

Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2017: Other Updates Under Consideration

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 consider improvements to the 2019 GHGI including incorporating newly reported data from EPA's Greenhouse Gas Reporting Program (GHGRP) and assessing options to update activity data sources and/or methodologies related to onshore oil and gas wells.

In June 2018, EPA released two memos detailing preliminary considerations for such improvements:

- *Inventory of U.S. GHG Emissions and Sinks 1990-2017: Updates Under Consideration for Incorporating GHGRP Data* (June 2018 GHGRP-based Updates memo)¹
- *Inventory of U.S. GHG Emissions and Sinks 1990-2017: Updates Under Consideration for Well-Related Activity Data* (June 2018 Well-related Activity Updates memo)²

EPA reviewed stakeholder feedback on the June 2018 memos and held two public meetings (June 6, 2018 webinar and October 17, 2018 workshop). EPA released two memos in October 2018 that focused on specific GHGRP-based updates:

- *Inventory of U.S. GHG Emissions and Sinks 1990-2017: Updates Under Consideration for Natural Gas Gathering and Boosting Emissions* (October 2018 G&B Updates memo)³
- *Inventory of U.S. GHG Emissions and Sinks 1990-2017: Updates Under Consideration for Liquefied Natural Gas Segment Emissions* (October 2018 LNG Updates memo)⁴

This memo summarizes previous analyses from the June 2018 memos and includes additional analyses and considerations toward updating the emissions and/or activity data for the sources listed in in Table 1 below. This memo also introduces a new topic under consideration for potential GHGI improvements—accounting for anomalous leak events that are not likely reflected in current GHGI emission factors (EFs). EPA continues to seek stakeholder feedback on how to use available data and improve methodologies for the sources discussed in this memo; refer to Section 4 for specific questions.

Table 1. Topics Covered in this Memo

Topic	Discussed in Memo Section...	New Information since June 2018 Preliminary Updates Memos
Incorporating Available GHGRP Data	1	
Incorporating GHGRP data for hydraulically fractured (HF) oil well completions and workovers	1.1	<ul style="list-style-type: none"> • Summary of stakeholder feedback (Section 1.1.4)
Incorporating GHGRP data for flaring N ₂ O emissions	1.2	<ul style="list-style-type: none"> • None
Incorporating GHGRP data for transmission pipeline blowdowns	1.3	<ul style="list-style-type: none"> • Analysis of available data (Section 1.3.2) • Time series considerations (Section 1.3.3) • Preliminary national emissions estimates (Section 1.3.4, Table 7) • Summary of stakeholder feedback
Updating Well-related Activity Data	2	
Updating well drilling activity estimates	2.1	<ul style="list-style-type: none"> • Summary of stakeholder feedback

¹ https://www.epa.gov/sites/production/files/2018-06/documents/2019-ghgi-updates-incorporating-ghgrp-data_2018-06-08.pdf

² https://www.epa.gov/sites/production/files/2018-06/documents/2019-ghgi-updates-well-activity_2018-06-08.pdf

³ https://www.epa.gov/sites/production/files/2018-10/documents/ghgi_2018stakeholders_boosting.pdf

⁴ https://www.epa.gov/sites/production/files/2018-10/documents/ghgi_2018stakeholders_segment.pdf

Updating well completions and workovers activity estimates	2.2	<ul style="list-style-type: none"> • Analysis of reported gas well event GHGRP data compared to GHGI (Table 8) • Summary of stakeholder feedback
Defining oil versus gas well types	2.3	<ul style="list-style-type: none"> • Analysis of alternative definition (Figure 1) • Summary of stakeholder feedback
Updating heavy versus light crude equipment service assumptions	2.4	<ul style="list-style-type: none"> • Analysis of available EIA data • Summary of stakeholder feedback
Identifying HF wells	2.5	None
Anomalous Leak Event Emissions	3	New topic

1 Incorporating Available GHGRP Data

Subpart W of the EPA’s GHGRP collects annual activity and emissions data on numerous sources from onshore natural gas and petroleum systems that meet a reporting threshold of 25,000 metric tons of CO₂ equivalent (mt CO₂e) emissions. Facilities that meet the subpart W reporting threshold have been reporting since reporting year (RY) 2011; however, HF oil well completions and workover data elements and transmission pipeline blowdowns were first required to be reported in RY2016. Subpart W activity and emissions data are currently used in the GHGI to calculate CH₄ and CO₂ emissions for many production, processing, and transmission and storage sources.

GHGRP subparts W and Y (petroleum refining) include reporting of N₂O from flaring. The GHGRP calculation methodologies specify that subpart W reporters must calculate N₂O emissions from flares using an EF of 0.0001 kg N₂O per million BTU, and subpart Y reporters using an EF of 0.0003 kg N₂O per million BTU. N₂O emissions are also reported to GHGRP for engine exhaust and other combustion sources, combustion emissions from which are generally included within GHGI estimates from fuel combustion, separate from natural gas and petroleum systems.

