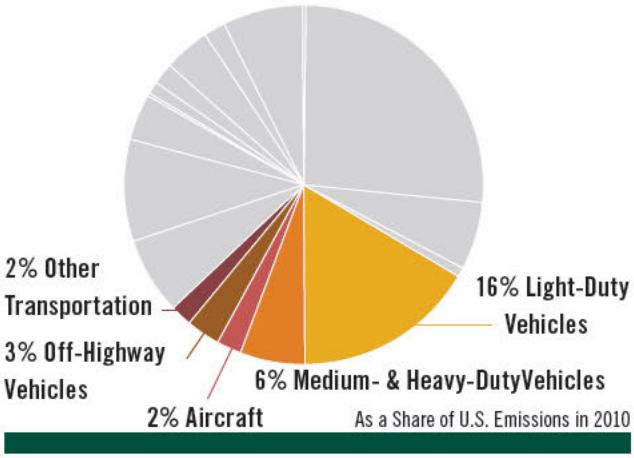
17. Due to modeling limitations, our analysis examines changes in HFC consumption. In the United States, HFC consumption is roughly equivalent to life-cycle emissions due to low rates of capture and destruction. See Appendix I for a more detailed discussion.

TABLE 4 Performance Standards to Reduce Emissions from Natural Gas Systems

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Emissions reductions of 26 percent from business-as-usual starting in 2019. Assumes implementation of plunger lift systems to reduce emissions from liquids unloading at new and existing wells, and leak monitoring and repair to reduce fugitive emissions from production, processing, and compressor stations.	Emissions reductions of 37 percent from business-as-usual starting in 2019. Assumes implementation of measures in lackluster scenario and conversion of existing high-bleed pneumatic controllers to low-bleed or no-bleed controllers to reduce emissions from production, processing, and transmission.	Emissions reductions of 67 percent from business-as-usual starting in 2019. Assumes implementation of measures in middle-of-the-road scenario, as well as desiccant dehydrators to reduce emissions during dehydration of wet gas; improved compressor maintenance to reduce emissions during processing; hot taps in maintenance of pipelines during transmission; and vapor recovery units to reduce emissions during storage.

by tightening standards for other air pollutants, such as volatile organic compounds and air toxics, as they recently did with respect to new equipment in the U.S. oil and gas sector. Through one or more of these regulatory paths, EPA could require equipment changes, upgrades, changes to operational practices, and inspection and leak prevention. Table 4 details the three scenarios analyzed. However, there is a great deal of uncertainty with regard to emissions for natural gas systems. This means that the absolute magnitude of abatement opportunities is uncertain. Nevertheless, our analysis identifies important opportunities to reduce emissions from this sector. Those reductions are some of the lowest cost opportunities identified in this analysis. See the appendix for a more detailed discussion of uncertainties and opportunities.

FIGURE 12 Transportation Emissions



E. TRANSPORT VEHICLES

Transportation is one of the largest sources of global warming pollution in the United States, accounting for 30 percent of the 2010 inventory. Improving the efficiency of motor vehicles has been a priority for the Obama Administration, which promulgated new standards to reduce emissions and raise the fuel efficiency of light-, medium- and heavy-duty vehicles. Our analysis finds that it is possible to achieve additional reductions from light-, medium-, and heavy-duty vehicles. In addition, there are opportunities to reduce emissions of global warming pollution from aircraft and off-highway vehicles.

1. Passenger vehicles

Under Title II of the Clean Air Act, EPA has the authority to regulate greenhouse gas emissions from new light-duty cars and trucks, and has done so already in two consecutive rulemakings covering vehicles sold through model year 2025. In conjunction with EPA's rulemaking, the Department of Transportation's National Highway Traffic Safety Administration (NHTSA) may promulgate corporate average fuel economy (CAFE) standards regulating the average fuel efficiency of new vehicles. Because standards have already been issued covering light-duty vehicles through model year 2025, our analysis focuses on the time period after 2025. Table 5 outlines the three scenarios, with the lackluster scenario projecting improvements at half the rate of the previous standards, middle-of-the-road projecting continuation of the same rate of improvement, and go-getter increasing the rate of improvement significantly.

2. Medium- and heavy-duty vehicles

For medium- and heavy-duty vehicles, EPA has established emissions standards and NHTSA has established fuel economy standards for model years 2014 through 2018. These standards are included in our business-as-usual emissions trajectory. Our emissions reduction scenarios pick up in model year 2020 using the same legal authority, but making different assumptions about the stringency of the next set of standards. As shown in Table 5, our lackluster scenario assumes a rate of improvement that is just half that of the current standards through 2035, middle-of-the-road projects a continuation of the current standards through 2035, and the go-getter scenario considerably increases new standards to meet the maximum level of efficiency currently thought to be technically achievable in that time frame.

3. Off-Highway engines

EPA may also regulate off-highway sources of global warming pollution under Title II of the Clean Air Act. For the lackluster, middle-of-the-road, and go-getter scenarios, respectively, the analysis assumes new standards can achieve 0.9 percent, 1.8 percent, and 2.4 percent annual improvement in the emissions rate for new equipment and engines from 2018 to 2035.

4. Aviation and aircraft

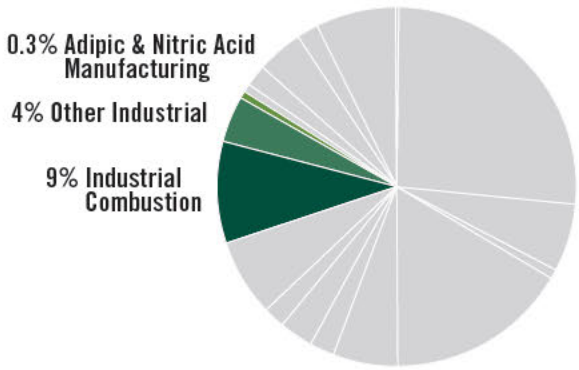
The Federal Aviation Administration (FAA) may make operational improvements in the air traffic control system that could achieve significant carbon pollution reductions over time. We draw our assumptions about operational improvements from an EPA analysis of the reductions possible and the FAA's comments on that analysis. Our scenarios, shown in Table 5, bound the range of reductions estimated by EPA and FAA.

