Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2020: Updates Under Consideration for Abandoned Oil and Gas Wells

This memo discusses updates under consideration for the 2022 *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (GHGI) for abandoned oil and gas well activity data.

1 Current GHGI Methodology

EPA began estimating abandoned oil and gas well emissions in the 2018 GHGI. Details of the abandoned well calculation methodology are provided in the memorandum *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2016: Abandoned Wells in Natural Gas and Petroleum Systems (2018 Abandoned Wells memo)*.[1]

The total population of abandoned wells over the time series is estimated using both historical data from U.S. state databases and the U.S. Geological Survey (USGS), as well as contemporary data (i.e., post-1975) from Enverus, a company that provides oil and gas industry data.[2] Historical datasets are used to account for old wells with installation and abandonment pre-dating Enverus data coverage (e.g., wells that were drilled in the 1800's which are not included in the Enverus dataset). Based on an analysis of oil, gas, and dry well counts from individual US State databases and the USGS, the historical number of abandoned wells not captured by Enverus is estimated to equal 1.1 million wells for year 1975. To develop a complete count of abandoned wells for each year in the GHGI, this value of 1.1 million abandoned wells is added to the count of abandoned wells from Enverus for each year of the time series.

Contemporary abandoned wells from Enverus are classified as either oil or gas wells based on well production volumes in Enverus, which are used to calculate the gas-to-oil ratio (GOR) for this assessment; abandoned wells are classified as oil wells if the GOR is less than 100 mcf/bbl and are classified as gas wells if the GOR is equal to or greater than 100 mcf/bbl. Remaining wells with a spud date or completion date but no production data are considered to be abandoned dry wells. Dry wells are assigned as either oil or gas wells using the ratio of wells that were classified as abandoned oil and gas wells within Enverus.[3]

The total national abandoned oil and gas well population (contemporary plus historic) is then split into plugged and unplugged wells for each year in the time series. Enverus data are first used to calculate the fraction of plugged abandoned wells for the years 2016 and later (31 percent in 2016, 34 percent in 2017 and 2018, and 41 percent in 2019). The plugged fraction for all earlier years is then calculated by assuming that all abandoned wells are unplugged in 1950 and applying linear interpolation between the 1950 and 2016 values.

Lastly, the abandoned well counts in each category are also split between wells in the Appalachia region and wells outside of the Appalachia region. Region-specific emission factors (EFs) for plugged and unplugged abandoned wells are then applied to these region-specific well counts to calculate national emissions from abandoned wells in the GHGI.

Due to changes in the structure of the Enverus data, the national fraction of plugged abandoned wells was calculated differently for year 2019 in the 2021 GHGI. A recent restructuring in the raw Enverus data resulted

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[1] https://www.epa.gov/sites/default/files/2018-04/documents/ghgemissions_abandoned_wells.pdf

[2] https://www.enverus.com/

[3] Due to changes in the structure of the Enverus data, the total number of abandoned oil and gas wells (including dry wells) were calculated using a different methodology in the 2021 GHGI. In the restructured Enverus data, fewer wells had production data available and as a result, more wells were classified as dry wells. To develop an estimate for the 2021 GHGI, the "production type" field within Enverus was used to classify some dry wells as gas or oil; the production type field is not populated by Enverus but typically the state agency provides the data and categories of oil, gas, and coal bed methane (CBM) are identified. This approach resulted in a comparable number of abandoned wells being assigned as gas or oil wells for the 2021 GHGI as for the 2020 GHGI.

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in significantly more abandoned wells that were plugged as of 2019 than in prior years, which would have led to a dramatic one-year increase in well plugging that potentially reflected a change in reporting rather than real plugging activity levels. Therefore, EPA applied a different methodology to calculate the fraction of plugged wells in year 2019 for the 2021 GHGI. To calculate a value for 2019, EPA for the first time considered the historical well counts by assuming that the 1.1 million historical abandoned wells are all unplugged. The previous methodology developed for the 2018 GHGI did not consider the historical abandoned wells when estimating the national fraction of plugged wells and relied only on the data available in Enverus. In the 2021 GHGI, EPA noted plans to revisit its calculation of the plugging status of abandoned wells.