The GHGRP data used in the analyses discussed in this memo are those reported to the EPA as of August 5, 2017. Appendix A documents the subpart W calculation methodologies for certain sources discussed in this memo. EPA will assess data for RY2017 as they become available. Stakeholders have suggested additional or alternate uses of GHGRP data, such as for certain sources using measurement data only. Stakeholders have also suggested modifications to the reported GHGRP data for use in the GHGI, such as through removal of stakeholder-identified outliers. In the current GHGI, EPA uses the publicly available GHGRP data set without modification for the GHGI, to ensure transparency and reproducibility of GHGI estimates. Prior to public release of the GHGRP data, the EPA has a multi-step data verification process for the data, including automatic checks during data-entry, statistical analyses on completed reports, and staff review of the reported data. Based on the results of the verification process, the EPA follows up with facilities to resolve identified potential issues before public release.

1.1 Incorporating GHGRP Data for HF Oil Well Completions and Workovers

As discussed above, HF oil well completions and workovers were newly required to be reported in RY2016. EPA analyzed the RY2016 subpart W data for this source as an initial step for considering potential updates to the existing GHGI methodology.

1.1.1 Current GHGI Methodology

In the current GHGI methodology for HF oil well completions, controlled and uncontrolled CH₄ EFs were developed using data analyzed for the 2015 NSPS OOOOa proposal. The current GHGI estimates CO₂ emissions using CO₂ EFs developed by applying a default production segment ratio of CO₂-to-CH₄ gas content. As such, this approach for does not fully account for CO₂ emissions from flaring.

The 2018 GHGI activity data time series (counts of HF oil well completions, which is also referenced in calculating non-HF oil well completions), was developed from analyzing DrillingInfo data on well-level dates of completion or first reported production. The existing GHGI methodology also includes assumptions to develop activity factors

(AFs) for apportioning total counts into control categories. In 2008, Colorado and Wyoming adopted regulations that require reduced emission completions (RECs); the current GHGI assumes that 7% of completions are RECs with 95% control efficiency, from 2008 forward.

For workovers, the current GHGI methodology estimates emissions from all oil well workovers without distinguishing HF from non-HF, using an EF developed for conventional wells and an assumption that 7.5% of all oil wells are worked over in each year.

1.1.2 Analysis of Available Data

EPA analyzed the RY2016 subpart W data for HF oil well completions and workovers to consider updating the existing GHGI methodology, which estimates emissions from HF oil well completions based on historical rulemaking data and does not include a specific emissions estimate for HF oil well workovers (as discussed in Section 4.1). The new subpart W data allow development of separate GHGI emissions estimates for HF completions and workovers, in parallel control categories that exist for HF gas well events (reflecting combinations of REC use, venting, and flaring).⁵

Additionally, as summarized in Section 4.1, the current GHGI HF oil well completion CO₂ EF is calculated by applying an associated gas CO₂-to-CH₄ content ratio, which does not account for CO₂ conversion during hydrocarbon combustion. This current methodological limitation would be obviated by using subpart W data to directly calculate CH₄ and CO₂ EFs, parallel to the current methodology for HF gas well events.

This section documents development of EFs and activity data for HF oil well completions and workovers according to the general methodology used in the current GHGI for HF gas well completions and workovers. The 2018 Well-related Activity Data companion memo details considerations for potentially improving the approach to estimating national total activity data for all completions and workovers (e.g., DrillingInfo query methodology, workover rate assumptions).

Table 2 below shows EFs calculated using RY2016 subpart W data for HF oil well completions and workovers for each event type/control category, compared to current GHGI EFs.

Table 3 shows AFs for each event type/control category.

Table 2. Emission Factors Calculated from Subpart W Compared to Current GHGI, for Year 2016

Event Type	Control Category	CH ₄ EF (mt/event)		CO ₂ EF (mt/event)	
		2018 GHGI	Subpart W	2018 GHGI	Subpart W
Non-REC	Vent	6.76	36.0	0.38	0.8
	Flare		1.1		248.8
REC	Vent	0.34	1.3	0.02	0.1
	Flare		2.6		287.1

⁵ The GHGI methodology for HF gas well completions and workovers incorporates GHGRP data. For HF gas well completions and workovers, EFs are developed from reporting year-specific GHGRP subpart W data (2011 through 2016), with year 2011 EFs applied for earlier time series years. The EFs are developed for four control categories: non-REC/vented; non-REC/flared; REC/vented; and REC/flared. The total counts of HF completions are developed from DrillingInfo data for years prior to 2011, and GHGRP data are used for year 2011 forward (as the directly reported counts are higher than DrillingInfo-based estimates). The counts are apportioned into control categories based on year-specific GHGRP data for 2011–2016; for years 1990–2000, it is assumed all events are non-REC, and 10% of events flare; interpolation is used to develop AFs in intermediate years. For HF gas well workovers, it is assumed that 1% of the count of existing HF gas wells in a given year (estimated from analyzing DrillingInfo data) are worked over.

