Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2016: Additional Revisions Considered for 2018 and Future GHGIs

1 Background

During development of EPA's 2018 *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (GHGI), EPA identified several estimates that might be improved using currently available data. EPA released draft and final memoranda discussing considerations and final revisions to three topics: carbon dioxide (CO_2) emission estimates for natural gas and petroleum systems, estimates for abandoned wells in natural gas and petroleum systems, and uncertainty estimates for natural gas and petroleum systems. In October 2017, EPA released a draft memo discussing background and considerations for additional revisions to implement in the 2018 GHGI or later GHGIs: *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2016: Additional Revisions Under Consideration* ("Additional Revisions memo")[1].

As an outcome to finalizing the 2018 GHGI, EPA released this updated version of the Additional Revisions memo to document revisions implemented in the final 2018 GHGI as well as revisions still under consideration. EPA also released a companion memo that details certain revisions implemented in the 2018 GHGI that involved creation of year-specific emissions and activity factors for various sources: *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2016: Revisions to Create Year-Specific Emissions and Activity Factors* (April 2018)[2] ("Year-specific Revisions memo").

Table 1 below documents the topics covered in this memo and identifies whether they were implemented in the final 2018 GHGI or are still under consideration. In addition to the specific stakeholder requests in sections below, EPA continues to seek stakeholder feedback on prioritizing the outstanding revisions for incorporation into the the 2019 GHGI and future GHGIs, and on other topics to consider for future GHGI updates.

Table 1. Additional Revisions Considered for 2018 and Future GHGIs

Topic	2018 GHGI Status	Memo Section
Production segment major equipment activity data	Implemented revision	2
Well completions, workovers, and testing	Implemented partial revision; see also April 2018 *Year-specific Revisions memo*	3
Transmission & Storage and Distribution segment voluntary emissions reductions	Implemented revision	4
Well-related activity data	Consider for future GHGIs	5
Liquefied natural gas (LNG) facilities	Consider for future GHGIs	6
Nitrous oxide (N_2O) emissions	Consider for future GHGIs	7
Liquids unloading – early time series emissions	Consider for future GHGIs	8
Offshore production platforms	Consider for future GHGIs	9
Natural gas leaks at point of use	Consider for future GHGIs	10
Additional use of GHGRP data	Consider for future GHGIs	11
Additional data assessments	Consider for future GHGIs	12

[1] https://www.epa.gov/sites/production/files/2017-10/documents/2018_ghgi_ng-petro_revisions_under_consideration_2017-10-26_pdf_to_post.pdf

[2] https://www.epa.gov/ghgemissions/natural-gas-and-petroleum-systems-ghg-inventory-additional-information-1990-2016-ghg

2 Production Segment Major Equipment Activity Data

2.1 Revisions Considered

The 2017 GHGI noted EPA's intention to revisit activity factors (AFs) for production segment major equipment counts using GHGRP data: "One stakeholder highlighted a discrepancy in well count data reported under different categories in GHGRP. EPA will update next year's Inventory with resubmitted data, which may result in minor changes in equipment counts per well for 2015."

Table 2 below shows the well counts used to calculate major equipment AFs (e.g., separators per well) in the final 2017 GHGI, and well counts recalculated from updated data that reflect resubmissions and newly submitted data.

Table 2. Subpart W Well Counts Data for Developing Equipment AFs

Basis	Gas Wells	Oil Wells	Total Wells
Final 2017 GHGI			
Subpart W Equipment Leaks[a] table – RY2015 data	307,737	219,433	527,170
Subpart W data as of August 5, 2017 [b]			
RY2015			
Equipment Leaks[a] table	309,132	213,380	522,512
Introduction[c] table AA.1.ii	290,003	211,618	501,621
RY2016			
Equipment Leaks[a] table	284,112	221,326	505,438
Introduction[c] table AA.1.ii	280,928	204,733	485,661

a – Reported by onshore production facilities under 40 CFR 98.233(r). Number of wellheads that contact streams with gas content greater than 10 percent CH_4 plus CO_2 by weight.
b – Data reported as of August 5, 2017.
c – 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.

EPA sought stakeholder feedback on the basis for calculating major equipment AFs (e.g., separators per well, heaters per well) for the 2018 GHGI. As documented in Table 2, the current GHGI methodology uses wellhead counts as reported in the subpart W equipment leaks table (98.233(r)) to develop AFs that are used in conjunction with national well counts to obtain national level equipment counts. The current methodology (in the 2017 GHGI) uses RY2015 subpart W data to calculate equipment-specific AFs that are applied for years 2011 forward (earlier years use GRI-based factors or interpolation). EPA considered revising the 2018 GHGI methodology to use recalculated RY2015 activity factors, year-specific subpart W AFs, or another approach based on stakeholder feedback.

2.2 2018 GHGI Revision to Production Segment Equipment Activity Data

In the 2018 GHGI, EPA updated production segment equipment AFs using RY2015 subpart W data reported as of August 5, 2017. EPA did not revise the current approaches of: (1) using well counts as reported in the Equipment Leaks table; and (2) applying RY2015 AFs to years 2011 forward.

Table 3 below shows the equipment AFs used in the 2018 GHGI compared to the 2017 GHGI.

Table 3. Equipment AFs for Natural Gas and Petroleum Production

Equipment Type	2017 GHGI AF (# per well)	2018 GHGI AF (# per well)	Change (%)
Natural Gas Production			
Heaters	0.206	0.131	-36%
Separators	0.685	0.710	+4%
Dehydrators	0.027	0.030	+11%

Equipment Type	2017 GHGI AF (# per well)	2018 GHGI AF (# per well)	Change (%)
Meters/Piping	0.857	0.838	-2%
Small Reciprocating Compressors	0.078	0.081	+4%
Chemical Injection Pumps	0.189	0.178	-6%
Petroleum Production			
Heater-Treaters	0.234	0.190	-19%
Separators	0.398	0.359	-10%
Headers	0.241	0.230	-5%
Chemical Injection Pumps	0.091	0.095	+4%

3 Well Completions, Workovers, and Testing

The IPCC guidelines[3] specify separate categories for emissions from exploration versus production. Exploration activities include well drilling, testing, and completions. To improve conformance with IPCC guidelines, EPA created a separate exploration segment in the 2018 GHGI and evaluated available GHGRP subpart W data for these sources (as well as for workovers, being closely related to completions) to consider methodological improvements for the 2018 GHGI. In the 2018 GHGI, EPA implements certain revisions as summarized below and detailed in the April 2018 *Year-specific Revisions* memo and is continuing to review current methodologies to identify revisions that might improve emission estimates for sources in the exploration segment.

3.1 Overview of 2017 GHGI Methodology

The 2017 GHGI did not include a line item specifically for well testing. However, the 2017 GHGI did include line items for the broader activity of well completions in both the natural gas and petroleum system onshore production segments. These completion estimates are separated between completions of conventional (i.e., without hydraulic fracturing, or "non-HF") wells and completions of hydraulically fractured (HF) wells. The factors for non-HF gas and oil well completions in the GHGI were derived from the GRI 1996 study which defines the factor as covering both gas well completions and well flow testing; and based on the assumption that all gas is flared. The 2017 GHGI used the same factor (733 scf CH_4/completion after flaring) for both gas and oil non-HF well completions and testing. As with non-HF completions, the 2017 GHGI used an EF based on data from the 1996 GRI/EPA study for non-HF workovers.

The 2017 GHGI methane emissions for HF gas well completions were based on recent GHGRP data for HF completions and workovers (2011-2013) and did not include well testing emissions. The 2017 GHGI emissions for HF oil well completions were based on an analysis of DrillingInfo data and also did not include well testing activities.

3.2 Revisions Considered

EPA considered several methodological revisions for the 2018 GHGI that would entail use of GHGRP subpart W data:

- Revise the EFs for non-HF gas well completions and workovers (to improve accuracy by creating year-specific and control category-specific EFs and AFs);
- Revise the EFs for HF gas well completions and workovers (to improve accuracy and respond to stakeholder feedback by creating year-specific EFs); and
- Develop EF(s) for well testing (to newly account for this source within the exploration segment).

For information on future updates related to HF oil well completions and workovers, also refer to Section 11 below which discusses newly reported GHGRP data.

[3] http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_4_Ch4_Fugitive_Emissions.pdf

3.3 2018 GHGI Revisions to Well Completions, Workovers, and Testing

Based on available data and stakeholder feedback, EPA revised the following aspects of the estimation methodologies for well completions, workovers, and testing:

- Created a distinct exploration segment that includes well drilling, completions, and non-completion testing, in both Natural Gas Systems and Petroleum Systems.
- Created emission estimates specific to well testing not associated with completion events, using subpart W data.
- Developed revised emissions and activity factors for non-HF gas well completions and workovers using year-specific subpart W data.
- Developed revised emissions factors for HF gas well completions and workovers using year-specific subpart W data.