The restructured Enverus data also includes additional well status codes that have the potential to impact the estimated plugged versus unplugged split. The well status code assignments were not adjusted for the 2021 GHGI, but considerations for that are discussed in Section 3.

2 Available Data

Enverus' DrillingInfo dataset provides well data (or lease-level data for certain states) and well-level (or lease-level) production data. The abandoned well queries completed for the GHGI use the DrillingInfo wells table, which includes basic production information such as the total volume of oil and gas produced over the life of a well. However, the number of wells that have production data within the DrillingInfo wells table is fewer now than previously was available from DrillingInfo data. In addition, certain DrillingInfo fields are populated differently. Section 3 provides details of the changes due to the restructured Enverus data.

3 Analysis of Available Activity Data

EPA analyzed potential approaches for estimating the total abandoned well counts and the population of abandoned wells that is plugged versus unplugged in light of the restructured Enverus data and discusses each of these in the following sub-sections.

3.1 National Abandoned Well Counts

The total population of abandoned wells over the time series is estimated using both Enverus DrillingInfo and historical data. The time series counts are recalculated for each inventory to reflect the most up-to-date information from Enverus. The restructured Enverus data, in particular the DrillingInfo wells table which is used to estimate the count of abandoned wells, contains fewer well records with production data than in past years. As such, fewer wells can be directly classified as gas or oil wells and are instead considered dry wells per the definition in Section 1. For the 2021 GHGI, EPA used an additional "production type" field for these wells to apportion the dry well population to either oil or gas wells. For example, for wells without recorded production volumes, wells with the "oil" production type were assigned to oil wells and the "gas" and "CBM" production types were assigned to gas wells.

Without data available to corroborate the production type field assignments in Enverus and to maintain consistency with the general GHGI approach to classify wells using GOR, EPA is considering reverting to the methodology developed for the 2018 GHGI and relying only on GOR to classify abandoned wells as oil, gas, or dry wells. Table 1 compares the counts of abandoned oil, gas, and dry wells for year 2019 from the 2021 GHGI and the update under consideration. In addition, other adjustments to querying the Enverus DrillingInfo wells data led to increases in the overall number of abandoned wells estimated to be within Enverus (i.e., 2.2 million abandoned wells in the 2021 GHGI versus 2.3 million abandoned wells in the 2022 GHGI update under consideration, from Table 1, though both approaches rely on the same data).

Table 1. Comparison of Year 2019 Abandoned Well Counts from Enverus DrillingInfo (Thousands of Wells)

Well Type	2021 GHGI[a]	Update Under Consideration for 2022 GHGI[b]
Oil Wells	1,025	778
Gas Wells	339	233
Dry Wells	844	1,320
Total	**2,208**	**2,331**

a. Wells are classified as oil and gas based on GOR analysis or production type.
b. Wells are classified as oil and gas based on GOR analysis only.

Relying exclusively on GOR to assign abandoned wells as oil or gas wells results in a small increase in the number of abandoned oil wells, compared to when the production type field is also considered. Table 2 compares the final count of abandoned oil and gas wells; these counts equal the Enverus abandoned well counts from Table 1 (with dry wells partitioned based on the relative oil/gas well counts) plus the 1.1 million historical abandoned wells.

Table 2. Total Count of Abandoned Wells in Year 2019 (Thousands of Wells)

Well Type	2021 GHGI	Update Under Consideration for 2022 GHGI
Oil Wells	2,713	2,842
Gas Wells	647	599
Total	**3,360**	**3,440**

3.2 Plugging Status - Assignment and Calculations

EPA uses the 'Well Status' field in Enverus DrillingInfo to estimate the fraction of abandoned wells that are plugged versus those that are unplugged in a given year. Note that Enverus does not provide the date when a well was plugged. Therefore, the national plugged versus unplugged fraction for each year since 2016 has been calculated from the Enverus data used for each inventory cycle and is considered to only be a snapshot of that point in time. The national plugging fraction for all years prior to 2016 is calculated using linear interpolation, as described in Section 1.