TABLE 5 Vehicle Emissions Standards, Efficiency Standards, and Operational Improvements

	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Light-duty vehicles	Vehicle standards continue to improve from 2026–2035 at roughly half the rate of the 2017–2025 standards (2 percent per year). This results in a 131 grams per mile emissions standard and a 61 mpg CAFE standard in 2035.	Vehicle standards continue to improve from 2026–2035 at roughly the same rate as the 2017–2025 standards (4 percent per year). This results in a 104 gram per mile emissions standard and a 75 mpg CAFE standard in 2035.	Vehicle standards continue to improve from 2026–2035 at 6 percent annually. This results in a 81 grams per mile and a 92 mpg CAFE standard in 2035.
Medium- & heavy-duty vehicles	Standards continue to improve through 2035 at half the rate of the 2013–2018 standards by vehicle category—about a 1.3 percent annual improvement.	Standards continue to improve through 2035 at the same rate as the 2013–2018 standards by vehicle category—about a 2.6 percent annual improvement.	By 2020–2022, the medium- and heavy-duty fleet reduces its emissions rate by an average 26 percent and by 42 percent in 2023–2025 compared to 2010. Standards continue to improve annually by 1 percent through 2035.
Off-highway	From 2018 to 2035, a 0.9 percent annual improvement in the emissions rate for new equipment and engines.	From 2018 to 2035, a 1.8 percent annual improvement in the emissions rate for new equipment and engines.	From 2018 to 2035, a 2.4 percent annual improvement in the emissions rate for new equipment and engines.
Aviation	Through 2035, a 0.17 percent annual emissions reduction from operational improvements via FAA's NextGen Program.	Through 2035, a 0.4 percent annual emissions reduction from operational improvements via FAA's NextGen Program.	Through 2035, a 1.4 percent annual emissions reduction from operational improvements via FAA's NextGen Program, plus a 2.3 percent annual improvement in the performance of new aircraft and engines.

EPA has statutory authority under Title II of the Clean Air Act to promulgate standards to reduce emissions from new and existing aircraft engines. To date, EPA has never exercised that authority to require aircraft engine manufacturers to meet standards that the industry association has not previously adopted voluntarily. Nevertheless, our go-getter scenario, shown in Table 5, projects the emissions reductions that could be achieved if EPA were to pursue this regulatory course of action.

FIGURE 13 Industrial Emissions



As a Share of U.S. Emissions in 2010

F. INDUSTRY

Emissions from industrial facilities comprised 13 percent of U.S. global warming pollution in 2010. Fossil fuel combustion at industrial facilities accounts for 9 percent of U.S. emissions, while non-combustion industrial processes account for 4 percent of emissions. When accounting for upstream, indirect CO_2 emissions from power plants, the industrial sector is responsible for 23 percent of total U.S. GHG emissions.

EPA may regulate industrial stationary sources of emissions through performance standards under section 111 of the Clean Air Act. As with power

TABLE 6 Performance Standards to Reduce Industry Emissions

	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Fossil-fuel combustion in manufacturing and cement kilns	Emissions reductions consistent with a 10 percent improvement in combustion efficiency by boilers.	Emissions reductions consistent with harnessing all cost-effective energy efficiency across all processes and energy uses at manufacturing facilities. Emissions standards also drive reductions in process emissions from cement kilns.	Emissions reductions consistent with harnessing all cost-effective energy efficiency across the entire manufacturing facility. All new units must meet emissions rate equivalent to natural gas combustion. Emissions standards also drive reductions in process emissions from cement kilns.
Refineries	Emissions reductions consistent with a 1 percent improvement in efficiency beyond business-as-usual projections.	Emissions reductions consistent with a 5 percent improvement in efficiency beyond business-as-usual projections.	Emissions reductions consistent with a 10 percent improvement in efficiency beyond business-as-usual projections.
Nitric and adipic acid manufacturing	A 13 percent reduction in emissions.	A 56 percent reduction in emissions.	A 75 percent reduction in emissions.

plants, this is accomplished through EPA's setting of standards for new sources and issuing regulations that provide states with guidelines for covering existing sources. New source requirements typically take the form of a simple emissions rate, while regulation of existing sources can be more flexible.

1. Fossil fuel combustion in manufacturing and cement kilns

As with fossil-fuel burning power plants, reducing the GHG emissions profile of the industrial sector can be accomplished through improvements to the efficiency of boilers, fuel switching, and use of renewable energy such as biomass or geothermal, among other methods. Additional reductions are possible if regulations require a manufacturing facility to capture all cost-effective process efficiencies across an entire operation, beyond the boiler. Table 6 details the three scenarios analyzed for projecting possible reductions from the industrial sector. In addition, for the middle-of-the-road and go-getter scenarios for cement kilns, we assume emissions standards are used to drive reductions in process emissions through greater use of blended cements, and potentially carbon capture and storage, achieving reductions in process emissions of 2 percent in 2020 and 13 percent in 2035.

2. Petroleum refineries

EPA's advanced notice of proposed rulemaking, *Regulating Greenhouse Gas Emissions Under the Clean Air Act,* indicated that efficiency improvements in refineries are possible in the range of 10 to 20 percent. Some efficiency improvements are included in our business-as-usual projections, however. Therefore, in order to generate conservative estimates of emissions reductions, starting in 2018 we model lackluster, middle-of-the-road, and go-getter scenarios with reductions in annual GHG emissions of 1, 5, and 10 percent reductions beyond business-as-usual projections, respectively.

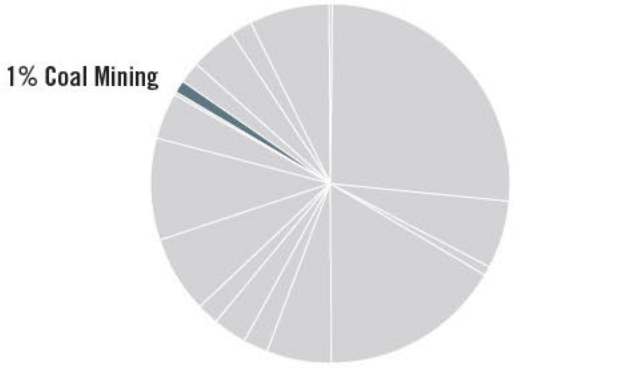
3. Nitric and adipic acid manufacturing

Nitric acid is primarily used as a feedstock for synthetic fertilizer, and also used to produce adipic acid and explosives. Adipic acid is used in the production of nylon and is a flavor enhancer in foods. The production of both compounds leads to emissions of nitrous oxide, a potent greenhouse gas. Though nitric and adipic acid manufacturing makes up less than 0.5 percent of total U.S. global warming pollution, there are opportunities to achieve dramatic reductions at low cost, making it a good target for policy.

