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

This memorandum documents the updates implemented in EPA's 2022 *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (GHGI) for abandoned oil and gas wells. Additional considerations for abandoned wells were previously discussed in a memorandum released in September 2021 (Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2020: Updates Under Consideration for Abandoned Oil and Gas Wells).[1]

1   Previous (2021) GHGI Methodology

EPA began estimating abandoned oil and gas well emissions in the 2018 GHGI. Additional details of the abandoned well calculation methodology used beginning in 2018 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).*[2]

The total population of abandoned wells over the time series was estimated using 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.[3] Historical datasets were 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 U.S. State databases and the USGS, the historical number of abandoned wells not captured by Enverus was 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 was added to the count of abandoned wells from Enverus for each year of the time series.

Contemporary abandoned wells from Enverus were classified as either oil or gas wells based on well production volumes in Enverus, which were used to calculate the gas-to-oil ratio (GOR) for this assessment; abandoned wells were classified as oil wells if the GOR was less than 100 mcf/bbl and were classified as gas wells if the GOR was equal to or greater than 100 mcf/bbl. Remaining wells with a spud date or completion date but no production data were considered to be abandoned dry wells. Dry wells were assigned as either oil or gas wells using the ratio of wells that were classified as abandoned oil and gas wells within Enverus.[4]

The total national abandoned oil and gas well population (contemporary plus historic) was then split into plugged and unplugged wells for each year in the time series. Enverus data were 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 was then calculated by assuming that all abandoned wells were unplugged in 1950 and applying linear interpolation between the 1950 and 2016 values.

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[1] https://www.epa.gov/system/files/documents/2021-09/2022-ghgi-update-abandoned-wells_sept-2021.pdf

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

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

[4] 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, as compared to prior Inventories. 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.

Lastly, the abandoned well counts in each category were 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 were 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, compared to years 2016 through 2018. A restructuring in the raw Enverus data resulted 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.

2   Available Activity Data for the 2022 GHGI

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 used for previous inventories. In addition, certain DrillingInfo fields are populated differently. Section 3 provides details of the changes due to the restructured Enverus data. The DrillingInfo wells table was most recently downloaded in August 2021, for use in the 2022 GHGI.

3   Approach Applied in the 2022 GHGI

EPA analyzed approaches for estimating abandoned well counts from Enverus (see section 3.1), the historical abandoned wells population (see section 3.2), and the population of abandoned wells that is plugged versus unplugged (see section 3.3) in light of the restructured Enverus data.

3.1   Abandoned Well Counts from Enverus

As in previous inventories and described in Section 1, 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 contemporary (post-1975) abandoned wells, contains less information on well-level production volumes than in past years. As such, in the 2022 GHGI, of the total abandoned wells in the Enverus dataset, fewer wells can be directly classified as gas or oil wells and are instead considered dry wells per the definition in Section 1. To account for this issue in the 2021 GHGI, EPA used an additional "production type" field available in the DrillingInfo wells table 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.

EPA considered reverting to the methodology developed for the 2018 GHGI and relying only on GOR to classify abandoned wells as oil, gas, or dry wells versus maintaining the 2021 GHGI methodology, which uses both GOR and the production type field to classify abandoned wells. Table 1 compares the counts of abandoned oil,

gas, and dry wells for year 2019 from the 2021 GHGI and the well counts following both approaches considered.

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

Well Type	2021 GHGI[a,c]	GOR + Production Type Option (Used in 2022 GHGI)[a]	GOR Only Option[b]
Oil Wells	1,025	1,338	978
Gas Wells	339	414	279
Dry Wells	844	808	1,301
Total	**2,208**	**2,559**	**2,559**

   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.
   c.   The abandoned well counts are lower in the 2021 GHGI due to an error in the Enverus DrillingInfo wells table download where certain records were inadvertently excluded.

Due to the large number of wells that would have been classified as dry wells otherwise, EPA decided to use the production type field, in addition to GOR calculations, to classify abandoned wells into oil, gas, and dry well types for the 2022 GHGI (similar to the 2021 GHGI methodology). Comments received in response to the stakeholder webinar and September 2021 memo supported using this approach.