EPA assigns each Enverus Well Status Code as either plugged, unplugged, or not applicable to the abandoned wells analysis (e.g., "active" Well Status Code). The 2018 Abandoned Wells memo presents the Well Status Codes that were available in Enverus at that time. Five additional Well Status Codes have been added in the restructured Enverus data. Table 3 presents the Well Status Codes that are currently available in Enverus. The five well status codes not previously available in the Enverus data are marked with "n/a" in Column 5 (Current Plugging Status Assignments). Column 4 (Plugging Status Assignments Under Consideration) identifies the plugging status assignments EPA is considering for the 2022 GHGI, including the initial proposed assignment for the five codes that were not previously in the data. EPA maintained the same plugging status for all Well Status Codes that were previously in Enverus. Table 3 data are considered to be representative of year 2019, except for the 2018 GHGI percentages presented for comparison in the last column of the table.

Table 3. Well Status Code Data - Summary and Plugging Status Assignments

Well Status Code	Number of Wells in Enverus (Millions)	Percent of Wells in Enverus	Plugging Status Assignments Under Consideration for 2022 GHGI	Current Plugging Status Assignments	*2018 GHGI Percent of Wells in Enverus*
P&A (plugged and abandoned)	1.388	41%	plugged	plugged	*20%*
ACTIVE	0.873	26%	exclude	exclude	*27%*
INACTIVE	0.823	24%	unplugged	unplugged	*42%*
COMPLETED	0.101	3%	unplugged	n/a	*n/a*
SHUT-IN	0.066	2%	unplugged	unplugged	*1%*
DRILLED	0.063	2%	unplugged	n/a	*n/a*
ABANDONED	0.032	0.9%	unplugged	unplugged	*1%*
TA (temporarily abandoned)	0.012	0.4%	unplugged	n/a	*n/a*
DUC (drilled but uncompleted)	0.006	0.2%	exclude	n/a	*n/a*
ORPHAN	0.006	0.2%	unplugged	n/a	*n/a*
All Other Codes	0.010	0.3%	exclude	exclude	*9%*

exclude = Well Status Code does not indicate likely abandonment.
n/a = Well Status Code was not available in Enverus when the abandoned wells methodology was originally developed for the 2018 GHGI.

When EPA calculated the national fraction of plugged and unplugged abandoned wells using the plugging status assignment (Columns 4 and 5 of Table 3) and the number of wells for each code (Column 2 of Table 3), 56-60 percent of abandoned wells in the year 2019 were estimated to be plugged. This is a large increase from previous years. For example, using the same approach, EPA estimated that 34 percent of abandoned wells were plugged in year 2018 (from the 2020 GHGI). This increase in plugging fraction is largely due to changes in the underlying Enverus data, particularly for wells with a Well Status Code of "P&A" and "inactive" (see Columns 3 and 6 of Table 3). Whereas most wells (42%) were identified as inactive in the previous Enverus data (which are considered to be unplugged), the restructured Enverus data now indicate most wells (41%) are plugged and abandoned (P&A).

In light of this significant change in the data, EPA is reconsidering whether and how to incorporate the historical data into the calculation of the national fraction of plugged and unplugged abandoned wells. As noted in Section 1, for year 2019 in the 2021 GHGI, EPA also considered all historical wells to be unplugged, which led to a fraction of plugged wells (41 percent) that was more consistent with the fraction of plugged wells calculated from Enverus-only data in prior years. EPA is considering applying this methodology moving forward, which is a change relative to the approach used in the 2018 through 2020 GHGIs. Table 4 presents the plugged versus unplugged split from recent inventories compared to the approaches under consideration. EPA also requests alternative approaches for consideration; see Section 6.