To reduce emissions from acid manufacturing, EPA can use its authority under section 111 of the Clean Air Act to set standards for new manufacturing plants and issue guidelines to states to cover existing sources. Our

lackluster, middle-of-the-road and go-getter scenarios project reductions of annual GHG emissions of 13 percent, 56 percent, and 75 percent, respectively, compared to the business-as-usual projections.

FIGURE 14 Coal Mine Emissions

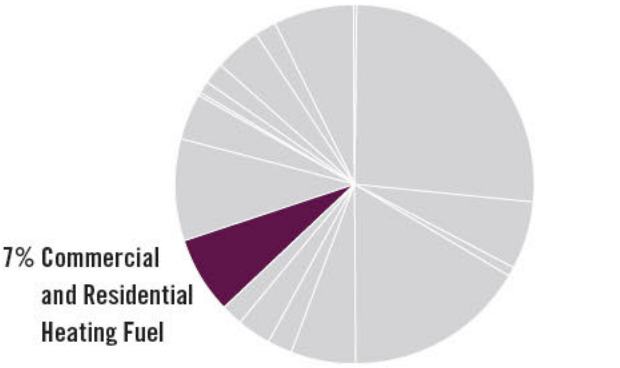


As a Share of U.S. Emissions in 2010

G. COAL MINES

Methane emissions from coal mines represented 1 percent of total U.S. global warming pollution in 2010. EPA may regulate coal mines as a source category under section 111 of the Clean Air Act. As discussed above for power plants and industry, this would entail EPA issuing performance standards for new coal mines and regulations to guide states in their regulation of existing coal mines. The statute does not prescribe the specific form of regulations applied to existing sources. For the lackluster, middle-of-the-road, and go-getter scenarios, we projected reductions from coal mines of 24 percent, 32 percent, and 39 percent, respectively, compared to business-as-usual projections.

FIGURE 15 Commercial & Residential Heating Emissions

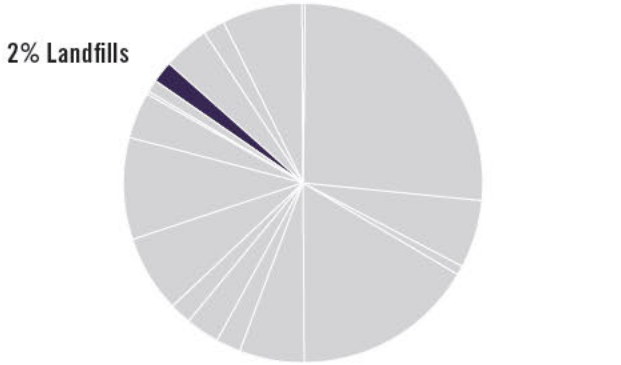


As a Share of U.S. Emissions in 2010

H. COMMERCIAL AND RESIDENTIAL HEATING

Carbon pollution from commercial and residential heating, mostly through natural gas combustion, accounted for 7 percent of U.S. emissions in 2010. This includes things such as home heating, cooking, and water heating. The most effective way to decrease emissions in this sector is to improve the building envelope—a path traditionally the province of state and local governments in the United States. However, the federal government can promulgate efficiency standards for appliances and equipment used to heat buildings. Based on our survey of the available literature, we conclude that efficiency standards implemented in 2015 could reduce natural gas demand by 126 Trillion British thermal units (TBtu) in 2025 and 235 TBtu in 2035, reducing GHG emissions by 6.7 million tons of CO_2 in 2025 and 12.5 million tons CO_2 in 2035 compared to business-as-usual projections. Due to limitations in the available literature, we project the same reductions level for all three scenarios.

FIGURE 16 Landfill Emissions



As a Share of U.S. Emissions in 2010

I. LANDFILLS

Methane emissions from landfills represented 2 percent of total U.S. global warming pollution in 2010. EPA already regulates emissions of volatile organic compounds from landfills under section 111 of the Clean Air Act. These standards provide the co-benefit of reducing methane emissions. EPA could either strengthen those standards or establish new standards for GHG emissions. The statute does not prescribe the form of regulations applied to existing sources. For the lackluster, middle-of-the-road, and go-getter scenarios, we projected reductions of 5 percent, 9 percent, and 9 percent, respectively, compared to our business-as-usual projections. The reductions we

project for landfills in this report are substantially smaller than the reductions projected in the 2010 report. These differences are attributable to changes in the EPA data used in the analysis.

V. Understanding the State Reduction Pathways

Policy action to address environmental challenges frequently begins at the state level, and greenhouse gases are no exception. States were the first to push ambitious emissions standards for vehicles, adopt greenhouse gas regulations for the power sector, and establish economy-wide reduction targets. Many states already have programs that reduce emissions from transportation, improve energy efficiency, and promote renewable generation. In the state scenarios, we examine what would happen if states continue to adopt policies that reduce their GHG footprint.

