

Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2017: Updates Under Consideration for Well-Related Activity Data

In supporting documentation associated with the development of EPA's 2018 *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (GHGI), EPA stated plans to assess options to increase consistency and improve activity data for a number of sources and activities related to onshore oil and gas wells.

This memo summarizes current methodologies and updates under consideration to increase consistency and accuracy for certain emission source estimates that rely on well-related activity data.

Note, this memo references a memo under concurrent development, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2017: Updates Under Consideration for Incorporating GHGRP Data*¹, which focuses on incorporating GHGRP data into the 2019 GHGI and includes a dedicated section on hydraulically fractured (HF) oil well completions and workovers.

1 Current GHGI Methodologies

Table 1 below summarizes the data sources that are currently used to develop activity data for emission sources that directly rely on counts of wells or well-related activities. Appendix A provides a table that shows all well-related activity data over the time series as used in the 2018 GHGI (as well as data elements from updates under consideration, as discussed in Section 3).

Note that several existing GHGI methodologies documented in Table 1 (e.g., developing counts of active wells) rely on EPA's analysis of DrillingInfo's subscription-based digital DI Desktop raw data feed²; this data set is referred to throughout this memo as "DrillingInfo data."

Table 1. 2018 GHGI Well-Related Activity Data Summary

| Emission Source/Activity Data Element | Activity Basis | Data Source/Basis |
|---|----------------|---|
| Natural Gas Systems | | |
| Non-associated gas wells (less HF wells) | Wellheads | DrillingInfo data analysis; active wells with GOR>100 mcf/bbl |
| Gas wells with hydraulic fracturing | Wellheads | DrillingInfo data analysis; subset of non-associated gas wells located in unconventional formation and/or horizontally drilled |
| Non-HF gas well completions | Events | 400 completions/year for all gas wells in 1992 (GRI/EPA 1996 ³), scaled in future years |
| Non-HF gas well workovers | Events | 4.35% of non-HF gas wells (GRI/EPA 1996) |
| HF gas well completions (four control categories) | Events | GHGRP direct counts (if higher than DrillingInfo data analysis; count of newly spud or newly producing gas wells located in unconventional formation and/or horizontally drilled) |
| HF gas well workovers (four control categories) | Events | 1% of HF gas wells are worked-over annually |

¹ <https://www.epa.gov/ghgemissions/stakeholder-process-natural-gas-and-petroleum-systems-1990-2017-inventory>

² <https://info.drillinginfo.com/products/di-plus/>

³ Methane Emissions from the Natural Gas Industry. Prepared by Harrison, M., T. Shires, J. Wessels, and R. Cowgill, eds., Radian International LLC for National Risk Management Research Laboratory, Air Pollution Prevention and Control Division, Research Triangle Park, NC. EPA-600/R-96-080a.

| Emission Source/Activity Data Element | Activity Basis | Data Source/Basis |
|--|----------------|--|
| Gas well drilling | Events | EIA – gas wells and fraction of dry wells drilled (data set last updated in 2010) |
| Petroleum Systems | | |
| Producing oil wells | Wellheads | DrillingInfo data analysis; active wells with GOR≤100 mcf/bbl |
| Heavy crude wells population fraction | Fraction | 7.05% of all oil wells (EPA/ICF 1999 ⁴) |
| Non-HF oil well completions | Events | EIA crude oil wells drilled, less HF oil well completions |
| Oil well workovers | Events | 7.5% of producing oil wells (Radian 1999 ⁵) |
| HF oil well completions (two control categories) | Events | DrillingInfo data analysis; count of newly spud or newly producing oil wells located in unconventional formation and/or horizontally drilled |
| Oil well drilling | Events | EIA – oil wells and fraction of dry wells drilled (data set last updated in 2010) |

2 Updates Under Consideration

EPA is considering implementing methodological updates focused on five general areas, to increase consistency and accuracy of activity data for certain emission sources shown in Table 1:

- **Well drilling:** The U.S. Department of Energy's Energy Information Administration (EIA) no longer maintains the well drilling activity data set within its *Monthly Energy Review* publication that was used to develop well drilling activity inputs in past GHGIs (most recent estimates cover through 2010), so the GHGI requires a new data source for the entire time series, or at least 2011 forward.
- **Well completions and workovers:** The non-HF gas well completion activity data methodology is based on industry characteristics in base year 1992 (from the 1996 GRI/EPA study). An updated data source should account for changing trends over time. Non-HF oil well completions are sometimes zero in recent time series years, due to limitations of the current data sources and methodologies for both oil well drilling and HF oil well completion counts. For HF gas well completions, the GHGRP reported counts are higher than those obtained from the DrillingInfo data analysis; due to the reporting threshold, GHGRP counts should represent a subset of national activity, so DrillingInfo counts should be equal to, or greater than, GHGRP direct counts. For HF oil well completions, EPA is beginning to review newly reported GHGRP activity data in comparison to existing activity developed from the DrillingInfo data analysis (refer to companion memo on incorporating GHGRP data into the 2019 GHGI). The current assumptions for workover rates have not been updated in recent years, and there is no current estimate representing HF oil well workovers.
- **Definition of oil versus gas well:** The current methodology estimates the count of active gas wells in a given year as any well in the DrillingInfo data set with a gas-to-oil ratio (GOR) > 100 mcf/bbl in that year, and active oil wells as those with GOR ≤ 100 mcf/bbl. Other industry data sets (e.g., those published by EIA) use different thresholds for defining oil versus gas wells. A value of 6 mcf/bbl is another common threshold. EPA reviewed available data reported under GHGRP subpart W to evaluate how reported GOR values compare to the current GHGI methodology.
- **Heavy versus light crude equipment service:** The fractions used to split counts of wellheads, headers, and separators between heavy and light crude service were developed in the 1990s and applied for all time series years. An updated data source should account for changing trends over time.
- **Identification of HF wells:** The current methodology identifies HF gas or oil wells as those horizontally drilled (based on DrillingInfo data) and/or located in a shale, low permeability, or coalbed formation.

⁴ Estimates of Methane Emissions from the U.S. Oil Industry (Draft Report). Prepared by ICF International. Office of Air and Radiation, U.S. Environmental Protection Agency. October 1999.

⁵ EPA/Radian (1999) Methane Emissions from the U.S. Petroleum Industry. Prepared by Radian International. U.S. Environmental Protection Agency. February 1999.

Potential GHGI updates to address these priority areas are discussed in more detail in the subsections below. Appendix A provides a table that shows all well-related activity data over the time series as used in the 2018 GHGI, as well as data elements from updates under consideration, as discussed below. After these priority areas are addressed, EPA might investigate updated methodology and/or data sources to potentially improve estimates for other well-related activity data elements.

2.1 Well Drilling

As described above, EIA no longer maintains the *Monthly Energy Review* well drilling activity data set that was used to develop well drilling activity inputs in past GHGIs (most recent estimates cover through 2010), so the GHGI requires a new data source for the entire time series, or at least 2011 forward. EPA is evaluating two general options to estimate well drilling counts over the time series:

1. Identify another data set published by EIA.
2. Develop methodology for querying DrillingInfo data set.

EPA is in the process of reviewing available EIA data that could provide updated well drilling activity. EPA is reviewing EIA's Drilling Productivity Report⁶ which provides counts of wells drilled, wells completed, and wells drilled but uncompleted; but the public data are not comprehensive (covers years 2014 forward, covers seven production regions (not all U.S. onshore), and does not include conventional wells). EPA is also reviewing data underlying a recently published EIA analysis of HF wells on its *Today in Energy* website⁷, which includes coverage of non-HF well drilling and completions. The *Today in Energy* drilling activity estimates, which are presented in graphical form on the website, are generally lower than those published in EIA's *Monthly Energy Review* over comparable time periods; this is due to exclusion of dry wells, which are included in current GHGI activity estimates.

At the same time, EPA is developing a methodology for querying the DrillingInfo data set to develop estimates of wells drilled. EPA is considering the following approach:

- Count all wells drilled in time series year N with:
 - Onshore location **-and-**
 - Spud date within year N **-or-** spud date not reported, but date of first production within year N+1
- Apportion counts between oil, gas, and dry production types
 - Dry or temporarily inactive (TIA) wells drilled: spud date within year N, but no production is reported in year N+1
 - Gas wells drilled: GOR in year N+1 >100 mcf/bbl
 - Oil wells drilled: GOR in year N+1 ≤ 100 mcf/bbl
- Apportion dry/TIA counts to natural gas and petroleum systems according to the year-specific split between gas wells drilled and oil wells drilled.

For a DrillingInfo-based methodology, EPA seeks feedback on a few additional considerations. First, whether this approach adequately accounts for dry wells (which are spud but do not achieve reportable production levels). Based on preliminary analysis of results, this approach does appear to sufficiently represent dry wells at comparable levels to the EIA data set; on average, dry wells (not including TIA wells which report production after year N+1) contribute 10% of total wells drilled. Second, whether this approach is overly inclusive of wells that may not be drilled for oil and gas production purposes but are present in the DrillingInfo data set. Second, how to account for time series coverage issues. For states without recently released data, EPA might develop a surrogate methodology wherein an early year's data are assigned to recent years to fill state-level data gaps, similar to the existing approach for counts of active wells. Additionally, total wells drilled in most recent time series year cannot

⁶ <https://www.eia.gov/petroleum/drilling/>

⁷ <https://www.eia.gov/todayinenergy/detail.php?id=34732>

be fully estimated by the current approach (i.e., GOR in year N+1 is not available); EPA is considering a surrogate approach such as using the previous year's estimate.