Table 3. Activity Factors Calculated from Subpart W Compared to Current GHGI, for Year 2016

Event Type	Control Category	HF Completions				HF Workovers	
		Subpart W		2018 GHGI ^a		Subpart W	
		# of Events	% of total	# of Events	% of total	# of Events	% of total
Non-REC	Vent	111	3%	11,567	93%	35	11%
	Flare	542	13%			16	5%
REC	Vent	1,345	33%	871	7%	186	56%
	Flare	2,061	51%			93	28%
Total		4,059	100%	12,438	100%	330	100%

a – For years 2008 forward, the current GHGI assumes 7% of HF oil well completions are controlled via REC due to state-specific regulations. The current GHGI does not include specific estimates for HF oil well workovers.

To develop national total activity data for HF oil well completions, EPA analyzed counts derived from the DrillingInfo data set compared to reported counts. For HF gas well completions, counts reported under GHGRP exceed DrillingInfo-based estimates, so are assumed to represent national coverage and used directly as national total activity in the GHGI. For HF oil well completions, this is not the case; DrillingInfo-based counts exceed reported counts. Therefore, to develop the preliminary national emissions estimates presented in Section 1.1.4, DrillingInfo-based activity data are used in conjunction with the EFs and AFs in Table 2 and

Table 3, respectively.

Workover data are not contained within EPA's DrillingInfo analysis data set, so an assumption of 1% annual workover rate is applied for HF gas wells in the current GHGI. In each year of the time series, 1% of existing HF wells (estimated from the DrillingInfo data set) are assumed to undergo workovers. For HF gas wells, this approach results in national total activity data that exceed HF workover counts reported under subpart W. For the preliminary national emissions estimates presented in Section 4.4, EPA applies the same assumption to HF oil wells to calculate national total workover activity. Similar to HF gas wells, this approach results in national total activity data that exceed HF oil well workover counts reported under subpart W.

As stated above, the 2018 Well-related Activity Data companion memo details considerations for potentially improving the approach to estimating national total activity data for all completions and workovers in the GHGI, which might include refining the DrillingInfo query methodology and/or further incorporating subpart W data. For example, the 2018 Well-related Activity Data memo estimates that within the RY2015–2016 subpart W data for gas wells, an 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).

1.1.3 Regional Variability and Time Series Considerations

For HF oil well completions and workovers, this memo presents preliminary emissions estimates (see Section 4.4) according to the existing GHGI methodology to develop estimates for HF gas well events; EFs and AFs are calculated at the national level. EPA seeks stakeholder feedback on whether a region-specific approach should be considered for these sources.

To develop the time series AFs for HF oil well completions and workovers based generally on the existing methodology for gas well events, and incorporating current control assumptions for HF oil well events, the following assumptions could be applied:

- For years 1990-2007, all completions and workovers are non-REC, and 10% of events flare.
- For the first year in which subpart W data are available, 2016, control fractions across the four categories are developed directly from reported subpart W data.

- For intermediate years, 2008–2015, control fractions are developed through linear interpolation.

This produces AFs across the time series that are generally consistent with the existing GHGI assumption that oil well RECs are introduced beginning in year 2008, during which 7% of completions and workovers are REC, and 10% of both REC and non-REC events flare. EPA seeks feedback on the assumptions above used to develop these control category AFs.

To apply EFs across the time series, EPA would apply year-specific EFs for GHGRP years, and EFs from the earliest GHGRP year to all prior years, consistent with the approach for HF gas well events. For the 2019 GHGI, this approach means that EFs calculated from RY2016 data would be applied for years 1990–2016, and RY2017 data would be used to develop EFs for year 2017.

1.1.4 Preliminary National Emissions Estimates

Table 4 below shows national total activity data and CH₄ emissions for select time series years based on the updates under consideration described above.

Table 4. Preliminary National Activity and Emissions Estimates for HF Oil Well Completions and Workovers, Select Years

Data Element	1990	2000	2005	2010	2015	2016
HF oil well completions (#)	3,075	2,246	4,594	8,188	12,438	12,438
Non-REC/Vent (%)	90%	90%	90%	61%	12%	3%
Non-REC/Flare (%)	10%	10%	10%	11%	13%	13%
REC/Vent (%)	0%	0%	0%	11%	29%	33%
REC/Flare (%)	0%	0%	0%	17%	45%	51%
HF oil well workovers (#)	846	848	947	1,235	1,916	1,884
Non-REC/Vent (%)	90%	90%	90%	64%	19%	11%
Non-REC/Flare (%)	10%	10%	10%	8%	5%	5%
REC/Vent (%)	0%	0%	0%	19%	50%	56%
REC/Flare (%)	0%	0%	0%	9%	25%	28%
Total CH₄ emissions (kt)	128	101	180	222	95	46
<i>2018 GHGI CH₄ emissions (kt)^a</i>	21	15	31	52	79	79
Total CO₂ emissions (kt)	100	79	142	688	2,179	2,402
<i>2018 GHGI CO₂ emissions (kt)^a</i>	1	1	2	3	4	4

a – Does not include estimate for workovers. The 2018 GHGI does not specifically estimate emissions from HF oil well workovers; the estimate for all (non-HF and HF) oil well workovers is negligible compared to the magnitude of other estimates shown in this table (<0.1 kt across the time series).