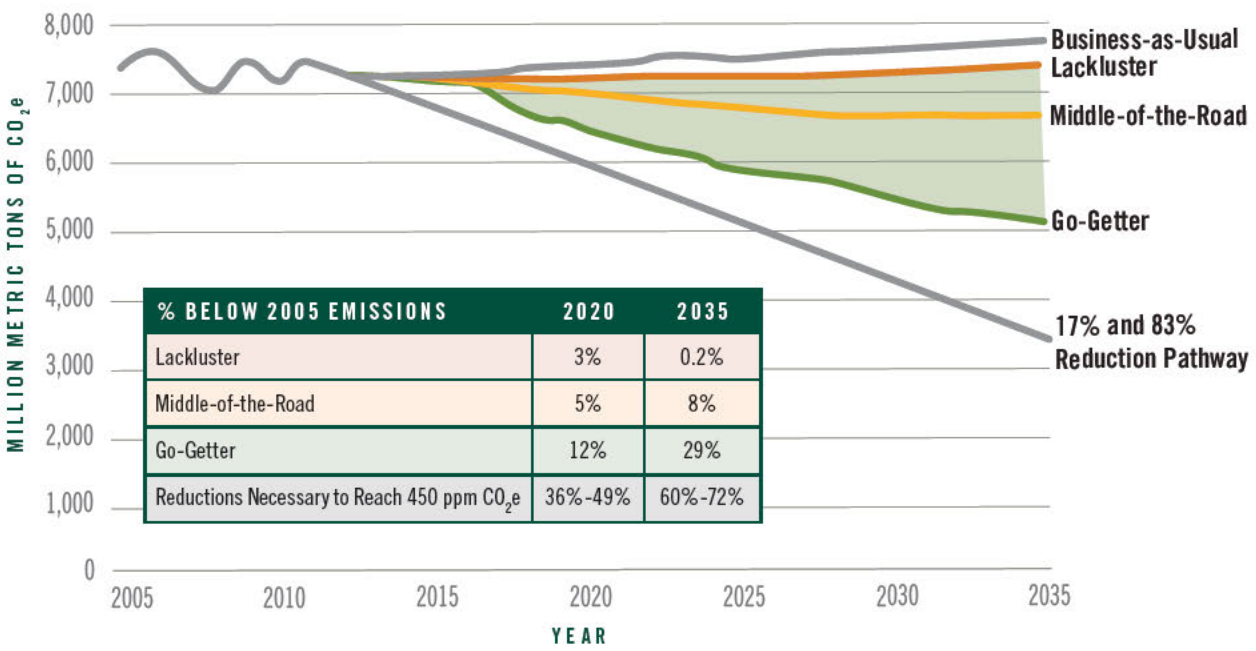
A. ABOUT THE STATES APPROACH

The state analysis takes a two-pronged approach. First, we project the potential greenhouse gas emissions reductions from transportation, end-use energy efficiency, and renewable electricity policies typically undertaken by states. Second, we consider the potential for state action in areas we also consider for the federal government, such as emissions standards for power plants and industry. This is based on the observation that the Constitution grants states broad authority to regulate their energy sources and emissions. States thus have the ability to implement many of the same policies as federal agencies.

In this analysis, the difference between lackluster and go-getter action at the state level is a function of the number and size of the states that adopt the measures modeled, and in some cases the ambition of the policies pursued. Unlike the federal analysis, in some cases state action would require new state legislation. However, we did not attempt to determine which states would require new legislation to implement the state measures and which states could implement without new legislation. A detailed discussion of our state methods is provided in Appendix II.

In addition to the direct emission reduction opportunities modeled here, state-level action can help trigger more ambitious action at the federal level. In the words of Justice Brandeis, states can serve as "laboratories of democracy," testing out approaches that provide possible models for federal action. Action at the state level can also lead to broader support for federal action, with the most ambitious states helping establish a floor for federal ambition.

FIGURE 17 Projected U.S Emissions when States Pursue the Full Range of Policies within their Authority (No Federal Action)



% BELOW 2005 EMISSIONS	2020	2035
Lackluster	3%	0.2%
Middle-of-the-Road	5%	8%
Go-Getter	12%	29%
Reductions Necessary to Reach 450 ppm CO_2e	36%-49%	60%-72%

Note: Due to modeling limitations, this figure depicts HFC consumption, which is generally thought to be equivalent to life-cycle emissions.

B. TRANSPORTATION

As noted above, the transport sector is responsible for about 30 percent of GHG emissions in the United States, making it the second largest emitting sector behind power plants. State and local policies have traditionally played a significant role in transportation, and as a result we project reductions that states might be able to achieve in this area, including through policies to encourage the use of lower carbon fuels and reduce vehicle miles traveled.

1. Lower Carbon Fuels

States may establish requirements for the fuels delivered in their jurisdictions to reduce the carbon profile of those fuels. To project potential reductions through state policies that reduce the life-cycle emissions of transportation fuels, we do not select specific policies in specific states. Rather, we model percent improvements in the carbon profile of fuels generally. These general improvements in the carbon profile of fuels are a proxy for what is likely to be a diverse set of measures across numerous states.

For modeling purposes, we assume that those policies further reduce the average life-cycle carbon intensity of transportation fuels by 1 percent per year between 2015 and 2035. In the lackluster scenario, we assume this annual reduction is achieved by states accounting for 15 percent of total energy consumption from U.S. transportation fuels. In the middle-of-the-road and go-getter scenarios, we assume that these policies are pursued by states accounting for 25 percent and 35 percent of total U.S. transportation fuel consumption, respectively.[18]

2. Reducing Vehicle Miles Traveled

States play a big role in designing and implementing policies that directly impact the number of vehicle miles traveled. These include smart growth strategies, such as targeting new development near public transportation, favoring infill, limiting sprawl, mixed-use development, and provision of smartly located affordable housing options. These strategies can be complemented by a variety of strategies, including improving and expanding public transportation options, bike and pedestrian pathways, car sharing, and HOV lanes, as well as through speed limit restrictions, intercity tolls, and strategies to limit driving within urban centers (e.g., parking restrictions).

In our lackluster and middle-of-the-road scenarios, we assume that states that implement policies and programs achieve VMT reductions of 0.5 percent per year beginning in 2016, leading to a 10 percent reduction below business-as-usual projections in 2035.

18. See Appendix II for context about what it would take to achieve the state uptake in this and the other state scenarios.

TABLE 7 State Transportation Measures

ACTION	POLICIES AND PROGRAMS DRIVING ACTION	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Reduce carbon content of fuels by 1 percent per year from 2015 to 2035	■ Low-carbon fuel standard ■ Clean fuel standard ■ Advanced biofuels standard ■ Infrastructure incentives	States accounting for 15 percent of transportation fuel consumption implement measures to achieve a reduction.	States accounting for 25 percent of transportation fuel consumption implement measures to achieve a reduction.	States accounting for 35 percent of transportation fuel consumption implement measures to achieve a reduction.
Vehicle miles traveled reductions of 0.5 or 1 percent per year from 2016 to 2035	■ Smart growth ■ Improved public transit ■ Pedestrian and biking infrastructure ■ Improved traffic systems operations	States accounting for 15 percent of GHG emissions from light-duty vehicles implement measures to achieve a reduction of 0.5 percent per year.	States accounting for 25 percent of GHG emissions from light-duty vehicles implement measures to achieve a reduction of 0.5 percent per year.	States accounting for 35 percent of GHG emissions from light-duty vehicles implement measures to achieve a reduction of 1 percent per year.