Appendix A shows well drilling counts across the time series in the 2018 GHGI, as well as relevant publicly available data from EIA's *Monthly Energy Review* publication and preliminary estimates by the DrillingInfo data analysis approach described above. EPA seeks stakeholder feedback on these approaches under consideration, or other data sets or methodologies to consider for well drilling activity data in the 2019 GHGI; see Section 3 for specific stakeholder feedback requests.

2.2 Well Completions and Workovers

As described above, the current methodology for well completion and workover event counts involves a mix of DrillingInfo data analyses, GHGRP data analyses, and historical assumptions.

EPA is investigating the use of DrillingInfo data and GHGRP data to update current activity data methodologies, including allocation across control categories. Specifically:

- Non-HF gas well completion counts: Currently based on industry characteristics in base year 1992 (from the 1996 GRI/EPA study). DrillingInfo data might offer an update to total activity across all time series years, and GHGRP data might be used to check/supplement DrillingInfo data and provide updated control assumptions in recent years.
- Non-HF oil well completion counts: Are sometimes zero in recent time series years, due to limitations of the current data sources and methodologies for both oil well drilling and HF oil well completion counts. DrillingInfo data might offer an update to total activity across all time series years.
- HF gas well completions: GHGRP reported counts are higher than those obtained from the DrillingInfo data analysis; due to the reporting threshold, GHGRP counts should represent a subset of national activity, so DrillingInfo counts should be equal to, or greater than, GHGRP direct counts. EPA is continuing to review DrillingInfo and GHGRP data to assess whether updates can be made to ensure that activity data for this source represents national coverage.
- HF oil well completions: EPA is beginning to review newly reported GHGRP activity data (refer to companion memo on incorporating GHGRP data into the 2019 GHGI) in comparison to existing activity developed from the DrillingInfo data analysis.
- Workover rates: Have not been updated in recent years, and there is no current estimate representing HF oil well workovers. EPA is beginning to review GHGRP activity data to ensure that activity data for workovers reflects trends over time and represents national coverage.

EPA has conducted a preliminary analysis to assess how workover rates reflected in the subpart W data compare to current GHGI assumptions. The subpart W data reporting structure and requirements limit the level of detail for such an analysis, due to: (1) there is not a specific reporting element indicating whether reported wells are HF or non-HF; and (2) non-HF oil well workovers are not reported. EPA analyzed the overall gas well workover rate, as summarized in Table 2. For gas wells reported under subpart W, the overall workover rate is 5-6% in recent years (compared to the current GHGI assumption of 4.35% for non-HF gas wells and 1% for HF gas wells).

Table 2. Subpart W Gas Well Workover Data and Calculated Workover Rate

| Subpart W Data Element | 2015 | 2016 |
|--|---------|---------|
| # Gas wells reported (Introduction ^a table AA.1.ii) | 309,132 | 284,112 |
| # Gas well workovers with HF reported | 263 | 103 |
| # Gas well workovers without HF reported | 18,031 | 14,957 |
| Calculated: Gas well workover rate | 6% | 5% |

a - Reported under 40 CFR 98.236(aa). Number of producing wells at the end of the calendar year. Data element "ii" refers to count from the "Sub-basin characterization" table.

Appendix A shows completion and workover counts across the time series in the 2018 GHGI. EPA seeks stakeholder feedback on improving the current methodology in the 2019 GHGI; see Section 3 for specific stakeholder feedback requests.

2.3 Definition of Oil versus Gas Well

The current methodology estimates the count of active gas wells in a given year as all wells in the DrillingInfo data set with a gas-to-oil ratio (GOR) > 100 mcf/bbl in that year, and active oil wells as those with GOR ≤ 100 mcf/bbl. By this definition, oil wells include associated gas wells.

Other data sets (e.g., those published by EIA) use different GOR thresholds for defining oil versus gas wells and might have different underlying assumptions regarding whether associated gas wells are a subset of oil wells. A value of 6 mcf/bbl is another common definition threshold, based on the oil and gas energy equivalence factor (6 mcf gas provides roughly the same amount of energy as 1 bbl oil equivalent (BOE); BOE is commonly used in financial statements to combine oil and gas production into a single measure).

EPA is beginning to review available data reported under GHGRP subpart W to evaluate how reported GOR values compare to the current GHGI methodology and consider whether the current production type delineation threshold of 100 mcf/bbl is appropriate. Reporters have been providing GOR data for oil wells under GHGRP subpart W since 2011, as summarized below. Per subpart W, oil wells are defined as producing from an oil formation, not defined by a specific GOR thresholds.