3.2 Historical Abandoned Well Counts

EPA used historical oil and gas well data from U.S. state databases and USGS to estimate the historical count of abandoned oil and gas wells in 1975. The historical data contains the number of wells drilled by 1973 and counts of active wells in 1975, by type of well. The historical data are available at the state-level. The previous GHGI methodology estimated abandoned well counts in the historical dataset by subtracting the total count of active wells from the total count of wells drilled at the national level, for both oil and gas wells individually. All dry wells drilled were assigned as abandoned. The total counts of national abandoned oil, gas, and dry wells for 1975 from Enverus were then subtracted from the corresponding historical dataset to calculate the missing historical abandoned well estimate. The resulting number of historical abandoned wells were then added to each year of the time-series, under the assumption that these wells are not captured by Enverus data.

For the 2022 GHGI, EPA developed the counts of historical abandoned wells at the state rather than national level, by subtracting the total active wells (sum of oil, gas, and dry) from the total wells drilled for each state. For almost all states, the total wells drilled exceeded the total active wells. For five states (AZ, MD, MO, NV, UT), the historical datasets indicated more active wells than wells drilled, which is in part due to different well type (e.g., gas, oil, dry) classification methods used by the multiple data sources that are used in this approach. In these cases, the number of historical abandoned wells is set to zero. The total active wells in these states for 1975 were fewer than 2,000 and have a minor impact on the overall results. After estimating the historical abandoned wells for each state in 1975, EPA subtracted the abandoned well counts in 1975 from Enverus DrillingInfo data for each state to estimate the historical abandoned wells not captured by Enverus for each state. Lastly, to apportion the total counts of abandoned wells in 1975 in each state to either oil or gas wells, EPA applied the percentage of drilled oil and gas wells in each state from the U.S. State databases and USGS.

Table 2 compares the estimate of historical abandoned wells not captured by Enverus using the state-level and national-level approaches, based on the most recent Enverus DrillingInfo dataset, as well as the historical abandoned wells counts from the 2021 GHGI. Using total well data at the state-level instead of counts by well type at the national-level does not significantly change the results (i.e., the counts increase by about two percent).

Table 2. Comparison of Historical Abandoned Wells Not Captured by Enverus DrillingInfo, Year 1975 (Thousands of Wells)

Well Type	2021 GHGI[a]	State-Level Approach (Used in 2022 GHGI)[b]	National-Level Approach[a]
Oil Wells	796	1,001	767
Gas Wells	95	171	84
Dry Wells	261	N/A	296
Total	**1,152**	**1,172**	**1,147**

    a. Estimated the number of abandoned wells using well type and national-level data.

    b. Estimated the number of abandoned wells using total wells and state-level data

3.3   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 calculated from the Enverus data is considered to only be a snapshot of that point in time.

EPA assigned 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 (developed for the 2018 GHGI) presents the Well Status Codes that were available in Enverus at that time. Recently, 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 (Previous Plugging Status Assignments). Column 3 (Plugging Status Assignments for 2022 GHGI) identifies the plugging status assignments EPA applied for the 2022 GHGI. EPA maintained the same plugging status for all Well Status Codes that were previously in Enverus. Table 3 data are representative of year 2020, except for the 2018 GHGI percentages presented 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)	Plugging Status Assignments for 2022 GHGI	Percent of Abandoned Wells in Enverus for 2022 GHGI[a]	Previous Plugging Status Assignments	Percent of Abandoned wells in Enverus for 2018 GHGI
P&A (plugged and abandoned)	1.607	plugged	58%	plugged	34%
INACTIVE	0.809	unplugged	29%	unplugged	63%
SHUT-IN	0.091	unplugged	3%	unplugged	1%
ABANDONED	0.032	unplugged	1%	unplugged	2%
COMPLETED	0.115	unplugged	4%	NA	NA
TA (temporarily abandoned)	0.059	unplugged	2%	NA	NA
DRILLED	0.032	unplugged	1%	NA	NA
ORPHAN	0.006	unplugged	0.2%	NA	NA
ACTIVE	1.216	exclude	NA	exclude	NA
DUC (drilled but uncompleted)	0.009	exclude	NA	n/a	NA
All Other Codes	0.010	exclude	NA	exclude	NA

    a. Percentages due not add to 100 due to rounding.

exclude = Well Status Code does not indicate likely abandonment.