Stakeholder feedback generally supported incorporating GHGRP data for this source, using an approach consistent with that currently used for HF gas well events. Stakeholders expressed interest in developing separate EFs for completions versus workovers (in the current approach for both gas and oil well events, both types of events are combined). EPA reviewed available data and notes that due to the approach wherein year-specific EFs are calculated for each of four control categories, the number of data points in some categories is relatively small. Therefore, EPA intends to implement the existing approach in the 2019 GHGI, wherein HF oil well completions and workovers data are combined to calculate EFs (while activity for each event type is separately estimated).

1.2 Flaring N₂O Emissions Updates Under Consideration

The current GHGI does not estimate N₂O emissions for natural gas and petroleum systems. However, with recent updates that use GHGRP data to estimate CH₄ and CO₂ flaring emissions, the EPA is considering updates to incorporate N₂O emissions for the same flaring sources. The EPA would apply the existing source-specific methodology for using GHGRP CH₄ data to develop N₂O EFs.

For purposes of presenting preliminary national total flaring N₂O emission estimates, EPA calculated a ratio of the GHGRP reported N₂O emissions to CO₂ emissions and then multiplied the N₂O-to-CO₂ ratio by the 2018 GHGI CO₂ emissions, for each emission source. Table 5 presents reported GHGRP N₂O and CO₂ flaring emissions, the calculated N₂O-to-CO₂ ratio, 2018 GHGI CO₂ emissions, and the resulting scaled N₂O emissions, for RY2016. This table focuses on sources that currently use a GHGRP-based methodology in the GHGI, but also includes reference GHGRP data for sources in this memo where updates are being considered.

Table 5. Preliminary National N₂O Emissions Estimates for Flaring Sources in Natural Gas and Petroleum Systems, Year 2016

Emission Source	GHGRP N ₂ O (as reported) ^a (mt)	GHGRP Flaring CO ₂ (as reported) (mt)	Ratio of N ₂ O:CO ₂ (x100,000)	2018 GHGI CO ₂ (mt)	Estimated National Total N ₂ O (mt)
Natural Gas & Petroleum Production					
Tank Flaring	9.3	4,966,089	-	8,510,234	16.7
NG: Large Condensate Tanks w/Flares	1.0	1,063,935	0.1	1,172,292	1.0
NG: Small Condensate Tanks w/Flares	+	31,800	0.1	35,039	+
Petro: Large Oil Tanks w/Flares	8.2	3,859,139	0.2	7,281,742	15.6
Petro: Small Oil Tanks w/Flares	+	11,215	0.1	21,161	+
Associated Gas	21.6	7,312,187	-	9,102,967	26.9
Petro: Associated Gas Flaring	21.6	7,312,187	0.3	9,102,967	26.9
NG: Flared Gas Well Completions and Workovers	2.1	135,343	-	186,054	2.3
HF Completions - Non-REC with Flaring	+	8,872	0.2	8,710	+
HF Completions - REC with Flaring	2.1	110,800	1.9	110,998	2.1
Non-HF Completions - flared	+	1,876	0.2	16,407	+
HF Workovers - Non-REC with Flaring	+	279	0.4	10,669	+
HF Workovers - REC with Flaring	+	1,582	0.2	33,436	0.1
Non-HF Workovers - flared	0	11,933	0	5,836	0
Petro: Flared Oil Well HF Completions and Workovers	18.2	757,150	-	4,382	+
HF Completions - Non-REC with Flaring	0.3	136,782	0.2	4,365 ^a	+
HF Completions - REC with Flaring	17.9	618,126	2.9	16 ^a	+
HF Workovers - Non-REC with Flaring	+	2,024	0.1	NE ^a	+
HF Workovers - REC with Flaring	0	218	0	NE ^a	0
Miscellaneous Production Flaring	7.7	2,633,587	-	3,583,254	10.4
NG	3.3	991,718	0.3	1,128,617	3.8
Petro	4.4	1,641,869	0.3	2,454,637	6.6
Well Testing	+	13,800	-	34,803	0.1
NG	0	220	0	323	0
Petro	+	13,580	0.2	34,481	0.1
Gathering and Boosting	25.9	5,930,105	-	225,373 ^{a,b}	1.0
Gathering and Boosting Stations	25.9	5,930,105 ^b	0.4	225,373 ^{a,b}	1.0
Offshore Production	10.9	457,617	-	-	-
Offshore Flaring	10.9	457,617	2.4	368,840 ^c	10.9 ^c
Natural Gas Processing					
Flare Stacks	10.4	3,621,791	0.3	5,404,328	15.5
Transmission and Storage					
Transmission Station Flare Stacks	+	25,116	0.05	88,409	+
Storage Station Flare Stacks	+	2,343	0.2	15,307	+