- RY2011-2014, summary data (Envirofacts table W_SUB_BASIN)
 - Average GOR for all oil wells operated by a company within a given sub-basin (i.e., county)
 - Well counts not directly reported
- RY2015-2016, summary data (Envirofacts table EF_W_FACILITY_OVERVIEW)
 - Average GOR for all oil wells operated by a company within a given sub-basin (i.e., county)
 - Associated counts of active wells as of the end of the calendar year are also reported
 - Available data cover over 400,000 wells
- RY2016, well-level data (Envirofacts table EF_W_ONSHORE_WELLS)
 - Well-level GOR, but only for oil wells that use measured data for calculating emissions from HF completions and workovers
 - Available data cover less than 160 wells

Table 3 below summarizes reported GOR data based on EPA's review of subpart W RY2015-2016 summary data (Envirofacts table EF_W_FACILITY_OVERVIEW, containing data for over 400,000 wells reported to the EPA as of August 5, 2017). For most oil wells reported under subpart W (73%), the sub-basin level average GOR falls within the current GHGI definition (≤100 mcf/bbl); while a significant fraction (27%) have higher average GORs. At a lower delineation threshold (e.g., 6 mcf/bbl), an even higher fraction of subpart W oil wells (roughly 50%) would be considered gas wells. Therefore, based on this analysis, EPA finds support for the current approach to delineating oil versus gas wells, but seeks stakeholder feedback (see Section 3 for specific requests on this topic).

Table 3. 2018 GHGI Well-Related Activity Data Summary

| Reporting Year | # Oil Wells with Specified GOR (mcf/bbl) | | | |
|----------------|--|-----------------|-----------------|-----------------|
| | GOR ≤10 | 10< GOR ≤100 | 100< GOR ≤1,000 | GOR >1,000 |
| 2015 | 123,446 [58%] | 28,104 [13%] | 11,674 [6%] | 48,091 [23%] |
| 2016 | 117,538 [57%] | 33,346 [16%] | 21,068 [10%] | 32,781 [16%] |
| Combined | 240,984 [58%] | 61,450 [15%] | 32,742 [8%] | 80,872 [19%] |

2.4 Heavy versus Light Crude Equipment Service

Heavy crude is defined as oil with lower than 20° API gravity. The GHGI uses separate EFs and activity data for wellheads, separators, and headers in heavy versus light crude service. Currently, the total counts of wellheads and headers are split into heavy versus light crude categories using an assumed split between heavy crude wells (7.05% of all oil wells) and light crude wells (92.95%). As documented in the 1999 EPA/ICF report⁸, this assumption, and its extension to wellhead and header activity, was developed for a 1995 base year; this split is currently applied to calculate equipment counts in all time series years. The split between heavy and light crude separators in base year 1995 is also documented in the 1999 EPA/ICF report: EPA assumed 90.1% of separators are in light crude service, and 9.9% in heavy crude service, and applied this split to all time series years. EPA has identified multiple data sources that might facilitate improvement to the current methodology by allowing calculation of the heavy versus light crude equipment splits in recent years.

GHGRP subpart W collects API gravity data associated with production in all oil sub-basins. Based on an analysis of RY2015 and RY2016 data, 19% and 18%, respectively, of oil wells reporting to GHGRP produce heavy crude. This value is higher than the current assumption of 7.05% of wells producing heavy crude (and subsequent assumption that 7.05% of wellheads and headers are in heavy crude service). To follow the existing methodology which assumes that per well equipment counts are the same for heavy crude and light crude wells (with the exception of separators, where on average over the time series each heavy crude well has 0.47 separators while each light crude well has 0.32 separators), EPA might analyze subpart W data specifically for facilities that produce heavy crude versus light crude. For this approach, however, only a subset of onshore production facility data can be analyzed—those with either all heavy crude sub-basin formation types or all light crude sub-basin formation types—since equipment counts (e.g., separators) are reported at a basin level. Table 4 summarizes the data availability and preliminary estimates of separator activity factors based on this approach. EPA might use subpart W data to update the equipment count splits in recent years and reflect updated industry trends.

Table 4. Subpart W Equipment Counts^a

| Data Set | Count of Separators | | Count of Wellheads | | Separators/Wellhead | | Number of Data Points (Facilities) | | Notes/Methodology |
|-----------------------------|---------------------|--------|--------------------|---------|---------------------|------|------------------------------------|------|---|
| | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | |
| All onshore oil prod | 76,690 | 86,890 | 213,380 | 221,326 | 0.36 | 0.39 | 319 | 315 | Counts from records classified in Table R.4 as "Crude oil production equipment" ^{tb} |
| Heavy crude-only facilities | 1,818 | 345 | 40,894 | 40,063 | 0.04 | 0.01 | 14 | 14 | Counts from records in Table R.4 – from facilities that produce only heavy crude (all sub-basins are oil with API gravity <20 in Table AA.1.ii) |
| Light crude-only facilities | 22,153 | 23,048 | 54,098 | 51,428 | 0.41 | 0.45 | 102 | 103 | Counts from records in Table R.4 – from facilities that produce only light crude (all sub-basins are oil with API gravity ≥20 in Table AA.1.ii) |

a - Data reported as of August 5, 2017.

b - For this approach, data from all facilities reporting presence of crude oil production equipment for equipment leak calculations can be used (ignoring the reported sub-basin formation type(s)).