This is on the conservative end of the range found in the state programs under way. Therefore, in our go-getter scenario we assume that states reduce VMT 1 percent per year. We assume that these policies and programs are implemented by states accounting for 15, 25, and 35 percent of GHG emissions from light-duty vehicles in our lackluster, middle-of-the-road, and go-getter scenarios, respectively.

C. ENERGY EFFICIENCY

Energy efficiency measures avoid the need to use fossil fuels and save consumers money, creating significant economic benefits.[19] States are on the front lines in designing and implementing programs to enhance energy efficiency, both for end-use electricity and heating fuels. Our analysis projects the emissions reductions states may achieve implementing energy efficiency programs, building codes, and the increased penetration of combined heat and power. Each type of measure is outlined below.

1. Electricity Savings

States have been the primary drivers of end-use energy efficiency within their borders. Many states have implemented energy efficiency portfolio standards and/or other ratepayer-funded programs to fund energy efficiency investments. Other states have sought to integrate energy efficiency into the process for procuring new generation resources (e.g., in the context of long-term resource planning), so that energy efficiency can compete as a viable alternative to more traditional generating resources.

To project potential emissions reductions from increased state-level energy efficiency policies, we made different assumptions about states with and without such policies. We assume that some states with and without existing energy efficiency targets adopt policies and programs that lead to electricity savings beginning in 2015. Both the rate of savings and the number of states covered varies across the scenarios, as shown in Table 8.

2. Natural Gas Savings

A number of states have also begun to implement energy efficiency programs targeted at natural gas consumption. These programs can resemble those for electricity savings, taking the form of energy efficiency portfolio standards or system benefit charges. As with the electricity savings scenarios, we assume that some states with targets increase those targets, and that some states without targets implement those targets. The scenarios are shown in Table 8.

3. Improving Building Performance

States and municipalities are generally responsible for adopting and updating state and local building energy codes, which apply to new construction and major renovations. Responsibility for enforcing these codes is part of the states' police powers. In our lackluster scenario, we assume that states accounting for 10 percent of the energy consumed by the building sector implement more ambitious building codes. In our middle-of-the-road and go-getter scenarios, we assume that states accounting for 30 and 50 percent of the energy consumed by the building sector implement more ambitious building codes, respectively.

4. Increased Penetration of Combined Heat and Power

The U.S. electricity system is designed to accommodate large central station power plants located away from the electricity customers. Fossil-fuel generating plants operate at 30 to 60 percent efficiency, wasting significant energy in unused heat from the combustion process. Combined heat and power (CHP), or cogeneration, is a form of distributed generation located at or very near end-use customers that captures and puts waste heat to beneficial use.

States have been at the forefront in driving the spread of CHP. They have done so through a variety of policies, including standard interconnection rules, reduced standby rates, net metering policies, friendly air quality regulations (such as output-based emissions regulations), technical assistance programs, and various financial incentives.[20] In our lackluster, middle-of-the-road, and go-getter scenarios, we assume that state action results in deployment of an additional 10, 20, and 40 GW of new CHP by 2025, respectively, beyond business-as-usual projections.[21]

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19. *The Long-Term Energy Efficiency Potential: What the Evidence Suggests.* American Council for an Energy Efficient Economy, Research Report E121, January 2012. Accessible at: < http://www.aceee.org/research-report/e121>.
20. *Challenges Facing Combined Heat and Power Today: A State-by-State Assessment.* ACEEE Report Number IE111, September 2011.
21. In the go-getter scenario, we assume that state action results in deployment of 27 GW of CHP in 2020, in addition to the 13 GW built into our business-as-usual projections. Combined, they result in CHP deployment consistent with the executive order target of 40 GW of new CHP by 2020.

TABLE 8 State Energy Efficiency Measures

ACTION	POLICIES AND PROGRAMS DRIVING ACTION	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Electricity savings from states with EE targets	■ Energy efficiency resource standards ■ System benefit charge funds or other funds ■ Least-cost procurement requirements	States responsible for 75 percent of electricity consumption that have annual energy efficiency targets below 1.5 percent increase their annual target to 1.5 percent from 2015 to 2035.	States responsible for 75 percent of electricity consumption that have annual energy efficiency targets below 2 percent increase their annual targets to 2 percent from 2015 to 2035.	States responsible for 75 percent of electricity consumption that have annual energy efficiency targets below 2.5 percent increase their annual targets to 2.5 percent from 2015 to 2035.
Electricity savings from states without EE targets		States responsible for 25 percent of electricity consumption achieve electricity savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 25 percent of electricity consumption achieve electricity savings of 1.5 percent of total demand per year from 2015 to 2035.	States responsible for 50 percent of electricity consumption achieve electricity savings of 1.5 percent of total demand per year from 2015 to 2035.
Natural gas savings from states with EE targets	■ Energy efficiency resource standards ■ System benefit charge funds or other funds	States responsible for 25 percent of natural gas consumption that have energy efficiency targets below 1 percent achieve savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 50 percent of natural gas consumption that have energy efficiency targets below 1 percent achieve savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 75 percent of natural gas consumption that have energy efficiency targets below 1.5 percent achieve savings of 1.5 percent of total demand per year from 2015 to 2035.
Natural gas savings from states without EE targets		States responsible for 10 percent of natural gas consumption achieve natural gas savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 25 percent of natural gas consumption achieve natural gas savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 50 percent of natural gas consumption achieve natural gas savings of 1.5 percent of total demand per year from 2015 to 2035.
Reduced energy consumption in buildings	■ Commercial and residential building codes ■ Financial incentives	States accounting for 10 percent of the energy consumed by the building sector implement more ambitious building codes.	States accounting for 30 percent of the energy consumed by the building sector implement more ambitious building codes.	States accounting for 50 percent of the energy consumed by the building sector implement more ambitious building codes.
Increased penetration of combined heat and power	■ Standard interconnection rules ■ Reduced standby rates ■ Net metering policies ■ Output-based emissions regulations	State action results in deployment of an additional 10 GW of new CHP beyond business-as-usual projections by 2025.	State action results in deployment of an additional 20 GW of new CHP beyond business-as-usual projections by 2025.	State action results in deployment of an additional 40 GW of new CHP beyond business-as-usual projections by 2025.