The April 2018 *Year-specific Revisions* memo contains detailed additional information on development of activity data and emissions factors, and time series considerations, for the above sources.

EPA continues to seek feedback on three topics related to completions and workovers but not revised in the 2018 GHGI:

- Updating the activity data methodology for non-HF gas and oil well completions and workovers—refer to Section 5 of this memo.
- Updating the emission factor(s) for non-HF oil well completions and workovers, subject to available data.
- Analyzing emissions and activity data for HF oil well completions and workovers reported under subpart W data to potentially revise the current GHGI methodology.

3.4 Requests for Stakeholder Feedback

1. Are there any technical references that should be considered for developing updated non-HF oil well completion and workover emissions and activity factors?
2. How might subpart W data on HF oil well completions and workovers be used to update the GHGI?

4 Transmission & Storage and Distribution Voluntary Reductions

The 2017 GHGI emission calculation methodologies applied voluntary reductions reported to the GasSTAR program for certain sources in the production, transmission and storage, and distribution segments. For sources that use a "potential" calculation methodology, EPA subtracts GasSTAR reductions to calculate net emissions. In recent years, EPA has moved toward using net calculation approaches for sources in the GHGI, wherein emission factors (EFs) and/or control type-specific activity data vary over the time series to show industry adoption of emissions-reducing technologies and practices.

For the 2018 GHGI, EPA reevaluated sources that used voluntary reductions in calculating emissions to identify instances where an emission source's calculation methodology could be updated to calculate net emissions or instances where the current methodology could be simplified to acknowledge sources that likely no longer necessitate consideration of GasSTAR reductions.

EPA recently reviewed and revised the methodology for including GasSTAR reductions in the production segment (see April 2016 EPA memo[4]). Sections 4.1 and 4.2 below discuss GasSTAR reductions included in the 2017 GHGI transmission and storage segment and distribution segment, respectively, and summarize revisions implemented in the 2018 GHGI.

[4] https://www.epa.gov/sites/production/files/2016-08/documents/final_revision_to_production_segment_emissions_2016-04-14.pdf

4.1 Transmission & Storage Segment

In the 2017 GHGI, EPA included GasSTAR reductions in the calculation methodologies for station fugitives, station venting, compressor exhaust, and "other" reductions. Considerations toward removing or adjusting these reductions, and revisions implemented in the 2018 GHGI, are discussed below.

4.1.1 Station Fugitives

2017 GHGI Methodology and Revisions Considered: The transmission and storage station fugitive emissions methodology was revised for the 2016 GHGI to calculate net emissions. The current GHGI approach for station fugitives includes both Zimmerle et al. study data and subpart W data, as utilized within the 2015 Zimmerle et al. study[5], to develop activity and emission factors for station component leaks and compressor leaks and vents. However, GasSTAR data associated with station fugitives are included in the "other reductions" category that is subtracted from the GHGI emissions estimates (according to the historical methodology of subtracting reductions from calculated potential emissions). Because the station fugitives methodology was revised to reflect current operations and practices in calculating net emissions, it is not appropriate to include these GasSTAR reductions in the calculations. The EPA considered adjusting the "other reductions" category of GasSTAR reductions to remove the transmission and storage station fugitives data for the 2018 GHGI; see Table 4 for the GasSTAR data.

Table 4. Transmission Station Fugitives GasSTAR Reductions, For Certain Years (mt CH_4)

Emission Source	1993	1995	2000	2005	2010	2015
Transmission Station Fugitives	22,915	46,840	92,268	158,284	35,526	4,419

2018 GHGI Revision: EPA removed transmission and storage station fugitives reductions data from the methodology for all time series years, due to the considerations discussed above.

4.1.2 Station Venting

2017 GHGI Methodology and Revisions Considered: The calculation methodology for station venting (i.e., blowdowns) was not updated when the EPA revised the methodology for certain transmission and storage segment sources for the 2016 GHGI. The current GHGI uses an EF developed from the 1996 GRI/EPA study, which evaluated company-tracked blowdown data.

The data source underlying the 2016 GHGI methodological revisions for most sources in transmission and storage is Zimmerle et al.,[6] which also estimated station venting emissions. Subpart W data are also available for station venting. EPA might consider revising the EF to incorporate these recent data sources. If the methodology is revised to calculate net emissions, the EPA would also remove GasSTAR reductions data from the GHGI, because the emissions estimates would reflect current operations and practices.

2018 GHGI Revision: None.

4.1.3 Compressor Exhaust

2017 GHGI Methodology and Revisions Considered: The transmission and storage compressor exhaust EF and activity data have not been recently revised. Compressor exhaust data in the GHGI were evaluated as part of the gas processing segment revision in the 2017 GHGI. The EPA retained the existing GHGI EF, but revised the AD to use an activity factor developed from subpart W data. The EPA is considering implementing a similar approach

[5] "Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2014: Revisions to Natural Gas Transmission and Storage Emissions," available at https://www.epa.gov/ghgemissions/natural-gas-and-petroleum-systems-ghg-inventory-additional-information-1990-2014-ghg.

[6] "Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2014: Revisions to Natural Gas Transmission and Storage Emissions," available at https://www.epa.gov/ghgemissions/natural-gas-and-petroleum-systems-ghg-inventory-additional-information-1990-2014-ghg.

involving developing a revised activity factor on a station level-basis (i.e., MMhp-hr/station) using subpart W data and maintaining the current GHGI EF. The EPA would also consider removing the compressor exhaust GasSTAR reductions data from the GHGI, because the emissions estimates would calculate net, and not potential, emissions.

2018 GHGI Revision: None.

4.1.4 "Other" Transmission & Storage GasSTAR Reductions

2017 GHGI Methodology and Revisions Considered: Certain GasSTAR reductions data cannot be attributed to specific sources, because insufficient detail is available. These reductions are classified as "other" transmission and storage station GasSTAR reductions for purposes of the GHGI.

EPA received feedback during the 2018 GHGI stakeholder engagement process on the current calculation methodology for sources in the transmission and storage segments. Stakeholders supported use of additional measured data reported under subpart W and forthcoming in reports from a Pipeline Research Council International (PRCI) project. In the PRCI project, researchers are gathering and analyzing Subpart W data from transmission compressor stations and underground storage facilities; findings were expected to be published in fall 2017. EPA will continue to review new data as it becomes available. In light of the current transmission and storage methodology, new information becoming available, and the revisions under consideration for station venting and compressor exhaust, the EPA will review the "other" transmission and storage GasSTAR reductions data. Depending on the revisions implemented and the results of the "other" reductions review, the EPA is considering removing the "other" transmission and storage GasSTAR reductions data from the GHGI or adjusting the "other" GasSTAR reductions downward to reflect the fact that most sources calculate net, and not potential, emissions.

2018 GHGI Revision: EPA adjusted the "other" transmission and storage segment Gas STAR reductions to remove reduction data associated with uncategorized activities, because such reductions were minimal and likely associated with sources that already use a net emissions calculation approach; see Table 5 for the GasSTAR data. Note, this table also reflects the impacts of removing station fugitives reductions, as discussed above and shown in Table 4.

Table 5. Transmission and Storage Segment "Other" GasSTAR Reductions, For Certain Years (mt CH_4)

GHGI	1993	1995	2000	2005	2010	2015
2017 GHGI	25,755	52,789	172,546	288,089	185,620	146,186
2018 GHGI	2,740	5,197	80,249	129,028	138,069	140,889

4.2 Distribution Segment

In the 2017 GHGI, EPA included GasSTAR reductions in the calculation methodologies for mishaps (dig-ins), pipeline blowdowns, and "other" reductions. Considerations toward removing or adjusting these reductions, and revisions implemented in the 2018 GHGI, are discussed below.

4.2.1 Mishaps (Dig-ins)

2017 GHGI Methodology and Revisions Considered: The mishaps (dig-ins) methodology was revised for the 2016 GHGI. The activity data for this source were revised, but the EF was not; the current EF is based on the 1996 GRI/EPA study. EPA's April 2016 memo on revisions to the distribution segment methodology[7] provides additional detail on this source and previous considerations. Available data (Lamb et al. 2015[8]) indicate that mishap

[7] https://www.epa.gov/sites/production/files/2016-08/documents/final_revision_ng_distribution_emissions_2016-04-14.pdf
[8] http://pubs.acs.org/doi/full/10.1021/es505116p

emissions may be higher than the calculated potential emissions in the current GHGI. Gas STAR reductions for mishaps in recent years account for just under two percent of the annual emissions, and for one year (2011) there are reductions equal to approximately ten percent of annual mishap emissions. Table 6 presents the GasSTAR data on mishaps. Based on this information, incorporating GasSTAR reductions for mishaps may not be appropriate. The EPA is considering removing the mishaps (dig-ins) GasSTAR reductions from the GHGI. EPA seeks stakeholder feedback on this issue, including on alternate methodologies or data sources for calculating emissions from mishaps.