Alternatively, EPA might use the methodology documented in the 1999 Radian report which was the basis for the 1999 EPA/ICF report estimates. The 1999 Radian report methodology analyzed state-level reported heavy oil

⁸ Estimates of Methane Emissions from the U.S. Oil Industry (Draft Report). Prepared by ICF International. Office of Air and Radiation, U.S. Environmental Protection Agency. October 1999.

production as a fraction of total oil production, then applied that fraction to state-level oil well counts to estimate heavy oil well counts in each state, and finally summed heavy oil well counts to estimate the national population fraction. The EIA data set described above provides oil production data by API gravity range for many states in years 2015 and 2016; EPA might pair this data set with state-level well counts from DrillingInfo to estimate the current national fraction of heavy oil wells in recent years. This approach would not facilitate development of a heavy versus light split for equipment other than wellheads (e.g., a specific split for separators as in the current methodology).

EPA seeks stakeholder feedback on the data sources and approaches described above, or other methodologies to consider for improving this aspect of the oil production segment major equipment activity estimates; see Section 3 for specific stakeholder feedback requests on this topic.

2.5 Identification of HF Wells

Appendix A shows current GHGI estimates of HF gas and oil well counts. There are limited public data estimating national total counts comparable to the GHGI; Appendix A shows year 2016 estimates from EIA's *Today in Energy* website.

EPA seeks stakeholder feedback on data sources and methodologies that might be used to update the current approach for identifying HF gas and oil wells within the DrillingInfo data set. EPA might retain the current assumption that all horizontally drilled wells are hydraulically fractured but update the methodology for identifying wells that do not report horizontal drill type but would be expected to be hydraulically fractured based on location in an unconventional formation. EPA is considering reviewing subpart W sub-basin-level (county-level) data to assess whether a crosswalk of location and HF indication might be constructed from or verified using reporting data, in order to estimate total national HF well counts (at least for recent time series years).

3 Requests for Stakeholder Feedback

Well Drilling (Section 2.1)

1. EPA seeks stakeholder feedback on data available to improve annual national activity estimates for well drilling across the time series. EPA seeks feedback on the most appropriate data source for updating the GHGI, whether it is highlighted in Section 2.1 (i.e., EIA or DrillingInfo) or another source that should be considered.
2. EPA seeks feedback on how to ensure time series consistency, given the current EIA data source provides annual activity through 2010. Should a new data source cover only recent years, or be used to entirely replace current estimates?
3. As EPA further considers developing annual well drilling activity estimates from DrillingInfo data, feedback is sought on the specific methodology and other considerations outlined in Section 2.1. Specifically:
 - a. Whether this approach adequately accounts for dry wells (which are spud but do not achieve reportable production levels). Based on preliminary analysis of results, this approach does appear to sufficiently represent dry wells at comparable levels to the EIA data set; on average, dry wells (not including TIA wells which report production after year N+1) contribute 10% of total wells drilled.
 - b. Whether this approach is overly inclusive of wells that may not be drilled for oil and gas production purposes but are present in the DrillingInfo data set (e.g., wells drilled specifically for injection). EPA expects a minor contribution from such wells, since estimates developed from the DrillingInfo approach under consideration are comparable with EIA estimates for the overlapping time frame (1990–2010), as shown in Appendix A. EPA estimates that that injection wells might contribute approximately 2-4% to total counts; it is difficult to identify such wells in the

DrillingInfo data set due to the presence of hundreds of reported production types. EPA seeks feedback on how the DrillingInfo-based methodology might take this issue into account.

- c. How to account for time series coverage issues (due to states with lagging reporting and therefore not fully represented in the DrillingInfo data set in recent years).

Well Completions and Workovers (Section 2.2)

4. EPA seeks stakeholder feedback on how to use available data to improve national activity estimates for well completion and workover events—specifically, how DrillingInfo and subpart W data sets might be used in conjunction, or if one data set should be used to develop estimates and the other to verify estimates.

Definition of Oil vs. Gas Well (Section 2.3)

5. EPA seeks stakeholder feedback on whether the current methodology for counting and allocating active well counts between oil and gas should be updated, and if so, how.