TABLE 9 State Renewable Energy Policies

	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Increased renewables from states with renewables targets	States responsible for 25 percent of electricity consumption increase their renewable generation by 1 percent annually after the last year for which a standard is set.	States responsible for 50 percent of electricity consumption increase their renewable generation by 1 percent annually after the last year for which a standard is set.	States responsible for 75 percent of electricity consumption increase their renewable generation by 1 percent annually after the last year for which a standard is set.
Increased renewables from states without renewables targets	States responsible for 10 percent of electricity consumption increase their renewable generation 0.5 percent annually beginning in 2015.	States responsible for 25 percent of electricity consumption increase their renewable generation 0.5 percent annually beginning in 2015.	States responsible for 50 percent of electricity consumption increase their renewable generation 0.5 percent annually beginning in 2015.

D. RENEWABLE ELECTRICITY GENERATION

Similar to energy efficiency, state policies have been major drivers of renewable electricity generation in the United States. Twenty-nine states and the District of Columbia have renewable energy portfolio standards or advanced energy standards. Numerous states also support distributed or customer-sited renewables as part of their RPS or through other ratepayer-funded programs. In order to capture the reductions possible from states taking new or additional action to increase renewable generation serving their residents, we assumed that a certain number of states without renewable energy targets add 0.5 percent renewables per year beginning in 2015. For those states that already have renewables targets, we assumed they continued to add 1 percent a year to those targets after the target is achieved. Table 9 provides details on differences across the scenarios.

E. WHEN STATES TAKE A MORE EXPANSIVE TACK

States have broad authority to regulate energy sources and emissions within their boundaries. They may therefore implement many of the same policies that we ascribe to the federal government in the federal analysis. In determining what reductions states might make in the future, the analysis considers not only traditional state energy policies, but also scenarios in which states decide to approach carbon pollution more expansively. For example, the states participating in the Northeast and Mid-Atlantic Regional Greenhouse Gas Initiative (RGGI) have chosen to design and implement a multistate cap-and-trade program to reduce carbon pollution from power plants in their states. Other states could join them, or take alternative approaches to reducing carbon pollution from power plants. The most significant example of this is California, which has taken an expansive approach to reducing GHGs in its Global Warming Solutions Act of 2006 and the regulations adopted under that law.

Because it is hard to predict which other states, if any, will pursue ambitious standards for greenhouse gases, we modeled more broad-based action by assuming a portion of total national emissions within each sector would be covered by the reduction measures analyzed for the federal government in section IV above. In the lackluster, middle-of-the-road, and go-getter scenarios, we assume these measures are adopted by states accounting for 10, 25, and 50 percent of GHG emissions from a given sector, respectively.

These approaches include state action for all sectors discussed in the federal action section, except for those policies that are ill-suited for state implementation. We deemed policies that eliminate HFCs, regulate off-highway vehicles, adopt appliance and equipment efficiency standards where federal standards already exist, or regulate aviation to be ill-suited to state implementation because they are preempted by federal law.

It is important to note that we vary both the number of states taking action and the level of ambition they each pursue. In all sectors, the level of ambition pursued is the same as the ambition defined in the federal scenario described in Section IV. Therefore, in our lackluster scenario for power plants, we assume states accounting for 10 percent of GHG emissions from the power sector

implement policies equivalent to the lackluster scenario for federal action. In our go-getter scenario, we assume states accounting for 50 percent of GHG emissions from the power sector implement policies equivalent to the go-getter scenario for federal action.

VI. Conclusion: Finding Our Way to a Low-Carbon Future

The enormous economic and social costs of climate disruption are increasingly evident in the United States. Yet the urgency conveyed by the mounting evidence is not yet reflected in U.S. federal and state actions or climate policies. The United States is not currently on path to meet its international pledge to reduce GHG emissions to 17 percent below 2005 levels by 2020, though it could meet this goal with go-getter action by the U.S. Administration under current laws. In order to achieve adequate mid-century reductions, it appears almost certain that the U.S. Congress will eventually have to enact new legislation aimed at getting deep reductions. Ultimately, a cooperative approach bringing together Congress, states, and the executive branch will be necessary for the United States to do its part.

States can contribute to U.S. emissions reductions, both through state-level transportation, energy efficiency, and renewables programs, as well as through new legislative efforts to initiate a wide array of other policies aimed at reducing GHGs. It appears unlikely that state actions alone will put the United States on the necessary course. However, they can help complement federal action, and can enable the United States to meet its 17 percent target if federal agencies fail to pursue go-getter-level action.

KEY RECOMMENDATIONS

- In the short term, federal agencies and the states should aggressively move forward with a "go-getter" emissions reduction scenario. This will necessitate taking action in the following key areas that present the greatest opportunities for GHG emissions reductions through 2020:
  - EPA and the states should focus on achieving significant reductions in carbon pollution from power plants and natural gas systems.
    - For power plants, EPA should finalize its proposed greenhouse gas emissions standards for new power plants and should move ahead with flexible and ambitious standards for existing power plants. States should move ahead with measures to reduce emissions from the power sector, such as increasing the use of renewable power and cogeneration and reducing electricity demand.
    - For natural gas systems, EPA and the states should propose rules that address methane as a greenhouse gas pollutant, which can result in significant reduction of methane leakage throughout the natural gas life cycle. Such rules would complement the volatile organic compound and air toxics rules established in 2012 for natural gas systems that have the co-benefit of reducing methane leakage.
  - The State Department should continue to seek reductions in hydrofluorocarbons through amendments to the Montreal Protocol. But, in the meantime, EPA should begin reducing consumption in the United States using its authority under the Clean Air Act.
  - EPA and the states should also work to improve energy efficiency in the residential, commercial, and industrial sectors.
- Over time, we will need to see reductions from all sectors, and the Administration should use its existing authorities to achieve go-getter-level reductions across the economy.
- Even with go-getter-level action, however, reductions will fall short of the long-term targets necessary to avoid the worst impacts of climate disruption. As a result, congressional action will be necessary.