Emission Source	GHGRP N ₂ O (as reported) ^a (mt)	GHGRP Flaring CO ₂ (as reported) (mt)	Ratio of N ₂ O:CO ₂ (x100,000)	2018 GHGI CO ₂ (mt)	Estimated National Total N ₂ O (mt)
LNG Storage Station Flare Stacks	+	2,506	-. ^d	NE	+. ^d
LNG Import/Export Station Flare Stacks	0.2	97,940	-. ^d	NE	0.2 ^d
Petroleum Refining					
Flare Stacks	36.0	3,604,229	1.0	3,604,229	36.0

NE – Not estimated

+ Does not exceed 0.05 mt

a – Current GHGI does not rely on subpart W data for this source, and 2018 GHGI estimated CO₂ emissions shown in this table do not fully account for combustion. Using CO₂ emissions estimates developed under the draft subpart W-based approaches discussed in the June 2018 GHGRP-based Updates memo, national N₂O emissions would be approximately 53 mt for flared oil well HF completions and workovers and 28 mt for G&B station flaring.

b – CO₂ includes vented and fugitive sources, in addition to flared sources.

c – Current GHGI does not rely on subpart W data for this source. As the GHGRP reported CO₂ emissions exceed the current GHGI estimate, the as-reported GHGRP N₂O emissions are shown.

d – Current GHGI does not estimate flaring CO₂ from these sources. Therefore, as-reported GHGRP N₂O emissions are shown as surrogate for national estimates.

1.3 Transmission Pipeline Blowdowns Updates Under Consideration

As discussed above, transmission pipeline blowdowns were newly required to be reported in RY2016. EPA analyzed the RY2016 subpart W data for this source as an initial step for considering potential updates to the existing GHGI methodology.

1.3.1 Current GHGI Methodology

The current GHGI shows emissions from transmission pipeline blowdowns as "pipeline venting for routine maintenance and upsets." Emissions are calculated using a CH₄ EF from GRI/EPA 1996 and annual transmission pipeline miles from the U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration (PHMSA). CO₂ emissions are calculated from the CH₄ EF and a default downstream gas profile of 93.4% CH₄ and 1.0% CO₂.

1.3.2 Analysis of Available Data

A subpart W transmission pipeline facility must report blowdown emissions from natural gas transmission pipelines (as defined at 40 CFR 98.238) that it owns and operates. EPA calculated a transmission pipeline blowdown EF from the subpart W data by summing the reported emissions and dividing by the reported transmission pipeline miles. Table 6 shows the calculated subpart W EF compared to the current GHGI EF. Note, the subpart W RY2016 data reflect approximately 50% of the total transmission pipeline mileage estimated in the current GHGI for year 2016 (147,000 of 300,000 miles).

Table 6. Emission Factors (mt/pipeline mile) Calculated from Subpart W Compared to Current GHGI, for Year 2016

Data Source	CH ₄	CO ₂
2018 GHGI	0.6	0.01
Subpart W	1.2	0.02

EPA compared subpart W reporters of this source to a PHMSA data set that includes transmission pipeline mileage by company, state and type (i.e., interstate or intrastate). Based on a preliminary analysis, approximately 71% of the national total interstate transmission pipeline miles and 11% of intrastate transmission pipeline miles were reported to subpart W in RY2016. EPA may further consider this distinction and calculate unique EFs for interstate and intrastate pipelines, which would be paired with activity data specific to each type.

1.3.3 Time Series Considerations

Preliminary stakeholder feedback suggested that the reported subpart W data for this source might not be representative of national emissions in recent years (e.g., facilities meeting the reporting threshold might generally have larger-diameter pipelines leading to higher emissions per mile). As discussed above, EPA is considering whether sufficient data are available to develop separate EFs and accompanying activity data for interstate versus intrastate pipelines as a potential means to recognize differences in the reporting versus nonreporting population. Establishing subcategories might offer improved representativeness, but is dependent on identifying an accurate method for categorizing subpart W data (interstate versus intrastate designation is not directly reported but might be inferred through analysis of external data sets such as published by PHMSA) and the statistical characterization of reported data points in each category (e.g., whether the data set size and variance support establishing separate EFs).

EPA continues to seek stakeholder feedback on how subpart W data for this source might be used to inform time series trends, including specific new questions in Section 4 regarding the establishment of subcategories.

1.3.4 Preliminary National Emissions Estimates

Table 7 below shows national total emissions for select time series years based on one approach EPA is considering for the 2019 GHGI public review draft: using existing GHGI activity (pipeline miles) for all years; existing EFs for years 1990 through 1992; newly calculated EFs from subpart W data starting in year 2016; and linear interpolation to calculate EFs in intermediate years. EPA notes that multiple approaches are under consideration and seeks stakeholder feedback on the most appropriate approach.

Note, the current GHGI methodology involves first calculating potential emissions for this source (i.e., EF multiplied by activity), then subtracting voluntary reductions (i.e., quantity of emissions reduced as reported to EPA's GasSTAR program) to calculate net emissions. EPA seeks stakeholder feedback on whether and how to reflect voluntary reductions in the update under consideration (e.g. does the updated approach reflect net emissions, and therefore an adjustment to include Gas STAR would double count reductions?).