Heavy vs. Light Crude Equipment Service (Section 2.4)

6. Based on RY2015 and RY2016 subpart W data, 19% and 18%, respectively, of oil wells in that data set produce heavy crude (API gravity less than 20), compared to the current GHGI basis of 7.05%. This updated heavy crude fraction is based on reported data for approximately 210,000 active oil wells (out of approximately 580,000 active oil wells nationwide). EPA seeks stakeholder feedback on incorporating this updated fraction into the GHGI time series.
 - a. Should EPA consider developing geographic-specific (e.g., NEMS region-level) estimates of heavy crude well fractions?
 - b. Should EPA retain the estimate of 7.05% of oil wells producing heavy crude (developed for base year 1995) for early years of the time series, and interpolate to the updated fraction based on subpart W data? Or is a different approach more appropriate—for example, where the heavy crude fraction is more tailored to the specific time period, rather than a set or linearly increasing value? EPA seeks information on data sources that might offer information to implement a more tailored approach.
7. How should EPA use API gravity data in conjunction with equipment count data reported under subpart W to improve oil production segment major equipment activity estimates? For example, Table 4 above presents activity factors for separators per oil well developed specifically for heavy and light crude populations.
 - a. Should EPA retain the current approach of extending the heavy/light crude well count split to wellhead and header activity data (for example, 19% of oil wells produce heavy crude, therefore 19% of headers are in heavy crude service)?
 - b. Should EPA retain the current approach of developing specific activity factors for separators in heavy versus light crude service, as shown in Table 4?

Identification of HF Wells (Section 2.5)

8. EPA seeks stakeholder feedback on whether it is reasonable to retain the current assumption that all wells with horizontal drill type according to the DrillingInfo data set are hydraulically fractured, or if there are recommendations for improving this assumption.
9. EPA seeks input on publicly available data sources and methodologies that might be used to identify wells that do not report horizontal drill type in the DrillingInfo data set but would be expected to be hydraulically fractured based on location in an unconventional formation (i.e., used to create a new formation type crosswalk).
 - a. EPA specifically seeks feedback on how GHGRP subpart W data might be used in this step to construct or verify such a crosswalk.