BOX 4 Risks and Uncertainties

Uncertainties associated with the methods and results of this analysis include:

- **Uncertainties inherent in the models.** As with any modeling analysis of this sort, there is significant uncertainty in projecting the future. The analysis relies heavily on the Energy Information Administration's *Annual Energy Outlook 2012*, which attempts to project energy and emissions trends into the future based on a number of assumptions, including likely fuel costs, economic activity, and source turnover rates. There are also considerable uncertainties in the estimates of fugitive emissions from natural gas systems. All projections are only as good as the assumptions that go into them and the quality of the data modeled.

- **Regulatory impetus.** As the different scenarios suggest, a major uncertainty in the analysis is whether the federal administration will carry out the regulatory actions in a manner sufficient to achieve the reductions that available studies suggest are technically feasible. The lackluster, middle-of-the-road, and go-getter scenarios stand for different levels of regulatory ambition. The go-getter scenario, it should be emphasized, will require steadfast resolve on the part of the Administration and the states.

- **Congressional action.** Federal agencies depend on the U.S. Congress for their budgets. In order to carry out a series of new regulatory actions, federal agencies will require sufficient resources through the annual budget process. In addition, it should be noted that existing authorities can be curtailed through new legislation.

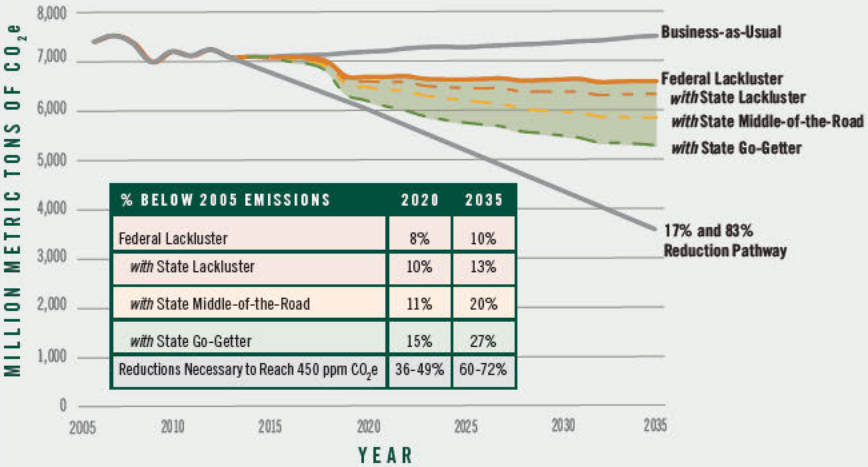
- **Legal risk.** The assumptions made in this analysis were informed by sound legal analysis and vetted with legal experts in the field. Nevertheless, when federal agencies take new actions under existing statutes, the new actions are often challenged in federal court on the grounds that the agency has exceeded the authority originally granted to it in the statute. It is impossible to predict with any precision whether the challenges will be successful.

- **Technological development.** The results modeled depend in part on the development and deployment of new technologies over time. Indeed, many of the regulatory policies are technology-based and must be revised by federal agencies as technology progresses. If technologies emerge rapidly, emissions reductions are more likely. Conversely, if technologies are slow to appear, emissions reductions will slow. This uncertainty is especially important further out into the future.

Supplemental Figures

BOX S-1 Greenhouse Gas Emissions Reductions from State Action Coupled with Lackluster Federal Action

FIGURE S-1 Projected U.S Emissions with State Action Coupled with Lackluster Federal Action



% BELOW 2005 EMISSIONS	2020	2035
Federal Lackluster	8%	10%
with State Lackluster	10%	13%
with State Middle-of-the-Road	11%	20%
with State Go-Getter	15%	27%
Reductions Necessary to Reach 450 ppm CO_2e	36-49%	60-72%

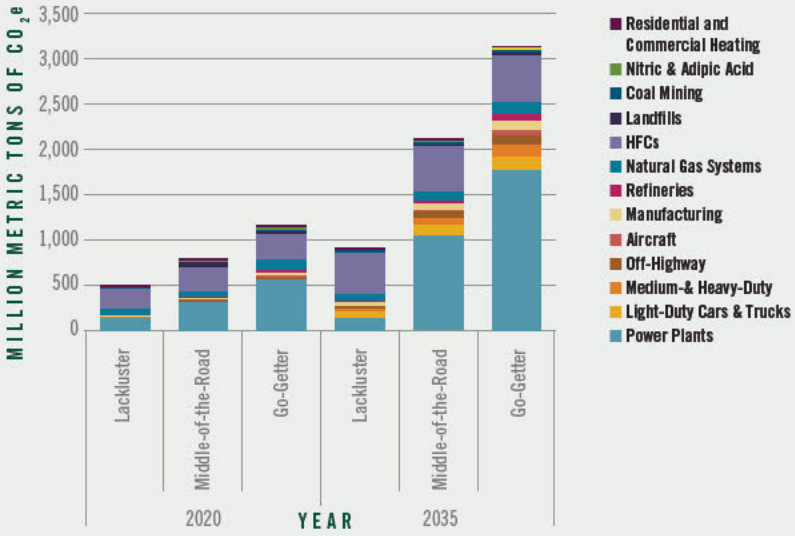
Note: Figure depicts changes in consumption of HFCs.

If the U.S. Administration pursues a lackluster effort, go-getter state action will not be sufficient to make up the emissions gap and reduce GHG emissions 17 percent below 2005 levels by 2020. However, as shown in Figure 2, the 17 percent GHG reduction goal can be achieved with a state go-getter effort along with middle-of-the-road federal action. State action with go-getter federal action is not shown, as it does not provide significant reductions above and beyond other combinations of state and federal action that were considered as a result of the way the scenarios are defined.

BOX S-2 Greenhouse Gas Emissions Reductions from Federal Action

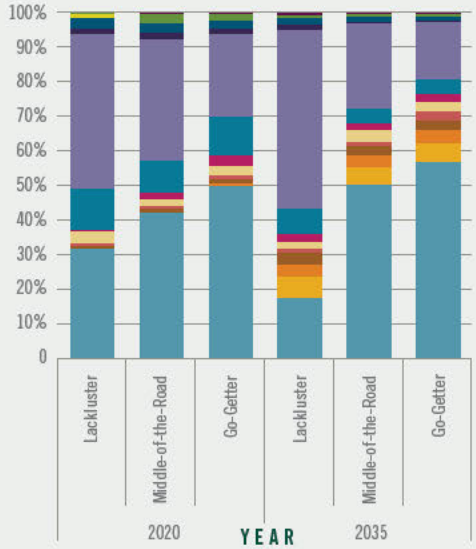
The majority of potential GHG benefits come from actions taken in the power sector, energy efficiency improvements, reducing HFC consumption, and reducing methane emissions from natural gas systems. These actions represent between 80 and 93 percent of potential GHG reductions across all scenarios in 2020 and 2035, and are necessary to achieve a 17 percent reduction below 2005 GHG emissions levels.