Table 7. Preliminary National Emissions Estimates for Transmission Pipeline Blowdowns, Select Years

Data Element	1990	2000	2005	2010	2015	2016
2018 GHGI						
# Pipeline miles	291,925	298,957	300,468	304,803	300,376	300,645
CH ₄ EF (mt/mile)	0.61	0.61	0.61	0.61	0.61	0.61
CO ₂ EF (mt/mile)	0.018	0.018	0.018	0.018	0.018	0.018
Potential total CH ₄ emissions (kt)	178	182	183	186	184	183
Net total CH ₄ emissions (kt)	178	149	58	58	124	124
Total CO ₂ emissions (kt)	5	5	5	5	5	5
Update under consideration						
CH ₄ EF (mt/mile)	0.61	0.81	0.93	1.05	1.17	1.20
CO ₂ EF (mt/mile)	0.018	0.020	0.021	0.022	0.024	0.024
Total CH ₄ emissions (kt)	178	241	279	320	353	360
Total CO ₂ emissions (kt)	5	6	6	7	7	7

EPA continues to seek stakeholder feedback on how subpart W data for this source might be used to update the time series estimates in the GHGI, including specific new questions in Section 4 regarding EFs calculated from subpart W data.

2 Updating Well-related Activity Data

Appendix B 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. Note that several existing GHGI methodologies documented e.g., developing counts of active wells) rely on EPA's analysis of DrillingInfo's subscription-based digital DI Desktop raw data feed⁶; this data set is referred to throughout this memo as "DrillingInfo data."

2.1 Well Drilling

The U.S. Department of Energy's Energy Information Administration (DOE/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 from 2011 forward.

As described in the June 2018 Well-related Activity Updates memo, EPA did not identify another data set published by EIA that provides complete well drilling activity over the GHGI time series. EPA developed a methodology for querying the DrillingInfo data set to develop estimates of wells drilled and presented preliminary results in the June 2018 Well-related Activity Updates memo. The DrillingInfo-based approach is:

- 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.

Stakeholder feedback on the DrillingInfo-based approach noted that preliminary estimates appeared reasonable for incorporation into the GHGI.

For a DrillingInfo-based methodology, EPA sought 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 plans to 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 be fully estimated by the current approach (i.e., GOR in year N+1 is not available); EPA plans to implement a surrogate approach of using the previous year's estimate.

Appendix B shows well drilling counts across the time series in the 2018 GHGI and preliminary estimates by the DrillingInfo data analysis approach described above.

⁶ <https://info.drillinginfo.com/products/di-plus/>

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 has conducted a preliminary analysis to assess how completion counts and workover rates reflected in the subpart W data compare to current GHGI assumptions. Regarding workover rates, 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 therefore analyzed the number of completion and workover events and the overall gas well workover rate, as summarized in Table 8.

In response to stakeholder feedback, EPA developed the following considerations based on this analysis and the estimation that approximately 70% of gas wells in the U.S. are covered by subpart W reporting:

- Non-HF gas well completion counts might be *over-estimated* in recent years of the GHGI.
- Non-HF gas well workover counts might be *under-estimated* in recent years of the GHGI.
- HF gas well workover counts might be *over-estimated* in recent years of the GHGI.

Table 8. Comparison of Gas Well Event Activity Data and Calculated Workover Rate

Activity Data Element	Current GHGI			GHGRP As-reported	
	Basis	2015	2016	2015	2016
# Non-HF gas well completions	Scaled from 400 events/year in 1992	786	770	108	88
# Non-HF gas well workovers	4.35% of active non-HF gas wells	7,549	7,315	18,031	14,957
# HF gas well workovers	1% of active HF gas wells	2,521	2,487	263	103
Overall gas well workover rate	4.35% of active non-HF gas wells; 1% of active HF gas wells			6% ^a	5% ^a

a – Calculated using number of reported gas well workover events (with and without HF) divided by the number of producing wells at the end of the calendar year (reported under 40 CFR 98.236(aa), found in the "sub-basin characterization" table).

Appendix B shows all categories of completion and workover counts across the entire time series in the 2018 GHGI. EPA seeks stakeholder feedback on improving the current methodology in the 2019 GHGI; see Section 4 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 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 reviewed 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. Per subpart W, oil wells are defined as producing from an oil formation, not defined by a specific GOR threshold.

Table 9 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 4 for specific requests on this topic).

Table 9. 2018 GHGI Well-Related Activity Data Summary

Reporting Year	# Oil Wells with Specified GOR (mcf/bbl)			
	GOR ≤ 10	10 < GOR ≤ 100	100 < GOR $\leq 1,000$	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%]

In response to recent stakeholder feedback, EPA calculated oil and gas well counts across the time series by two different GOR delineation thresholds (100 mcf/bbl and 6 mcf/bbl). The results of this sensitivity analysis are shown in Figure 1.