Appendix A. Well-Related Activity Data

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | |
|--|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|------------------|------------------|----------------|----------------|
| Well counts | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2018 GHGI | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Non-HF gas wells | 135,552 | 141,052 | 139,823 | 140,834 | 142,127 | 142,245 | 144,501 | 144,082 | 148,078 | 148,112 | 144,545 | 156,621 | 157,696 | 162,506 | 167,595 | 168,855 | 175,567 | 178,970 | 187,366 | 186,667 | 187,098 | 187,153 | 182,776 | 179,300 | 179,305 | 173,544 | 168,151 | |
| HF gas wells | 62,074 | 78,538 | 76,875 | 82,527 | 88,242 | 90,423 | 99,399 | 103,820 | 108,880 | 113,260 | 122,364 | 135,526 | 142,815 | 154,003 | 162,832 | 179,615 | 195,683 | 207,348 | 227,138 | 234,576 | 242,301 | 248,162 | 250,614 | 248,528 | 252,141 | 252,107 | 248,730 | |
| Total active gas wells | 197,626 | 219,590 | 216,698 | 223,361 | 230,369 | 232,668 | 243,900 | 247,902 | 256,958 | 261,372 | 266,909 | 292,147 | 300,511 | 316,509 | 330,427 | 348,470 | 371,250 | 386,318 | 414,504 | 421,243 | 429,399 | 435,315 | 433,390 | 427,828 | 431,446 | 425,651 | 416,881 | |
| Non-HF oil wells * | 469,317 | 467,760 | 454,605 | 446,499 | 432,774 | 423,199 | 418,579 | 419,582 | 401,394 | 381,938 | 382,314 | 379,071 | 375,274 | 372,953 | 372,994 | 374,960 | 379,859 | 380,541 | 391,513 | 387,949 | 389,226 | 393,598 | 401,244 | 404,373 | 405,284 | 398,424 | 373,608 | |
| HF oil wells * | 84,582 | 88,843 | 86,070 | 87,745 | 87,088 | 84,442 | 86,754 | 87,650 | 84,935 | 82,132 | 84,785 | 86,243 | 86,547 | 88,223 | 91,457 | 94,672 | 98,627 | 97,217 | 112,992 | 113,657 | 123,494 | 135,121 | 151,260 | 165,297 | 184,166 | 191,593 | 188,356 | |
| Total active oil wells | 553,899 | 556,603 | 540,675 | 534,244 | 519,862 | 507,641 | 505,333 | 507,232 | 486,329 | 464,070 | 467,099 | 465,314 | 461,821 | 461,176 | 464,451 | 469,632 | 478,486 | 477,758 | 504,505 | 501,606 | 512,720 | 528,719 | 552,504 | 569,670 | 589,450 | 590,017 | 561,964 | |
| Total HF wells * | 146,656 | 167,381 | 162,945 | 170,272 | 175,330 | 174,865 | 186,153 | 191,470 | 193,815 | 195,392 | 207,149 | 221,769 | 229,362 | 242,226 | 254,289 | 274,287 | 294,310 | 304,565 | 340,130 | 348,233 | 365,795 | 383,283 | 401,874 | 413,825 | 436,307 | 443,700 | 437,086 | |
| Total active wells | 751,525 | 776,193 | 757,373 | 757,605 | 750,231 | 740,309 | 749,233 | 755,134 | 743,287 | 725,442 | 734,008 | 757,461 | 762,332 | 777,685 | 794,878 | 818,102 | 849,736 | 864,076 | 919,009 | 922,849 | 942,119 | 964,034 | 985,894 | 997,498 | 1,020,896 | 1,015,668 | 978,845 | |
| EIA Today in Energy | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Total HF wells | NPA | NPA | NPA | 670,000 |
| Total active wells | NPA | NPA | NPA | 977,000 |
| Drilling event counts | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2018 GHGI | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Gas wells drilled (incl. fraction of dry) | 15,096 | 13,066 | 10,887 | 13,047 | 12,232 | 10,465 | 11,498 | 14,473 | 14,507 | 14,564 | 19,863 | 25,350 | 20,041 | 23,582 | 27,180 | 31,969 | 36,536 | 36,255 | 35,824 | 20,266 | 18,837 | 18,837 | 18,837 | 18,837 | 18,837 | 18,837 | 18,837 | 18,837 |
| Oil wells drilled (incl. fraction of dry) | 17,234 | 16,796 | 12,540 | 11,744 | 9,587 | 10,679 | 11,255 | 14,105 | 9,575 | 5,818 | 9,424 | 10,208 | 7,830 | 9,251 | 9,877 | 12,053 | 14,893 | 14,816 | 18,478 | 12,537 | 17,774 | 17,774 | 17,774 | 17,774 | 17,774 | 17,774 | 17,774 | 17,774 |
| Total wells drilled | 32,330 | 29,862 | 23,427 | 24,791 | 21,819 | 21,144 | 22,753 | 28,578 | 24,082 | 20,382 | 29,287 | 35,558 | 27,871 | 32,833 | 37,057 | 44,022 | 51,429 | 51,071 | 54,302 | 32,803 | 36,611 | 36,611 | 36,611 | 36,611 | 36,611 | 36,611 | 36,611 | 36,611 |
| EIA Monthly Energy Review (basis of 2018 GHGI) | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Gas (EIA) | 11,246 | 9,793 | 8,163 | 9,839 | 9,375 | 8,082 | 9,027 | 11,498 | 11,639 | 12,027 | 17,051 | 22,072 | 17,342 | 20,722 | 24,186 | 28,590 | 32,838 | 32,719 | 32,246 | 18,088 | 16,696 | NE | NE | NE | NE | NE | NE | NE |
| Oil (EIA) | 12,839 | 12,588 | 9,402 | 8,856 | 7,348 | 8,248 | 8,836 | 11,206 | 7,682 | 4,805 | 8,090 | 8,888 | 6,775 | 8,129 | 8,789 | 10,779 | 13,385 | 13,371 | 16,633 | 11,190 | 15,753 | NE | NE | NE | NE | NE | NE | NE |
| Dry (EIA) | 8,245 | 7,481 | 5,862 | 6,096 | 5,096 | 4,814 | 4,890 | 5,874 | 4,761 | 3,550 | 4,146 | 4,598 | 3,754 | 3,982 | 4,082 | 4,653 | 5,206 | 4,981 | 5,423 | 3,525 | 4,162 | NE | NE | NE | NE | NE | NE | NE |
| Total wells drilled | 32,330 | 29,862 | 23,427 | 24,791 | 21,819 | 21,144 | 22,753 | 28,578 | 24,082 | 20,382 | 29,287 | 35,558 | 27,871 | 32,833 | 37,057 | 44,022 | 51,429 | 51,071 | 54,302 | 32,803 | 36,611 | 36,611 | 36,611 | 36,611 | 36,611 | 36,611 | 36,611 | 36,611 |
| Preliminary DrillingInfo Data Analysis (described in Section 2.1)^o | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Gas | 13,417 | 6,719 | 7,464 | 6,794 | 7,208 | 7,648 | 16,608 | 9,557 | 9,089 | 10,507 | 14,449 | 17,131 | 14,390 | 17,237 | 20,018 | 23,060 | 24,733 | 24,964 | 23,600 | 11,636 | 12,172 | 9,206 | 5,512 | 4,725 | 4,385 | 2,580 | 1,550 | |
| Oil | 15,013 | 11,030 | 11,854 | 10,720 | 9,145 | 10,210 | 18,925 | 12,636 | 7,746 | 8,447 | 10,981 | 11,232 | 9,558 | 11,570 | 13,498 | 15,553 | 16,951 | 18,820 | 18,633 | 12,566 | 20,697 | 25,874 | 29,953 | 30,422 | 30,209 | 14,049 | 8,246 | |
| Dry/TIA | 7,971 | 5,650 | 5,220 | 4,641 | 4,249 | 3,909 | 4,228 | 4,601 | 3,898 | 3,601 | 5,095 | 6,782 | 4,875 | 5,549 | 6,477 | 6,872 | 9,190 | 7,631 | 9,232 | 4,773 | 5,614 | 6,271 | 5,781 | 5,304 | 7,037 | 3,861 | 1,964 | |
| Gas wells drilled (incl. fraction of dry/TIA) | 17,179 | 8,858 | 9,481 | 8,594 | 9,081 | 9,322 | 18,584 | 11,538 | 11,193 | 12,503 | 17,344 | 21,227 | 17,319 | 20,557 | 23,886 | 27,164 | 30,186 | 29,315 | 28,759 | 13,931 | 14,251 | 10,852 | 6,410 | 5,438 | 5,277 | 3,179 | 1,861 | |
| Oil wells drilled (incl. fraction of dry/TIA) | 19,222 | 14,541 | 15,057 | 13,561 | 11,521 | 12,445 | 21,177 | 15,256 | 9,540 | 10,052 | 13,181 | 13,918 | 11,504 | 13,799 | 16,107 | 18,321 | 20,688 | 22,100 | 22,706 | 15,044 | 24,232 | 30,499 | 34,836 | 35,013 | 36,354 | 17,311 | 9,899 | |
| Total wells drilled | 36,401 | 23,399 | 24,538 | 22,155 | 20,602 | 21,767 | 39,761 | 26,794 | 20,733 | 22,555 | 30,525 | 35,145 | 28,823 | 34,356 | 39,993 | 45,485 | 50,874 | 51,415 | 51,465 | 28,975 | 38,483 | 41,351 | 41,246 | 40,451 | 41,631 | 20,490 | 11,760 | |