Table 6. Distribution Segment Mishaps GasSTAR Reductions, For Certain Years (mt CH_4)

Emission Source	1993	1995	2000	2005	2010	2011	2015
Mishaps	0	0	0	255	793	4,687	846

2018 GHGI Revision: EPA removed mishaps (dig-ins) reductions data from the methodology for all time series years due to the considerations discussed above.

4.2.2 Pipeline Blowdowns

2017 GHGI Methodology and Revisions Considered: Similar to the revision to the mishaps emission source, the pipeline blowdowns methodology was revised for the 2016 GHGI; the activity data were revised but the EF was not, and the current EF is based on the 1996 GRI/EPA study, and Gas STAR data are taken into account to calculate net emissions. EPA's April 2016 memo on revisions to the distribution segment methodology[9] provides additional detail on this source and previous considerations.

Available data (Lamb et al. 2015[10] and reported Gas STAR reductions) indicate that pipeline blowdown emissions may be higher than the calculated potential emissions in the GHGI. The Gas STAR data for pipeline blowdown emissions shows varying magnitudes of reduction with no clear trend over time, and 13 years of the 1990-2015 time series do not have reported pipeline blowdown GasSTAR reductions. In recent years, the pipeline blowdown emission reductions are less than three percent of the GHGI emissions calculated for this source; however, in prior years, Gas STAR reductions equal approximately 36 percent of the GHGI emissions (excluding those years with no reductions reported) and for one year, 2005, the Gas STAR reductions are 99 percent of the GHGI emissions for pipeline blowdowns. Table 7 presents the pipeline blowdowns GasSTAR data.

Table 7. Distribution Segment Pipeline Blowdowns GasSTAR Reductions, For Certain Years (mt CH_4)

Emission Source	1993	1995	2000	2005	2010	2011	2015
Pipeline Blowdowns	0	0	0	3,821	530	18	81

The Lamb et al. survey resulted in a lower EF for pipeline blowdowns than the current GHGI basis. However, the surveys conducted for both the GRI/EPA study and the Lamb et al. study had a limited number of respondents, so the Lamb et al. study combines the data sets to determine average emission factors based on a larger pool, rather than drawing a conclusion regarding industry trends over time toward lower emissions.

Pipeline blowdown emissions are also a small emissions source, and contribute approximately 0.35% of distribution segment emissions over the time series. Due to the lack of a clear trend over time and consideration toward the overall magnitude of this source's emissions, the EPA considered removing the pipeline blowdowns GasSTAR reductions from the GHGI which would simplify the methodology, and seeks stakeholder feedback on this approach.

[9] https://www.epa.gov/sites/production/files/2016-08/documents/final_revision_ng_distribution_emissions_2016-04-14.pdf
[10] http://pubs.acs.org/doi/full/10.1021/es505116p

2018 GHGI Revision: EPA removed distribution pipeline blowdowns reductions data from the methodology for all time series years due to the considerations discussed above.

4.2.3 "Other" Reductions

2017 GHGI Methodology and Revisions Considered (October 2017): Certain GasSTAR reductions data cannot be attributed to specific sources, because sufficient detail are not available. These reductions are classified as "other" distribution segment GasSTAR reductions for purposes of the GHGI. Less than 2% of the distribution segment emissions are attributable to sources that have not been recently revised, and still use a potential emissions calculation approach. The "other" GasSTAR reductions exceed the total emissions estimated for sources that use the potential emissions approach by approximately 2.5 times on average over the time series. Table 8 presents the "other" distribution segment GasSTAR data. Due to these considerations, the EPA considered removing "other" GasSTAR reductions from the GHGI, or developing a scaling factor to decrease the magnitude of the reductions. EPA requested stakeholder feedback on this issue.

Table 8. "Other" Distribution Segment GasSTAR Reductions, For Certain Years (mt CH_4)

Emission Source	1993	1995	2000	2005	2010	2011	2015
"Other" Reductions	20,535	19,693	29,868	44,223	53,216	53,295	40,290

2018 GHGI Revision: EPA removed "other" distribution segment reductions data from the methodology for all time series years due to the considerations discussed above.

5 Well-related Activity Data

EPA has identified a number of older data sources and inconsistencies in the GHGI methodologies for developing activity data for a number of sources and activities related to onshore oil and gas wells, and is assessing options to increase consistency and improve data points for more recent years of the time series.

5.1 Overview of Current GHGI Methodology

Table 9 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.

Table 9. 2017 GHGI Well-Related Activity Data Summary

Emission Source/Activity Data Element	Data Source/Basis
Natural Gas Systems	
Non-associated gas wells (less HF wells)	DrillingInfo
Gas wells with hydraulic fracturing	DrillingInfo
Gas well completions without hydraulic fracturing	400 completions/year for all gas wells in 1992 (GRI/EPA 1996), scaled in future years
Gas well workovers without hydraulic fracturing	4.35% of non-HF gas wells (GRI/EPA 1996)
Hydraulic fracturing completions and workovers (four control categories)	GHGRP direct counts (if higher than DrillingInfo-based estimates)
Well drilling	EIA – gas wells and fraction of dry wells drilled (data set last updated in 2010)
Petroleum Systems	
Producing oil wells	DrillingInfo
Heavy crude wells population fraction	7.05% of all oil wells (EPA/ICF 1999)
Oil well completions without hydraulic fracturing	EIA crude oil wells drilled, less HF oil well completions
Oil well workovers	7.5% of producing oil wells (Radian 1999)
Hydraulic fracturing completions (two control categories)	DrillingInfo
Well drilling	EIA – oil wells and fraction of dry wells drilled (data set last updated in 2010)

5.2 Revisions Under Consideration for the GHGI

EPA has identified four general focus areas to increase consistency and accuracy of activity data for certain emission sources identified in Table 9:

- **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.
- **Well drilling**: EIA no longer maintains the well drilling activity data set (most recent estimates cover through 2010), so the GHGI requires a new data source for the entire time series, or at least 2011 forward.
- **Gas and oil well completions without HF:** 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.
- **HF gas well completions**: The GHGRP reported counts are higher than those obtained from the DrillingInfo 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.

Potential GHGI revisions to address these priority areas are discussed in more detail below. After these priority areas are addressed, EPA might investigate updated methodology and/or data sources to potentially improve estimates for well workover activity.

5.2.1 Activity data for heavy versus light crude equipment service

Heavy crude is defined as oil with lower than 20^{o} 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 report[11], 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 data, 19% 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 revise the equipment count splits in recent years and reflect updated industry trends.

[11] EPA/ICF (1999) 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.

Table 10. RY2015 Subpart W Equipment Counts[a]

Data Set	Count of Separators	Count of Wellheads	Separators/ Wellhead	Number of Data Points (Facilities)	Notes/Methodology
All onshore oil prod	76,623	213,278	0.36	337	Counts from records classified in Table R.4 as "Crude oil production equipment"[b]
Heavy crude-only facilities	1,818	40,894	0.04	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	54,098	0.41	102	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 a 1999 Radian report[12] 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. 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.

5.2.2 Activity data for well drilling

EPA is currently investigating the use of DrillingInfo's DI Desktop raw data feed for developing counts of wells drilled over the time series. A draft methodology that indirectly calculates well drilling activity data is discussed in the June 2017 EPA memo regarding estimates for emissions from abandoned wells[13]. The draft methodology discussed in the memo involves counting wells with a reported spud date and/or completion date within a given calendar year. Both fields are considered together because not all state databases consistently record well spud dates (i.e., the date drilling begins). Based on preliminary estimates, this methodology produces higher counts than EIA estimated; for example, 47,000 wells drilled in 2009 compared to EIA's estimate of 33,000. EPA plans to further investigate how these data fields are populated in the database to refine the methodology and bring estimates closer to existing estimates for years where EIA data are available. For example, EPA might count wells with a spud date in a given year plus wells with null spud date but that report first production within a given year. Note, while using this draft methodology may over-estimate well drilling activity data, it does not necessarily

[12] EPA/Radian (1999) Methane Emissions from the U.S. Petroleum Industry. Prepared by Radian International. U.S. Environmental Protection Agency. February 1999.
[13] "Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2016: Update Under Consideration for Abandoned Wells in Natural Gas and Petroleum Systems," available at https://www.epa.gov/sites/production/files/2017-06/documents/updates_under_consideration_for_2018_ghgi_estimates_for_abandoned_wells_in_natural_gas_and_petroleum_systems_508.pdf

over- or under-estimate abandoned well activity data, due to additional query logic discussed in the June 2017 memo.