FIGURE S-2 Greenhouse Gas Emissions Reductions from Federal Action, in million metric tons



Note: Figure depicts changes in consumption of HFCs.

FIGURE S-3 Greenhouse Gas Emissions Reductions from Federal Action, as a percent of total reductions



Note: Figure depicts changes in consumption of HFCs.

BOX S-3 Greenhouse Gas Emissions Reductions from State Action Only

Improvements in the power sector largely drive reductions in all of the scenarios that examine the impact of state actions without any new federal actions. This is accomplished through a combination of GHG performance standards, renewable and energy efficiency standards, building codes, and policies to promote combined heat and power. In our scenarios those actions can alleviate the demand for up to 1,280 terra watt-hours of conventional sources of electricity in 2035. This is offset to a limited extent through increased vehicle electrification, which increases demand by up to 66 terra watt-hours of electricity in 2035.

States can implement many of the same types of policies as federal agencies. They can also take additional actions that increase electric efficiency, renewable electricity generation, building performance, and combined heat and power penetration.

However, states are less well-equipped to reduce HFC consumption, adopt appliance and equipment efficiency standards where federal standards already exist, and to drive reductions in GHG emissions from off-highway vehicles and aviation. As a result, under our scenarios, state action alone is insufficient to achieve the near-term and long-term GHG reduction targets.

FIGURE S-4 State Actions that Affect Electricity Supply and Demand

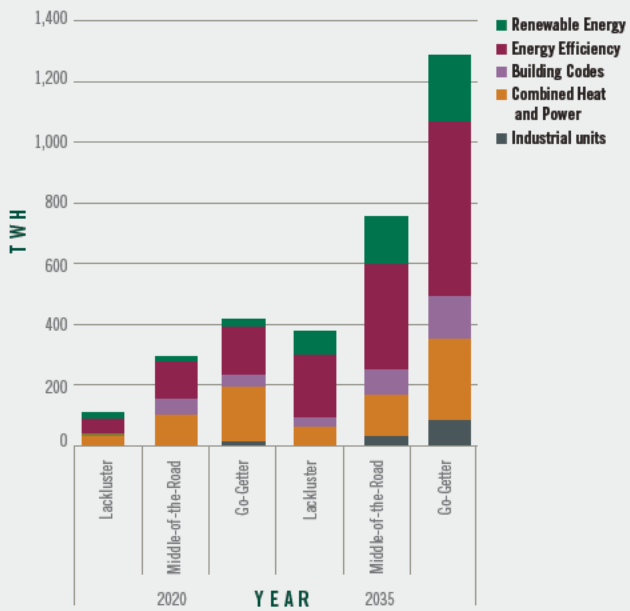


FIGURE S-5 Greenhouse Gas Emissions Reductions from State Action, in million metric tons

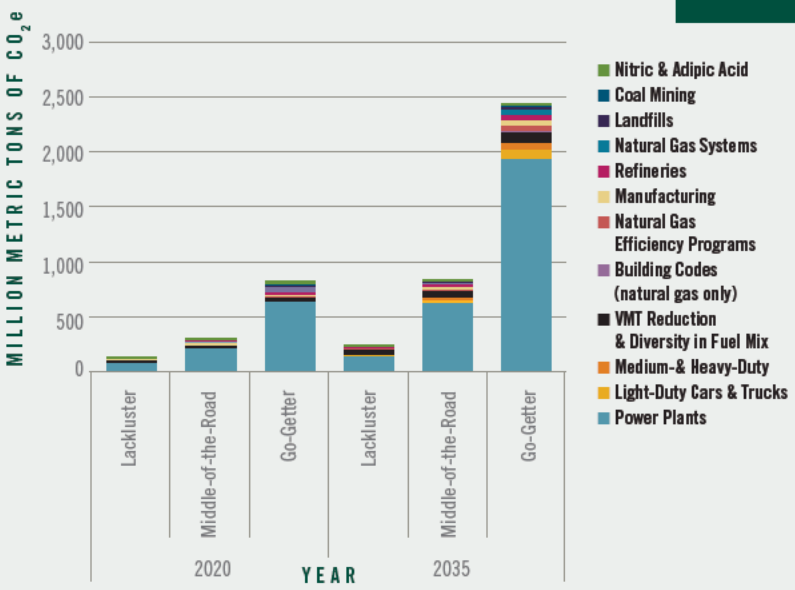
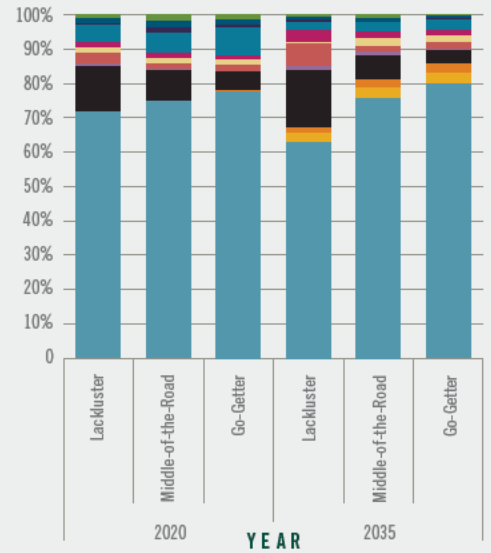


FIGURE S-6 Greenhouse Gas Emissions Reductions from State Action, as a percent of total reductions from state actions



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We operate globally because today's problems know no boundaries. We are avid communicators because people everywhere are inspired by ideas, empowered by knowledge, and moved to change by greater understanding. We provide innovative paths to a sustainable planet through work that is accurate, fair, and independent.

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WORLD
RESOURCES
INSTITUTE

10 G Street, NE (Suite 800)
Washington, DC 20002
USA
Tel: (1 202) 729 76 00
Fax: (1 202) 729 76 10
www.wri.org

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