NA = 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 3 and 5 of Table 3) and the number of wells for each code (Column 2 of Table 3), 58 percent of total abandoned wells in the year 2020 were estimated to be plugged. This is a large increase from previous years (i.e., 2016 – 2018). 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 5 of Table 3). Whereas most wells (63%) were identified as inactive in the previous Enverus data (which are considered to be unplugged), the restructured Enverus data now indicate most wells (58%) are plugged and abandoned (P&A).

In the 2022 GHGI, EPA considered all historical wells to be unplugged. Table 4 presents the plugged versus unplugged split from recent inventories compared to the updated approach.

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

Year	Treatment of Historical Wells	Total Plugged Well Fraction	Total Unplugged Well Fraction
Previous Inventories			
Year 2016 (2018 GHGI)	Apply plugging percentage from Enverus dataset	31%	69%
Year 2017 (2019 GHGI)	Apply plugging percentage from Enverus dataset	34%	66%
Year 2018 (2020 GHGI)	Apply plugging percentage from Enverus dataset	34%	66%
Year 2019 (2021 GHGI)	Assume all are unplugged	41%	59%
Approach in 2022 GHGI			
Year 2020 (2022 GHGI)	Assume all are unplugged	41%	59%

4   Time Series Considerations

For the time series of the national fraction of plugged and unplugged wells, EPA used the latest inventory year (2020) data as a new end point for the plugging interpolation, recalculating the entire time series using an interpolation between zero percent plugged in 1950 and the plugging fraction for the latest year (2020). Using the year 2020 data as the new end point for linear interpolation (and interpolating back to zero percent plugged wells in 1950) increased the percent of plugged abandoned wells across the time series; the percent of plugged abandoned wells in a given year increased by approximately 25 percent across the time series.

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

5   Updated National Emissions Estimates

Table 5 compares the year 2019 national abandoned oil and gas well CH_4 emissions for the 2021 GHGI and the 2022 GHGI. The estimates for CO_2 are developed based on the calculated CH_4 and therefore were updated as well, changing from 4.2 in 2019 in the 2021 GHGI to 4.5 kt in 2019 in the 2022 GHGI for abandoned oil wells and from 2.4 in 2019 in the 2021 GHGI to 2.5 kt in 2019 in the 2022 GHGI for abandoned gas wells. See Table 1 and Table 2 for abandoned well counts and Table 4 for the split between plugged and unplugged abandoned wells.

Table 5. Comparison of National CH$_4$ Emissions (kt) for Abandoned Wells

Year	Abandoned Oil Well Emissions (kt)		Abandoned Gas Well Emissions (kt)	
	Plugged	Unplugged	Plugged	Unplugged
Year 2019 (2021 GHGI)	0.82	207.8	0.25	54.3
Year 2019 (2022 GHGI)	0.77	219.9	0.22	57.8

6 Requests for Stakeholder Feedback

EPA sought stakeholder feedback on the approaches under consideration through two 2021 webinars, in the September 2021 memo, and in the public review draft of the GHGI. EPA received stakeholder comments on the September 2021 version of the memo and through the public review draft of the Inventory. Stakeholder feedback is summarized here.

A stakeholder recommended using the production type field in the DrillingInfo wells table to apportion dry wells to oil and gas wells. A stakeholder did not support applying the assumption that all historical abandoned wells not captured by Enverus are unplugged. Instead, the stakeholder recommended looking at wells abandoned by 1975 in the DrillingInfo wells table and applying the percentage of those wells that are plugged to the historical wells not captured by Enverus. A stakeholder requested further information on the development of the count of historical wells not captured by Enverus and how dry wells are considered.

The requests for stakeholder feedback below were not updated for this memorandum and are copied from the September 2021 memorandum:

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.