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| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|--------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Completion event counts | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2018 GHGI | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Gas well non-HF completions | 365 | 405 | 400 | 412 | 425 | 429 | 450 | 458 | 474 | 482 | 493 | 539 | 555 | 584 | 610 | 643 | 685 | 713 | 765 | 778 | 793 | 804 | 800 | 790 | 796 | 786 | 770 |
| Gas well HF completions | 3,769 | 3,630 | 2,630 | 3,425 | 3,322 | 3,034 | 4,057 | 5,352 | 4,785 | 4,583 | 6,881 | 8,675 | 7,536 | 8,911 | 10,459 | 12,866 | 14,176 | 14,206 | 15,223 | 8,811 | 8,691 | 9,749 | 7,665 | 7,382 | 7,141 | 5,272 | 3,105 |
| Oil well non-HF completions | 9,764 | 9,644 | 6,395 | 5,916 | 4,742 | 5,855 | 6,203 | 7,671 | 5,359 | 3,476 | 5,844 | 5,791 | 4,285 | 4,618 | 5,046 | 6,185 | 7,369 | 7,142 | 8,305 | 6,117 | 7,565 | 3,252 | 0 | 0 | 0 | 3,315 | 3,315 |
| Oil well HF completions | 3,075 | 2,944 | 3,007 | 2,940 | 2,606 | 2,393 | 2,633 | 3,535 | 2,323 | 1,329 | 2,246 | 3,097 | 2,490 | 3,511 | 3,743 | 4,594 | 6,016 | 6,229 | 8,328 | 5,073 | 8,188 | 12,501 | 16,335 | 17,332 | 19,154 | 12,438 | 12,438 |
| Workover event counts | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2018 GHGI | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Gas well non-HF workovers | 5,897 | 6,136 | 6,082 | 6,126 | 6,183 | 6,188 | 6,286 | 6,268 | 6,441 | 6,443 | 6,288 | 6,813 | 6,860 | 7,069 | 7,290 | 7,345 | 7,637 | 7,785 | 8,150 | 8,120 | 8,139 | 8,141 | 7,951 | 7,800 | 7,800 | 7,549 | 7,315 |
| Gas well HF workovers | 621 | 785 | 769 | 825 | 882 | 904 | 994 | 1,038 | 1,089 | 1,133 | 1,224 | 1,355 | 1,428 | 1,540 | 1,628 | 1,796 | 1,957 | 2,073 | 2,271 | 2,346 | 2,423 | 2,482 | 2,506 | 2,485 | 2,521 | 2,521 | 2,487 |
| Oil well workovers | 41,542 | 41,745 | 40,551 | 40,068 | 38,990 | 38,073 | 37,900 | 38,042 | 36,475 | 34,805 | 35,032 | 34,899 | 34,637 | 34,588 | 34,834 | 35,222 | 35,886 | 35,832 | 37,838 | 37,620 | 38,454 | 39,654 | 41,438 | 42,725 | 44,209 | 44,251 | 42,147 |

* Values not published in the 2018 GHGI, but underlie the current estimates of HF oil well completion event counts

N/A - Not applicable

NPA - Not publicly available

NE - Not estimated

a – Results of preliminary approach discussed in Section 2.1. This does not include state-level adjustments to account for lagging reporting that EPA implements for other well-related data elements that are based on DrillingInfo data. After adjustments that would be implemented in a final methodology, estimates in recent years (e.g., 2015 forward) will likely increase.