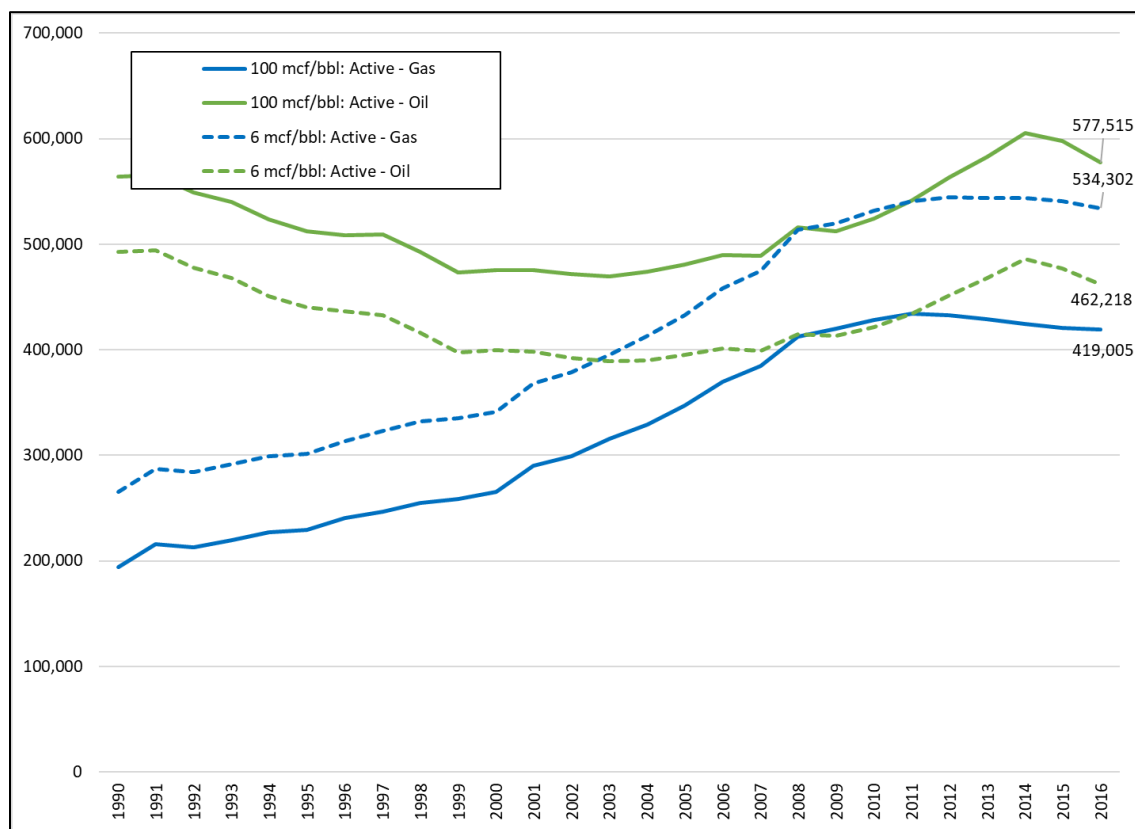


Figure 1. Active Oil and Gas Well Counts by Two Different GOR Delineation Thresholds

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 report⁷, 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 average 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 10 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 10. 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" ^b
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)).

EPA also reviewed 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 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. This approach does 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); additionally, inherent in this

⁷ 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.

approach is an assumption that heavy and light crude wellheads have the same average production rates. EPA recently reviewed EIA state-level production and API gravity data and estimated that 4-5% of crude produced in the lower 48 states in recent years is heavy crude. Due to the assumptions and limitations of this analysis (i.e., using production split between heavy and light as surrogate for wellhead split), EPA is focusing further efforts toward how subpart W data, such as that summarized in Table 10, might be used to update the GHGI for recent time series years.

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 4 for specific stakeholder feedback requests on this topic.

2.5 Identification of HF Wells

Appendix B 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 B 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 Anomalous Leak Events

In recent GHGIs, EPA incorporated an emissions estimate for the Aliso Canyon gas leak during years 2015 and 2016 in the storage well category. EPA used the California Air Resources Board (CARB) published estimate of the methane release from the leak.⁸

EPA seeks stakeholder feedback on existing data sources or suggested methodologies for identifying similar events across natural gas and petroleum systems, with emissions beyond what is likely accounted for in GHGI EFs.

4 Requests for Stakeholder Feedback

HF Oil Well Completions and Workovers (Section 1.1)

1. EPA seeks feedback on the national representativeness of subpart W-based HF oil well completion and workover emissions factors (emissions per event) and activity factors (i.e., allocation of total event counts across four control categories).
2. EPA seeks feedback on how to consider regional and temporal variability for HF oil well completions and workovers.
3. EPA seeks stakeholder feedback on the methodology and assumptions for allocating events into the four control categories across the time series (i.e., control category AFs, as detailed in Section 4.2). Specifically, for years 1990–2007, it is assumed all events are non-REC, and 10% of events flare; in contrast, the GHGI methodology for HF gas well event AFs assumes that RECs are introduced earlier, in year 2000.
4. Historical analyses for HF gas well events data (RY2011–2015) included all HF well event data reported, and therefore might have included reported data from HF oil well events if any reporters reported data from these activities in those years. Should EPA revisit these historical EFs (e.g., discard from the EF data

⁸ https://www.epa.gov/sites/production/files/2017-04/documents/2017_aliso_canyon_estimate.pdf

set any events seemingly conducted at oil wells? develop factors specific to oil well events prior to RY2016?)?