Because some wells are drilled but do not achieve reportable production levels (dry wells), EPA cannot entirely rely on the existing methodology for apportioning wells between natural gas and petroleum production types for querying the DrillingInfo database (the existing methodology relies on reported production volumes of gas and hydrocarbon liquids). Also for recent time series years, most wells drilled may not yet have publicly available data on production due to the time required for well completion/testing, data submittal to state agencies, and state agency public release schedules. EPA seeks stakeholder feedback on how to apportion counts of dry wells between gas and oil production types; and on how to apportion counts of wells drilled but without public production data.

5.2.3 Activity data for well completions

EPA is also investigating the use of DrillingInfo's DI Desktop raw data feed for developing counts of wells completed over the time series. EPA might develop counts of total gas and oil wells completed, and counts of wells completed with HF, then assign the difference between the two counts as non-HF well completions. The methodology for these counts would be similar to the methodology developed for well drilling counts. The primary difference would be that a well would only be counted as completed in a given year if it subsequently reported production. The same considerations discussed above regarding apportionment between gas and oil for newer wells (i.e., lack of availability of production data) would apply to completion counts.

For HF gas well completions, where GHGRP counts are higher than DrillingInfo-based estimates, EPA might investigate GHGRP and DrillingInfo activity on a regional basis to better understand potential gaps or other issues. EPA might also analyze newly reported GHGRP RY2016 subpart W data for HF oil well completions to assess completeness of the DrillingInfo counts.

5.3 Requests for Stakeholder Feedback

1. Based on RY2015 subpart W data, 19% 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.
2. 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?

3. EPA seeks stakeholder feedback on how to use available data to improve national activity estimates for well drilling across the time series. Section 5.2.2 discusses potentially using DrillingInfo data; EPA seeks feedback on this data source/approach in general, and specifically on how to apportion event counts between natural gas and petroleum source categories for wells drilled but without public production data (i.e., dry or newly drilled and not yet reporting).
4. EPA seeks stakeholder feedback on how to use available data to improve national activity estimates for well completion 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. Section 4.2 discusses available subpart W data in greater detail.

6 Liquefied Natural Gas (LNG) Facilities

6.1 Overview of Current GHGI Methodology

The current GHGI estimates emissions from LNG storage stations and LNG import terminals in the transmission and storage segment of natural gas systems. Each LNG facility type estimate includes estimates for station fugitives, reciprocating and centrifugal compressor fugitives, compressor exhaust, and station venting (i.e., blowdowns). The GHGI uses the same source-specific EFs for both LNG storage stations and LNG import terminals. The EFs are based on the 1996 GRI/EPA study, which developed EFs using underground natural gas storage and transmission compressor station data. Specific emissions data for LNG storage stations and LNG import terminals were not available in the GRI/EPA study.

The GHGI considers both complete storage stations and satellite facilities (that do not perform liquefaction) to calculate activity data for LNG storage stations. The GHGI assumes that satellite facilities have approximately one-third of the equipment found at complete storage stations, and thus only includes one-third of the satellite facility count in the emissions calculations. Complete storage station and satellite facility counts are available for 1993 and 2003.[14] Storage station counts for years before 2003 are calculated by applying linear interpolation between the 1993 and 2003 values. Storage station counts for years after 2003 are set equal to the 2003 counts. The count of reciprocating and centrifugal compressors are estimated by applying a certain ratio of compressors per plant. Compressor exhaust activity data are estimated by applying a certain ratio of hp-hr per facility throughput.

The GHGI determines LNG import terminal counts using data available from FERC.[15] The terminal counts include onshore and offshore facilities. FERC provides both import and export terminal data, but only import terminals are considered for the GHGI, since export terminals have only recently been constructed in the U.S. The GHGI also reduces the count of reported import terminals from FERC by 30%, assuming that import terminals have approximately two-thirds of the equipment found at complete facilities (as they do not perform liquefaction). Compressor counts and exhaust activity data are determined in the same manner as for LNG storage, applying ratios.

6.2 Revisions Under Consideration for the GHGI

Subpart W of the EPA's Greenhouse Gas Reporting Program (GHGRP) collects data from LNG storage and LNG import and export facilities that meet a reporting threshold of 25,000 metric tons of CO_2 equivalent (MT CO_2e) emissions. Subpart W collects emissions and activity data for centrifugal and reciprocating compressors, and equipment leaks for LNG storage and LNG import and export facilities. Subpart W also collects blowdown emissions for LNG import and export facilities. Facilities began reporting flare emissions under a unique flare stacks source starting in RY2015; in prior RYs, compressor flaring emissions were reported with the centrifugal

[14] Energy Information Administration, Department of Energy. "US LNG Markets and Uses." 2004. Available at http://www.eia.doe.gov/pub/oil_gas/natural_gas/feature_articles/2004/lng/lng2004.pdf.
[15] FERC. "North American LNG Import/Export Terminals – Existing." Available at http://www.ferc.gov/industries/gas/indus-act/lng/lng-existing.pdf.

and reciprocating compressor emissions data. The subpart W emission calculation methodologies for each emission source are:

- Reciprocating compressor vented/fugitive emissions are calculated using direct leak measurement for the following major component sources: rod packing emissions (in operating mode), blowdown valve emissions (in operating mode and standby, pressurized mode), and isolation valve emissions (in not operating, depressurized mode). Facilities use the measured leak rate data in conjunction with relevant hours of operation in each compressor mode to determine annual emissions.
- Centrifugal compressor vented/fugitive emissions are calculated using direct leak measurement for the following major component sources: wet seal oil degassing emissions (in operating mode), blowdown valve emissions (in operating mode), and isolation valve emissions (in not operating, depressurized mode). Facilities use the measured leak rate data in conjunction with relevant hours of operation in each compressor mode to determine annual emissions.
- Equipment leak emissions are calculated using leak surveys or population counts, depending on the component type.
    - Leak surveys: Applicable to valves, connectors, pump seals, and other components. Facilities use leaking component counts, the time each component is leaking (hours), and component-specific "leaker" EFs to calculate emissions. Facilities conduct leak surveys to determine the number of leaking components. The component-specific leaker EFs provided in subpart W were developed using light liquid data for (synthetic organic chemical manufacturing industry (SOCMI) facilities from the *Protocol for Equipment Leaks*.[16]
    - Population counts: For vapor recovery compressors, facilities use the total number of compressors and their operating hours in a year, coupled with the population EF, to calculate emissions.
- Flare emissions are calculated in subpart W using a continuous flow measurement device or engineering calculations, the gas composition, and the flare combustion efficiency. A default flare combustion efficiency of 98% may be applied, if manufacturer data are not available.

A coverage analysis comparing RY2015 GHGRP data to U.S. Department of Energy (DOE) data shows that 86% of the LNG import facilities, 100% of the LNG export facilities, and 10% of LNG storage capacity are GHGRP reporters. A comparison of the current GHGI and reported subpart W emissions, including average emissions per station, is presented in Table 11.

Table 11. LNG Storage and LNG Import/Export Terminal CH_4 Emissions Comparison

Source	2011	2012	2013	2014	2015
LNG Storage					
2017 GHGI					
CH_4 Emissions (mt)	73,124	73,124	73,124	73,124	73,124
# Stations[a]	70	70	70	70	70
CH_4 EF (mt/station)	1,041	1,041	1,041	1,041	1,041
Subpart W (as reported)[b]					
CH_4 Emissions (mt)	67	10	31	17	70
# Stations	6	5	5	5	7
CH_4 EF (mt/station)	11	2	6	3	10
LNG Import/Export Terminals					
2017 GHGI (Import Terminals)					
CH_4 Emissions (mt)	15,681	12,377	10,902	10,190	10,801
# Terminals	8	8	8	8	8

[16] EPA. *Protocol for Equipment Leak Emission Estimates.* Emission Standards Division. U.S. EPA. SOCMI, Table 2-7. November 1995.

Source	2011	2012	2013	2014	2015
CH_4 EF (mt/terminal)	2,036	1,607	1,416	1,323	1,403
Subpart W – Import Terminals (as reported)[b]					
CH_4 Emissions (mt)	2,481	2,151	1,249	6,939	650
# Terminals	7	7	7	7	6
CH_4 EF (mt/terminal)	354	307	178	991	108
Subpart W – Export Terminals (as reported)[b]					
CH_4 Emissions (mt)	1,826	1,990	1,572	1,067	801
# Terminals	1	1	1	1	1
CH_4 EF (mt/terminal)	1,826	1,990	1,572	1,067	801

a – 2003 estimate is carried forward for all years. This number reflects all complete storage stations (57) and one-third the count of satellite stations (39).
b – Data reported as of August 13, 2016.