Table 4. Approaches to Estimate the Split Between Plugged and Unplugged Abandoned Wells.

Year	Well Status Code Assignment (Current or Update under Consideration)[a]	Includes Historical Well Counts in Calculation?	Plugged Well Fraction	Unplugged Well Fraction
Previous Inventories				
Year 2016 (2018 GHGI)	Current	No	31%	69%
Year 2017 (2019 GHGI)	Current	No	34%	66%
Year 2018 (2020 GHGI)	Current	No	34%	66%
Year 2019 (2021 GHGI)	Current	Yes, assume all are unplugged	41%	59%
Other Approaches and Updates Under Consideration				
Year 2019	Current	No	60%	40%
Year 2019	Update under Consideration	No	56%	44%
Year 2019	Update under Consideration	Yes, assume all are unplugged	38%	62%

a. From Columns 4 and 5 of Table 3.

4 Time Series Considerations

For the time series of the national fraction of plugged and unplugged wells, EPA is considering whether to maintain the use of the national fractions calculated for years 2016-2018 (which rely on the previous versions of the Enverus data) or to use the latest inventory year data as a new end point and recalculate the entire time series using an interpolation between zero percent plugged in 1950 and the plugging fraction for the latest year. If EPA maintains the data for years 2016-2018, there is an increase in plugged wells between 2018 and 2019 of approximately 250,000 wells that may not be representative of the actual number of wells plugged in one year. Using the year 2019 data as the new end point for linear interpolation (and interpolating back to zero percent plugged wells in 1950) would increase the number of plugged abandoned wells across the time series; the percent of plugged abandoned wells in a given year would increase by approximately 4% across the time series.

EPA would continue to use information from Enverus (i.e., last date of production, completion date, spud date) to estimate the total population of abandoned wells in each year of the time series, supplemented with an estimate of historic abandoned wells not included in Enverus.

5 Preliminary National Emissions Estimates

Table 5 presents the national abandoned oil and gas well CH_4 emissions estimated using approaches discussed in this memo.

Table 5. National CH_4 Emissions (kt) for Various Abandoned Well Approaches

Year	Total # Abandoned Wells Approach[a]	Well Status: Assignment / Historical Wells Approach[b]	Abandoned Oil Well Emissions (kt)		Abandoned Gas Well Emissions (kt)	
			Plugged	Unplugged	Plugged	Unplugged
Year 2019 (2021 GHGI)	2021 GHGI	Current / Included, All Unplugged	0.82	207.8	0.25	54.3
Year 2019	Update Under Consideration	Current / Not Included	1.25	146.8	0.34	33.9
Year 2019	Update Under Consideration	Update Under Consideration / Not Included	1.17	163.0	0.32	37.7
Year 2019	Update Under Consideration	Update Under Consideration / Included, All Unplugged	0.80	227.9	0.22	52.7

a. See Section 3.1 and Table 1 for background.
b. See Section 3.2 and Table 4 for more detailed explanations of the approaches.

6 Requests for Stakeholder Feedback

EPA seeks stakeholder feedback on the update under consideration discussed in this memo and the questions below.

1. EPA seeks feedback on the recommended approach to estimate the population of abandoned wells from Enverus data. Should only the GOR be used to determine oil and gas wells, or should the Enverus "production type" field also be used to apportion some dry wells to oil and gas wells?
2. EPA seeks feedback on the plugging status assignments in column 4 of Table 3.
3. EPA seeks feedback on whether the 1.1 million historical abandoned wells that are not captured in Enverus should be considered unplugged wells when estimating the national fraction of plugged and unplugged abandoned wells. EPA also seeks feedback on alternative approaches and/or data sources to estimate the fraction of plugged and unplugged abandoned wells.
4. For the time series of the national fraction of unplugged and plugged wells, EPA is considering whether the fractions calculated from previous Enverus datasets for the years 2016-2018 should be retained or if these data should be removed and only the fractions based on the restructured Enverus data (beginning in year 2019) should be used.