N₂O Emissions (Section 1.2)

5. EPA seeks feedback on updating the GHGI to include N₂O from flaring, based on GHGRP data.
 - a. Specifically, EPA seeks feedback on time series calculations—such as whether calculated ratios of N₂O:CO₂ from GHGRP from 2016 (or several years') data could be applied to each year of the time series from 1990-2017.
6. EPA seeks feedback on other available data sources for N₂O emissions.

Transmission Pipeline Blowdowns (Section 1.3)

7. EPA seeks feedback on the general use of subpart W data to update the current GHGI methodology for this source.
8. Are the EFs calculated from RY2016 subpart W data (shown in Table 6) nationally representative, specifically:
 - a. Should EFs calculated from subpart W data be applied to the non-reporting population (approximately 50% of national total pipeline mileage) or is there a more appropriate approach for estimating emissions from this population?
 - b. Do available subpart W data support development of subcategories that might improve EF representativeness—for example interstate versus intrastate EFs?
9. EPA seeks feedback on time series calculations, specifically
 - a. Whether GHGI EFs be retained for early time series years or if subpart W EFs should be applied for all years.
 - b. Whether year-specific EF(s) should be developed from subpart W data for RY2016 forward. Based on preliminary analyses, EPA notes significant variation in calculated EFs in the available years of subpart W data. Specifically, the average RY2016 CH₄ EF was calculated to be 1.2 mt/mile, compared to 0.6 mt/mile using recently published RY2017 data. EPA seeks stakeholder feedback on whether these differences reflect industry trends, or if an approach such as combining early reporting years' data is appropriate.
10. EPA seeks feedback on whether and how to include GasSTAR reductions in an updated methodology for this source.

Well Drilling (Section 2.1)

11. 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.
12. 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?
13. 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 B. 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)

14. 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)

15. 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)

16. 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.
17. 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 10 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 10?

Identification of HF Wells (Section 2.5)

18. 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.
19. 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.

Anomalous Leak Events (Section 3)

20. EPA seeks stakeholder feedback on existing data sources or suggested methodologies for identifying similar events across natural gas and petroleum systems, with emissions beyond what is likely accounted for in GHGI EFs.
21. EPA seeks information from stakeholders on any anomalous leak events that have occurred over the 1990-2017 time series that should be included in the 2019 GHGI, in addition to the Aliso Canyon leak in years 2015 and 2016.

Appendix A. GHGRP Measurement Methodologies from Data Sources Considered for Updates

Emission Source	Measurement and/or Calculation Type	# Sources	Location & Representativeness	EF Calculation Method
Oil Well HF Completions and Workovers	Emissions calculated for each event, based on (1) measured actual flowback gas volumes from the well or (2) calculated flowback gas volume based on well parameters (e.g., pressure differentials, temps). If flared, then flare control efficiency is applied.	Emissions data (for 2016) are available for 4,059 completions and 330 workover events at HF oil wells	Facilities in the U.S. that exceed 25,000 mt CO2e reporting threshold.	For this memo, the EPA used reported data to calculate, event/control category specific (e.g., REC, flare), average EFs
Flare Stacks	CH ₄ and CO ₂ emissions calculated using: (1) gas volume sent to the flare, (2) combustion efficiency (from manufacturer or assume 98%), fraction of feed gas sent to an un-lit flare, and (3) gas composition for CO ₂ , CH ₄ , and hydrocarbon constituents. N ₂ O emissions calculated using amount of fuel combusted, fuel heating value, and prescribed EF of 1.0 × 10 ⁻⁴ kg N ₂ O/mmBtu	Varies by industry segment	Facilities in the U.S. that exceed 25,000 mt CO2e reporting threshold.	For this memo, to estimate emissions for each source, EPA calculated a ratio of the GHGRP reported N ₂ O emissions to CO ₂ emissions and then multiplied the N ₂ O-to-CO ₂ ratio by the 2018 GHGI CO ₂ emissions
Transmission Blowdown Vent Stack	Emissions calculated using: <ul style="list-style-type: none"> • Blowdown volumes, number of blowdowns, and the ideal gas law modified for compressibility; or • Flow meter to measure emissions for all equipment associated with a blowdown event. Blowdown volumes <50 scf are exempt.	Emissions data (for 2016) are available from 9,093 blowdowns (which occurred over 147,187 miles).	Facilities in the U.S. that exceed 25,000 mt CO2e reporting threshold.	For this memo, EPA calculated EFs as a straight average of all available data.

Appendix B. 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	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	670,000
Total active wells	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	NPA	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
Preliminary DrillingInfo Data Analysis (described in Section 2.1)^a																												
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	
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																												

November 2018

	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
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.