The EPA reviewed the subpart W activity data and calculated activity factors for reciprocating and centrifugal compressors. A comparison of the 2017 GHGI and subpart W activity data for year 2015 is presented in Table 12.

Table 12. LNG Storage and LNG Import/Export Terminal Activity Data Comparison for Year 2015

Source	2017 GHGI	Subpart W (as reported)[a]
LNG Storage		
# Stations	70	7
# Recip. Compr.	270	10
# Recip. Compr. per Station	3.8	1.4
Recip. Compr., MMhphr	579	12.7
Recip. Compr., MMhphr per Station	8.2	1.8
Recip. Compr., MMhphr per Compr.	2.1	1.3
# Centr. Compr.	64	2
# Centr. Compr. per Station	0.9	0.3
Centr. Compr., MMhphr	113	24.4
Centr. Compr., MMhphr per Station	1.6	3.5
Centr. Compr., MMhphr per Compr.	1.8	12.2
LNG Import/Export Terminals		
# Terminals	8	7
# Recip. Compr.	37	17
# Recip. Compr. per Terminal	4.9	2.4
Recip. Compr., MMhphr	435	132.9
Recip. Compr., MMhphr per Terminal	56.5	19.0
Recip. Compr., MMhphr per Compr.	11.6	7.8
# Centr. Compr.	7	10
# Centr. Compr. per Terminal	0.9	1.4
Centr. Compr., MMhphr	93	104.2
Centr. Compr., MMhphr per Terminal	12.1	14.9
Centr. Compr., MMhphr per Compr.	14.1	10.4

a – Data reported as of August 13, 2016.

The EPA might calculate EFs based on the subpart W data for each of the vented/fugitive emission sources described above. Linear interpolation could then be applied from the 1992 EFs (based on GRI/EPA) to a recent year EF (such as RY2015 calculated EFs) to calculate EFs over the time series. The current GHGI EFs are not based on data specific to LNG facilities (they are based on data from transmission and storage stations), and therefore, the EPA might also apply subpart W EFs to all years of the GHGI. Subpart W does not collect blowdown data from

LNG storage facilities; the EPA could apply the current GHGI EF or use the subpart W LNG import/export blowdown data for this source. The EPA might also develop facility-level EFs using subpart W data due to the minimal emissions from LNG facilities and to allow for straightforward implementation of subpart W data.

Compressor exhaust data in the GHGI were evaluated as part of the gas processing segment revision in the 2017 GHGI. The EPA retained the existing GHGI EF, but revised the AD to use an activity factor developed from subpart W data. The EPA is considering implementing a similar approach involving developing a revised activity factor on a station level-basis (i.e., MMhp-hr/station) using subpart W data and maintaining the current GHGI EF.

Sources of activity data for scaling LNG storage emissions include the national LNG storage database maintained by PHMSA[17], and for scaling LNG import/export emissions include the national LNG import/export activity database maintained by EIA.[18] EPA plans to investigate these two sources of activity data for use in calculating LNG facility emissions over the 1990–2016 time period.

The GHGI does not currently include LNG export terminals while subpart W does include reporting from one LNG export terminal. EPA may revise the GHGI methodology to include LNG export terminals. FERC identifies 2 LNG export terminals,[19] and the one that is not currently reported under subpart W (as of RY2015) started operations in 2016. In addition, several LNG export terminals are under construction, are approved for construction, or are proposed to be constructed.[20,21] LNG export terminals may not have been a significant emissions contributor over most of the GHGI time series, but LNG export emissions may be expected to increase as additional terminals go into operation.

7 N_2O Emissions

7.1 Revisions Under Consideration for the GHGI

N_2O emissions from flaring within petroleum and natural gas systems are not currently included in the GHGI.GHGRP subparts W and Y include reporting of N_2O from flaring. The instructions in GHGRP subparts W and Y for petroleum and natural gas system reporters, and for refinery reporters, respectively, specify they must calculate N_2O emissions from flares using N_2O emission factors from Table C-2 of GHGRP subpart C (Conventional Stationary Combustion Sources). For consistency with sources using methodology based on GHGRP data, future GHGIs could use N_2O data reported to GHGRP.

Table 13. RY2015 Flaring Sources in Petroleum and Natural Gas Systems

Combustion Source	GHGRP N_2O (as reported) (mt)[a]
NG & Petroleum Production	
NG: Large Condensate Tanks w/Flares	13.9
NG: Small Condensate Tanks w/Flares	
Petro: Large Oil Tanks w/Flares	
Petro: Small Oil Tanks w/Flares	
Petro: Associated Gas Flaring	32.4

[17] http://www.phmsa.dot.gov/pipeline/library/data-stats/distribution-transmission-and-gathering-lng-and-liquid-annual-data
[18] http://energy.gov/fe/downloads/lng-annual-report-2015
[19] FERC. "North American LNG Import/Export Terminals – Existing." Available at http://www.ferc.gov/industries/gas/indus-act/lng/lng-existing.pdf.
[20] FERC. "North American LNG Import/Export Terminals – Approved." Available at https://www.ferc.gov/industries/gas/indus-act/lng/lng-approved.pdf
[21] FERC. "North American LNG Export Terminals – Proposed." Available at https://www.ferc.gov/industries/gas/indus-act/lng/lng-proposed-export.pdf

Combustion Source	GHGRP N_2O (as reported) (mt)[a]
NG: Gas Well HF and non HF Completions and Workovers	8.6
Petro: Oil Well HF Completions and Workovers	N/A
Gathering and Boosting Station Flares	N/A
Flare Stacks	9.6
Well Testing	1.3
Offshore Flaring	11.5
Gas Processing	
Flares	16.6
NG Transmission and Storage	
Flare Stacks	0.04
LNG Storage	
Flare Stacks	0.14
LNG Import and Export	
Flare Stacks	0.15
Petroleum Refineries	
Flares	92

a – Data reported as of August 5, 2017.
N/A = Not Applicable. Hydraulically fractured oil well completions and gathering and boosting stations did not report this data in RY2015. EPA will assess N_2O updates for this source when it assesses GHGRP data for potential incorporation for this source. RY2016 N_2O emissions from flaring from gas *and* oil well completions with hydraulic fracturing were 20.3 mt, and RY2016 N_2O emissions from flare stacks in gathering and boosting were 4.8 mt.

N_2O emissions are also reported to GHGRP for engine exhaust, dehydrators, and other sources. EPA is assessing these sources to determine whether any emissions should be included in natural gas and petroleum systems.

7.2 Requests for Stakeholder Feedback

1. EPA seeks feedback on updating the GHGI to include N_2O from flaring, based on GHGRP data, including scale up considerations.
2. EPA seeks feedback on incorporation of N_2O emissions from other sources.

8 Liquids Unloading—Early Time Series Emissions

8.1 Overview of Historical and Current GHGI Methodology

Prior to the 2010 GHGI, EPA estimated emissions from liquids unloading using an EF and activity data developed in the 1996 GRI/EPA study. GRI/EPA collected operating data for approximately 6,000 wells located at 24 sites. GRI/EPA calculated that 41.3% of gas wells require liquids unloading, and 49,571 scfy CH_4 was emitted per venting well (based on engineering calculations and various assumptions). The GRI/EPA study did not acknowledge liquids unloading using plunger lift or non-emitting technologies, which industry generally adopted after the timeframe of the study.

In the 2010 GHGI, EPA aimed to reduce uncertainty surrounding the GRI/EPA EF for liquids unloading, and revised the EF based on calculations using a sample of well and reservoir characteristics from an industry database along with an engineering statics equation. This methodological change increased emissions by more than 22 times compared to estimates based on the GRI/EPA EF.

In the 2013 GHGI, EPA revised the liquids unloading methodology to use data from a 2012 report published by the American Petroleum Institute (API) and America's Natural Gas Alliance (ANGA). The EPA compared the API/ANGA

report data with preliminary subpart W data, which showed similar emissions levels. The report also showed that there is more widespread use of emissions control technologies than had been assumed in the previous Inventories, and it demonstrated that duration of emissions from liquids unloading activities is shorter than had been assumed in the previous methodology. EPA revised the GHGI methodology to use the API/ANGA report fraction of gas wells requiring liquids unloading with and without plunger lift, by region, for all time series years; and EFs for both plunger and non-plunger lift wells.

In the 2017 GHGI, the EPA revised the liquids unloading EFs and activity data to reflect the most up-to-date data available from GHGRP subpart W. EPA calculated EFs for liquids unloading with and without plunger lifts by summing the emissions reported under GHGRP subpart W in each category for RY2011-RY2015 and dividing by the total number of wells in each category over those years. These EFs were used for all years in the GHGI time series.

For the 2018 GHGI, EPA again revised the liquids unloading EFs to reflect year-specific data available from GHGRP subpart W. EPA calculated year-specific EFs for liquids unloading with and without plunger lifts for years 2011 forward, and applied year 2011 EFs for all prior years. Refer to the companion April 2018 *Year-specific Revisions* memo for additional information on 2018 GHGI revisions that impacted recent time series years.

For the 2018 GHGI, EPA developed activity data using both subpart W data and the API/ANGAA report, with minor updates to the 2017 GHGI methodology to calculate year-specific factors where possible, as documented in the April 2018 *Year-specific Revisions* memo. Data from the API/ANGAA report were used to develop the national average fraction of gas wells requiring liquids unloading (56%) throughout the time series. The EPA assumed that in 1990, all wells conducting liquids unloading vent without plunger lifts (and that no wells vent with plunger lifts or use non-emitting technologies). The EPA used the subpart W RY2015 activity factor (AF) for the percent of all non-associated gas wells that vent during liquids unloading with and without plunger lifts, 16.6%, to calculate activity data for 2011 through 2015, and applied the RY2016 AF, 14.4% to year 2016. The EPA then applied the year-specific fraction of wells that vent with plunger lifts (varies from 53-63%) and wells that vent without plunger lifts (varies from 37-47%) for 2011-2016. Finally, the EPA applied linear interpolation from the 1990 data points to the 2011 data points.

8.2 Revisions Under Consideration for the GHGI

The emissions and activity data methodology implemented in the 2018 GHGI rely exclusively on recently collected data (i.e., both subpart W and the API/ANGAA report use data from 2011 or later). The EPA is evaluating the liquids unloading data collected for the 1996 GRI/EPA study to determine if it better represents early time series years. As presented in Table 14 below, there are significant differences between average emissions per well requiring liquids unloading in comparing the GRI/EPA study and the 2017 GHGI.

Table 14. Liquids Unloading CH_4 Average Emissions per Well (scfy CH_4/well)

Data Source	With Plunger Lift	Without Plunger Lift
2017 GHGI	148,589	160,411
1996 GRI/EPA	– [a]	49,571

a – 1996 GRI/EPA did not identify liquids unloading events with plunger lifts.

The GRI/EPA EF for liquids unloading without plunger lifts is less than one third of the 2017 GHGI EF, which is based on subpart W data. The EPA is considering whether it is appropriate to use the lower GRI/EPA EF for early time series years (e.g., 1990 to 1992), or to maintain the current approach.

The GRI/EPA liquids unloading data represent conventional wells only, whereas the subpart W data includes conventional and unconventional wells. The EPA reexamined the subpart W data to evaluate whether differences

between conventional and unconventional well liquids unloading might explain why the GRI/EPA EF is much lower. The EPA analyzed reported subpart W data for liquids unloading without plunger lifts (to parallel the GRI/EPA basis), comparing "high permeability gas" formation type data (i.e., conventional wells) to "other tight reservoir rock" and "shale gas" formation type data (i.e., unconventional wells). Table 15 presents the relevant subpart W RY2015 data and calculated EFs.

Table 15. Subpart W RY2015 Liquids Unloading without Plunger Lifts Data and Calculated EFs compared to GRI/EPA

Data Set	CH_4 Emissions (mt)	# of Wells	CH_4 EF (scfy/well)
Subpart W[a] – Conventional[b]	14,805	3,118	246,539
Subpart W[a] – Unconventional[c]	50,308	16,735	156,083
GRI/EPA – Conventional	6,934	2,641	49,571

a – Data reported as of August 13, 2016.
b – Subpart W data reported for the high permeability gas formation type.
c – Subpart W data reported for other tight reservoir rock and shale gas formation types.

The subpart W liquids unloading without plunger lifts EF for conventional wells is higher than that for unconventional wells. As such, this analysis by itself does not support using the relatively low GRI/EPA EF for early time series years. However, comparing the emissions per well, as in Table 15, does not consider other potential differences in liquids unloading operations between the GRI/EPA and subpart W data sets that might explain why the GRI/EPA EF is lower than the subpart W-based EF, such as the duration of unloadings (i.e., hours per event), the frequency of unloading, or the volume of gas vented per unloading. The GRI/EPA study and subpart W both provide data on the number of unloadings in a year; these data are compared in Table 16.

Table 16. Number of Unloadings from Subpart W RY2015 and GRI/EPA for Liquids Unloading without Plunger Lifts

Data Set	# of Wells with Liquids Unloading	# of Unloadings	# of Unloadings per Well
Subpart W[a] – Conventional[b]	3,118	39,253	13
Subpart W[a] – Unconventional[c]	16,735	349,655	21
GRI/EPA – Conventional	2,641	102,274	39

a – Data reported as of August 13, 2016.
b – Subpart W data reported for the high permeability gas formation type.
c – Subpart W data reported for other tight reservoir rock and shale gas formation types.

Based on the calculated EFs in Table 15, where the GRI/EPA EF is the lowest, one might expect the GRI/EPA data to show very infrequent unloadings per well (assuming all other event characteristics equal). However, the GRI/EPA event frequency is higher than that of subpart W conventional and unconventional wells with liquids unloading, implying that the duration and/or total volume per event is significantly lower on average in the GRI/EPA data set compared to the GHGRP data sets. Data on unloading durations and volumes are not readily available for comparison in order to better understand potential trends over time. The EPA requests stakeholder feedback on the analyses presented in this memo and any other available data or analyses that might be taken into account to consider whether the GRI/EPA EF for liquids unloading without plunger lifts should be incorporated into early years of the GHGI time series.

The GRI/EPA study provides total well counts (6,387) and the number of wells that required liquids unloading (2,641) for the sites evaluated. This equals 41.4% of the well population requiring liquids unloading, and venting. The current GHGI assumes for all time series years that 56% of wells require liquids unloading, with 56% of wells venting from liquids unloading in early years and 16.8% in recent years. If the GRI/EPA data is used to revise the

current GHGI methodology, the activity data might also be updated. EPA seeks feedback on any other available data or methodologies that might be used to reconsider the percent of wells requiring liquids unloading, particularly for early time series years.

8.3 Requests for Stakeholder Feedback

1. Is the GRI/EPA EF for liquids unloading without plunger lifts more appropriate than the current methodology for early years of the GHGI time series?
2. Is there additional information or data the EPA should consider when determining whether and how the GRI/EPA data should be incorporated into the GHGI?
3. Have changes in the characteristics of liquids unloading operations occurred over time—such as the duration of liquids unloading, the frequency of liquids unloading, or the volume of gas vented per unloading—that would explain the difference between the GRI/EPA EF (from 1992) and the subpart W-based EF?
4. How should available data be reflected in the GHGI time series to show the percent of wells requiring liquids unloading over time (e.g., data from GRI/EPA show 41% of gas wells, while API/ANGAA show 56%)?

9 Offshore Production Platform Emissions

9.1 Overview of Current GHGI Methodology

To calculate emissions from offshore production platforms in the 2015 and later GHGIs, EPA used EFs developed from the most recent available year of data (2011) from DOI/Bureau of Ocean Energy Management's (BOEM) Gulf Offshore Activity Data System (GOADS). EPA developed EFs for four offshore production platform categories: deepwater gas, deepwater oil, shallow water gas, and shallow water oil. EPA calculated EFs on both a complex basis and a structure basis to compare and consider the appropriateness of each.

Because the existing activity data in the GHGI were based on a count of structures, the 2015 GHGI used the structure-based EF. Table 17 presents the EFs for methane (CH_4) and carbon dioxide (CO_2) developed from the 2011 GOADS database. The structure-based EFs are presented in the third column. As seen in Table 17, when gas platforms are defined as producing more than 100 thousand cubic feet of gas per barrel of hydrocarbon liquid (mcf/bbl), there are no deepwater gas platforms in the GOADS database, resulting in no EF for this platform group. EPA assigned the deepwater oil platform EF to deepwater gas platforms as a surrogate.

Table 17. Methodology for 2015 GHGI—EFs Based on 2011 GOADS Database

Pollutant/Platform Category	Complex EF (scf/day)	Structure EF (scf/day)
CH_4		
DEEP GAS >656ft	– [a]	– [a]
DEEP OIL >656ft	93,836	93,836
SHALLOW GAS	10,142	8,899
SHALLOW OIL	19,567	16,552
CO_2 [b]		
DEEP GAS >656ft	– [a]	– [a]
DEEP OIL >656ft	1,100	1,100
SHALLOW GAS	189	166
SHALLOW OIL	327	276

a – No available data to calculate.

b – Note that the EFs in Table 17 exclude CO_2 emissions from flaring on offshore platforms, which is a separate line item in natural gas systems source category.

9.2 Revisions Under Consideration for the GHGI

Due to the availability of new data in the 2014 GOADS database, EPA is considering updating its estimates to use the latest data to improve accuracy in the 2018 GHGI. The sections below discuss updates under consideration to emissions data and activity data.

9.2.1 Offshore Platforms Emissions Data

Since the development of EFs using 2011 GOADS data for the 2015 GHGI, the 2014 GOADS database has been finalized. A comparison of EFs based on the 2011 GOADS Database to the EFs based on the 2014 GOADS Database is provided in Table 18. Some of the trends in offshore activity that lead to the observed changes in emissions between 2011 and 2014 include: the shutting down of marginal platforms in response to dropping energy prices, the reduction in venting of waste gas, the shift towards fewer platforms but more wells and production per platform, and improvements in how dual fuel engine emissions are calculated. For more information on trends in the GOADS data over time, refer to BOEM's *Year 2014 Gulfwide Emissions Inventory Study*[22]. There are competing trends between 2011 and 2014, that result in some emission factors increasing and some emission factors decreasing.

EPA is considering using the EFs from the 2014 GOADS database in one of several ways in the 2018 GHGI. For example, EPA might use the current EF for years before 2014, and updated EFs for years 2014 forward; or combine emissions data from the 2011 and 2014 data sets (or possibly other data sets) to develop revised EFs for applying to all years.

Table 18. Comparison of EFs Based on 2011 GOADS Database to the EFs based on the 2014 GOADS Database

Pollutant/Platform Category	GOADS 2011		GOADS 2014	
	Complex EF (scf/day)	Structure EF (scf/day)	Complex EF (scf/day)	Structure EF (scf/day)
CH_4				
DEEP GAS >656ft	– [a]	– [a]	-[a]	-[a]
DEEP OIL >656ft	93,836	93,836	67,603	67,603
SHALLOW GAS	10,142	8,899	11,656	9,950
SHALLOW OIL	19,567	16,552	21,146	17,931
CO_2 [b]				
DEEP GAS >656ft	– [a]	– [a]	-[a]	-[a]
DEEP OIL >656ft	1,100	1,100	430	430
SHALLOW GAS	189	166	155	132
SHALLOW OIL	327	276	400	339

a – No available data to calculate.

b – Note that the EFs in Table 18 exclude CO2 emissions from flaring on offshore platforms, which is a separate line item in natural gas systems source category.

As noted in the footnotes to Table 17 and Table 18, CO_2 emissions from all offshore flaring activities have been calculated as a single separate line item in the natural gas systems inventory. The activity data for the calculation of these emissions from 1990 through 2008 was provided by U.S. Mineral and Mining Service (MMS) staff (U.S. Department of Interior) based on data collected in their Oil and Gas Operations Reports (OGOR). The data that they provided was the total volume of gas vented and flared at offshore platforms in the Gulf of Mexico and the estimated percentage of this gas that was flared. Since 2009, this data had not been available, so the 2008 values have been used for all years since. The OGOR data is now available on the internet, with some notable limitations: the total volume of gas vented and flared is available for all years from 1990 through present, but the separate portions of gas vented and flared has only been available since 2011 (the first year that they have complete data

[22] https://www.boem.gov/espis/5/5626.pdf

on this activity). Prior to 2011, the portions of gas vented versus flared were estimated based on anecdotal information. For this reason, there is some disconnect between the estimated volumes of flared gas up through 2008 and the specifically measured volumes of flared gas that have been collected since 2011 in the OGOR reports. The volumes of flared gas used in the GHGI and the volumes of flared gas reported in OGOR are compared in Table 19 below for 2008 and subsequent years.

Table 19. Comparison Between OGOR and GHGI of Flared Gas Volumes for Offshore Production Platforms (Bscf/yr)

Data Source	2008 - 2010	2011	2012	2013	2014	2015
OGOR	NA	7.0	7.1	6.0	6.5	7.1
2017 GHGI	6.0	6.0	6.0	6.0	6.0	6.0

NA - Not available; OGOR reports did not collect this data prior to 2011

9.2.2 Offshore Platforms Activity Data

For the 2015 and earlier GHGIs, activity data—i.e., platform counts in each of the four categories (deepwater gas, deepwater oil, shallow water gas, and shallow water oil)—were based on a nationwide DOI platform census that has not been updated since 2010. Additionally, the DOI data source did not differentiate between active and inactive platforms and may not have differentiated between production platforms and other structures; therefore, past methodology applied an EF for active platforms to a total platform count and possibly a total structure count, which may have overestimated source emissions. EPA is therefore considering revising the activity data for this emission source in the 2018 GHGI, to ensure consistency with the EF basis.

The Bureau of Ocean Energy Management (BOEM) and its counterparts at the Department of Interior have developed an online database that includes information on when offshore structures were installed and removed and the depth of water at the structure (https://www.data.boem.gov/Leasing/OffshoreStatsbyWD/Default.aspx). A production structure will contain typical production activities such as gas-oil separation, well unloading, fugitive leaks, gas dehydration, acid gas removal, liquid hydrocarbon storage, and gas compression. A small portion of these production structures have associated support structures such as caissons, wellhead protectors, and living quarters. The production structure and any associated support structures form a "complex."

The BOEM database does not identify which structures are production structures, making a count of production structures difficult. Since there is a similar number of production structures and complexes, emissions should also correlate with the number of complexes—a data element that is more readily available.

The BOEM database also contains the years that each structure was installed and removed. Since structures must be removed as soon as possible, but no later than 5 year of ceasing production (30 CFR 250.1703(c)), the list of structures in place for a given year is also a fairly accurate count of operating structures that year. This database can be queried to also provide a count of in-place complexes in any given year.

To ensure correct interpretation of the BOEM data set in a revised approach to developing GHGI activity data on a complex basis, EPA compared counts of structures and complexes from querying the BOEM database to those published in BOEM's 2011 Gulfwide Emission Inventory (GEI)[23]. Table 20 below compares year 2011 data on the number of structures and associated complexes in the Gulf of Mexico (GOM). The BOEM database counts in the first three populated rows were developed by three different options: counting all platforms that had been installed by the end of 2010 and subtracting those platforms that had been removed by either 2013 (Approach A), 2014 (Approach B), or 2015 (Approach C). For example, Approach A assumes all platforms existing in 2011 but scheduled for removal in 2011, 2012, or 2013 are likely not producing in 2011 and have been removed from the counts of operating platforms. The fourth populated row of Table 20 indicates the number of structures and

[23] https://www.boem.gov/2011-Gulfwide-Emission-Inventory/

complexes in the 2011 GEI reporting with emissions. The count of 2,312 structures and 1,989 complexes is thought to be missing a sizeable number of non-reporters based on a QA/QC assessment conducted as part of the Year 2011 GEI Study report[24]. There were approximately 330 platforms that did not respond to the survey, but in audits of previous inventories they had determined that a significant portion of the non-responders had ceased production. Therefore, Approach A may be the best estimate of the total population of active facilities in 2011 (close to the GEI numbers but accounting for likely missing reporters). Of the reporting facilities with emissions, 1,997 structures and 1,717 complexes had the full complement of activity data to allow them to be sorted into the four platform types, based on oil or gas production and ocean depth. These were used to develop the EFs in Table 17, above.

Table 20. Gulf of Mexico Offshore Activity Data for Year 2011

Data Source	Structures	Complexes
BOEM Database		
Approach A: excluding structures removed by 2013	2,563	2,103
Approach B: excluding structures removed by 2014	2,361	1,933
Approach C: excluding structures removed by 2015	2,233	1,815
BOEM Gulfwide Emission Inventory		
GEI reports for operating platforms and structures	2,312	1,989
GEI reports available for EF development [a]	1,997	1,717

a – Structures and complexes that had the full complement of activity data to allow them to be sorted into the four platform types for EF development.

EPA is considering using the BOEM databases for the Gulf and the Pacific, to first calculate the number of in-place structures and complexes each year since 1990, segregated into the four categories: shallow water gas production, deep water gas production, shallow water oil production, and deep-water oil production. Then, EPA would reduce these numbers by the number scheduled for removal in the following 3 years to obtain estimates of active structures and complexes for use as activity data in the GHGI.

Based on the availability of appropriate activity data discussed in this section, EPA would pair updated activity data on a complex basis with complex-based EFs developed from the GOADS data such as those presented in Table 18.

For developing the activity data needed to calculate the CO_2 emissions from flared offshore gas, EPA is considering using the activity data provided by MMS staff for the years 1990 through 2008 since no other source of that data has been found. For developing the activity data on flared gas volumes since 2011 EPA is considering using the OGOR data now available on the MMS website for these years. For the two years where this data is missing (2009 and 2010), EPA is considering using a linear extrapolation of the 2008 and 2011 values.

9.3 Requests for Stakeholder Feedback

3. EPA seeks feedback on the appropriate data set and methodology to use for developing activity data on complex and structure populations to pair with the current set of EFs in the GHGI.
4. EPA seeks feedback on how the GHGI EFs should be revised to utilize the various GOADS emission data sets, and which methodology is most representative of emissions (e.g., complex- versus structure-based emission factors). The GOADS report 2014 trends analysis noted that there were issues with each GOADS inventory that were corrected in subsequent inventories:
    a. 2000 was the first reporting year and reporters were unfamiliar with the methodology,
    b. 2005 was a low response year due to the impact of several Gulf hurricanes,
    c. 2008 began recording minor emission sources, but omitted loading emissions,

[24] https://www.boem.gov/ESPIS/5/5440.pdf

   d. 2011 had reporting issues with dual fueled turbines that inflated exhaust emissions,
   e. 2014 included loading emissions and corrected the dual fuel reporting errors.
5. EPA seeks feedback on the appropriate data set and methodology to use for developing activity data on volumes of gas flared to pair with the current set of EFs in the GHGI.

10 Natural Gas Emissions at Point of Use

Recent studies have drawn attention to emissions from natural gas points of use. This type of emission source is not currently included in natural gas systems source categories. EPA seeks stakeholder feedback regarding whether and how to incorporate the sources discussed below into the GHGI.

10.1 Residential and Commercial Customer Natural Gas Use

Methane emissions occur downstream of customer meters at the point of use (e.g., domestic heating boiler cycling and pre-ignition losses from domestic and commercial gas appliances). The current GHGI estimates emissions from customer meters, but not further downstream. Note that the current GHGI methodology considers indoor residential meter emissions negligible; the EF for residential customer meters is based on measurements from outdoor meters, as it was assumed in multiple studies that significant emissions from indoor meters would be identified and repaired. Revisions under consideration discussed below aim to quantify emissions from natural gas use from indoor appliances prior to combustion (CO_2 from combustion and methane from incomplete combustion are accounted elsewhere).

Limited data are available on this emission source. At least one country, the United Kingdom, includes an emission estimate for this source in its national greenhouse gas emissions inventory. The 2015 estimate for gas leakage at the point of use for domestic boilers, domestic cooking appliances, and commercial gas appliances in the U.K. is 2.53 kt CH4, or 0.06 MMT CO_2e[25]. The U.K. calculation is based on U.K. specific data on gas appliance sizes, pattern of use, and combustor design parameters. The U.K. emission rate is equivalent to a leak rate of 82.46 scf/mmscf of residential and commercial natural gas usage. The EPA has not conducted a detailed analysis of boiler data to determine if U.K. emission factors are appropriate for the United States. The EPA has calculated a rough estimate of U.S. emissions using data on domestic and commercial gas consumption data for the U.S. and the U.K. In 2013, the U.S. residential and commercial gas consumption was around six times higher than that of the U.K. Scaling up the U.K. emissions based on relative consumption, emissions from natural gas leaks at point of customer use in the United States could be around 12.4kt CH_4 or 0.3 MMTCO_2e.

The EPA seeks stakeholder feedback on the potential addition of this emission source to the GHGI, including available U.S.-specific emissions and activity data for this source over the time series, and/or data sources in addition to the U.K. estimate which could be assessed.

10.2 Natural Gas-fired Power Plant Leaks

A recent study by Lavoie et al.[26] found that leaks from natural gas-fired power plants (NGPP) and oil refineries may be large sources of methane.

The EPA is currently investigating whether additional data sources are available and whether and how to incorporate new data for this source into the GHGI, and seeks stakeholder feedback on this issue.

[25] UK Greenhouse Gas Inventory, 1990 to 2015, Annual Report for Submission under the Framework Convention on Climate Change, page 682;
http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/8812.php

[26] http://pubs.acs.org/doi/full/10.1021/acs.est.6b05531

11 Additional Use of GHGRP Data

EPA plans to consider newly reported (i.e., RY 2016) GHGRP data for the 2019 GHGI, including data covering the gathering and boosting (G&B) segment, hydraulically fractured (HF) oil well completions and workovers, and transmission pipeline blowdowns.

EPA requests stakeholder feedback on the following considerations:

1. Updating the GHGI to use GHGRP data on emissions from G&B. Which reported G&B activity data elements should be evaluated for scale-up considerations (e.g., subpart W collects data on the quantity of gas and hydrocarbon liquids received and transported, along with pipeline mileage)? EPA also seeks feedback on data sources that provide national-level totals for purposes of considering scaling approaches (e.g., while total gathering pipeline mileage is reported to GHGRP, PHMSA only reports gathering miles for "regulated gathering lines," which is a small subset of the total).

   Table 21 provides a comparison of the RY2016 subpart W data and the 2017 GHGI (year 2015) data for the G&B segment.

Table 21. Gathering and Boosting Segment Data from Subpart W and the 2017 GHGI

Emission Source	Total Pipeline Mileage	Total CO_2 Emissions (mt)	Total CH_4 Emissions (mt)
Subpart W (RY2016)[a]			
G&B Stations[b]	n/a	5,930,910	779,890
Gathering Pipelines[c]	405,714	8,166	137,298
2017 GHGI (Year 2015)			
G&B Stations	n/a	207,544	1,968,205
Gathering Pipelines	408,465	19,340	161,559

a – Data reported as of August 5, 2017.
b – Subpart W does not report G&B emissions by "station." Therefore, these emissions equal the sum of reported subpart W emissions, minus combustion emissions and gathering pipeline emissions.
c – Gathering pipeline emissions as reported under the equipment leaks section.

2. Updating the GHGI to use GHGRP data on emissions from HF oil well completions and workovers, including scale up considerations.
3. Updating the GHGI to use GHGRP data on emissions from transmission pipeline blowdowns, including scale up considerations.
4. RY2016 was the first GHGRP reporting year to include well ID numbers (i.e., US Well Numbers, formerly API Numbers) at a facility's sub-basin level and corresponding to certain activities. How should these data be used to inform or improve GHGI methodologies?

Stakeholders have suggested additional or alternate uses of GHGRP data, such as for certain sources using measurement data only, or using rolling averages for GHGRP data. 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.

12 Additional Data Assessments

In addition to updates noted above, stakeholders have identified additional data assessments that EPA is considering for future GHGIs. The additional assessments fall into three main groups and are identified below. EPA seeks stakeholder feedback on these assessments.

12.1 Upcoming Data

Stakeholders recommended the EPA evaluate the following specific studies for potential inclusion in future GHGIs:

- API field study on pneumatic controllers
- Pipeline Research Council International (PRCI) project in which researchers are gathering and analyzing subpart W data on transmission compressor stations and underground storage facilities.

In addition, EPA will continue to review other sources of new data as they become available such as DOE-funded work on vintage and new plastic pipelines (distribution segment), industrial meters (distribution segment), and sources within the gathering and storage segments.

12.2 Regional/Temporal Variability

Stakeholders suggested that differences due to regional and temporal variability should be considered, particularly for sources where variation is expected, including for the following sources:

- Associated gas venting and flaring regional variation – see separate 2018 *CO_2 Revisions* memo[27]
- Associated gas venting and flaring temporal variation – see 2017 Production memo[28]
- Abandoned wells regional variation – see separate abandoned wells memo[27]
- Anomalous leak events (e.g., Aliso Canyon leak) regional and temporal variation – see separate 2017 storage segment memo[28]
- Miscellaneous production flares regional variation – see separate *2018 CO_2 Revisions* memo[27]
- Liquids unloading regional variation – see separate 2018 *Year-specific Revisions* memo[27]

12.3 Consider Different Activity Data Bases

Stakeholders have recommended further investigation into the basis of the activity data used for scale-up, including for the following segment:

- Natural gas processing plants – reconsider using EIA plant counts or throughput approach

[27] https://www.epa.gov/ghgemissions/natural-gas-and-petroleum-systems-ghg-inventory-additional-information-1990-2016-ghg.

[28] https://www.epa.gov/ghgemissions/natural-gas-and-petroleum-systems-ghg-inventory-additional-information-1990-2015-ghg.