Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2017: Updates Under Consideration for Incorporating GHGRP Data

In supporting documentation associated with the development of EPA's 2018 *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (GHGI), EPA stated plans to consider newly reported data from EPA's Greenhouse Gas Reporting Program (GHGRP) for the 2019 GHGI. EPA plans to consider newly reported GHGRP data and other relevant data, described in Section 1 below, for updating current emission estimation methodologies in the 2019 GHGI. The following sections discuss considerations toward updating the emissions and/or activity data specifically for:

- Gathering and boosting (G&B) segment (stations and pipelines) (Section 2),
- Hydraulically fractured (HF) oil well completions and workovers (Section 3),
- Flaring N_2O emissions (Section 4),
- Transmission pipeline blowdowns (Section 5), and
- Liquefied natural gas (LNG) facilities (Section 6).

EPA seeks stakeholder feedback on whether and how to incorporate data from the GHGRP or other data sources into the 2019 or future GHGI methodologies for these emission sources; refer to Section 7 for specific questions.

Note, a June 2018 companion memo, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2017: Updates Under Consideration for Well-Related Activity Data* (2018 Well-related Activity Data memo) details further considerations for potentially improving current approaches for well-related emission sources. Section 3.2 below, which discusses updates under consideration for HF oil well completions and workovers, refers to this memo.

1 Available GHGRP Data

This section summarizes data sources that EPA has reviewed to develop preliminary approaches and considerations toward updating the GHGI methodologies for the sources covered in this memo.
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 CO_2 equivalent (mt CO_2e) 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, transmission pipeline blowdowns, and G&B facilities were first required to be reported in RY2016. In addition, subpart W natural gas processing, transmission, underground storage, LNG import/export, and LNG storage facilities report emissions from all flaring under the "flare stacks" emission source as of RY2015. Subpart W activity and emissions data are currently used in the GHGI to calculate CH_4 and CO_2 emissions for many production, processing, and transmission and storage sources.

Subpart W specifies facility definitions specific to certain segments. Onshore production and G&B facilities in subpart W are each defined as a unique combination of operator and basin of operation. Therefore, subpart W does not delineate data for G&B stations versus pipelines. However, the data are reported on an emission source level, so each source can be assigned as likely occurring at either G&B stations or pipelines. For the preliminary analyses in this memo organized around separate station and pipeline estimates, most subpart W G&B emission sources were assigned to G&B stations. Blowdown vent stacks from the "pipeline venting" emission source are assigned to gathering pipelines, and all other blowdown venting data were assigned to G&B stations. For equipment leaks, data for pipelines (cast iron, plastic/composite, protected steel, and unprotected steel gathering pipelines) were assigned to G&B pipelines, and all other equipment leak data were assigned to G&B stations.

GHGRP subparts W and Y (petroleum refining) include reporting of N_2O from flaring. The GHGRP calculation methodologies specify that subpart W reporters must calculate N_2O emissions from flares using an EF of 0.0001 kg

N_2O per million BTU, and subpart Y reporters using an EF of 0.0003 kg N_2O per million BTU. N_2O 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. 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.

2 Gathering & Boosting Segment Updates Under Consideration

In the April 2018 memo *Inventory of U.S. GHG Emissions and Sinks 1990-2016: Additional Revisions Considered* (2018 Additional Revisions memo),[1] EPA stated that incorporating additional subpart W data would be considered for the 2019 GHGI and requested stakeholder feedback on certain items including the incorporation of subpart W G&B data. This section presents the G&B data that are available from subpart W and recent studies, compares these data to the current GHGI basis, and discusses options for updating estimates of national total emissions. G&B stations and pipelines are discussed separately.

2.1 Current GHGI Methodology

For the 2016 GHGI, EPA made updates to the G&B segment methodology to incorporate recent study data for G&B stations, while the methodology for G&B pipelines has been unchanged in recent years, as summarized below.

EPA's April 2016 memo *Inventory of U.S. GHG Emissions and Sinks 1990-2014: Revision to Gathering and Boosting Station Emissions* (2016 G&B memo)[2] and April 2017 memo *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2015: Revisions to Natural Gas and Petroleum Systems Production Emissions* (2017 Production memo)[3] document the historical considerations and full methodology used for G&B stations in the current GHGI. In summary, the current GHGI estimates emissions based on station counts in each year paired with station-level EFs for normal events (documented in the 2016 G&B memo) and episodic events (documented in the 2017 Production memo). The total G&B station count in each year of the time series is estimated as the marketed onshore gas production in the given year (obtained from EIA) divided by the year 2012 throughput per station from the Marchese et al. 2015 study cited in the April 2016 memo. The current GHGI pairs this station count AD with a station-level CH_4 EF for normal vented and fugitive emissions calculated using data from the Marchese et al. 2015 study. The current GHGI separately estimates episodic event emissions using a station-level CH_4 EF from Marchese et al. 2015. The current GHGI estimates CO_2 emissions from G&B station normal and episodic events using CO_2 EFs developed by applying a default production segment ratio of CO_2-to-CH_4 gas content, and as such does not fully account for CO_2 from combustion.

The current GHGI estimates gathering pipeline mileage as the total producing gas wells in a given year, multiplied by a factor of pipeline miles per well from the joint Gas Research Institute (GRI)/EPA study published in 1996 (GRI/EPA 1996), plus an assumed 82,600 miles of gathering pipeline owned by transmission companies (per

[1] https://www.epa.gov/ghgemissions/natural-gas-and-petroleum-systems-ghg-inventory-additional-information-1990-2016-ghg
[2] https://www.epa.gov/sites/production/files/2016-08/documents/final_revision_gb_station_emissions_2016-04-14.pdf
[3] https://www.epa.gov/sites/production/files/2017-04/documents/2017_ng-petro_production.pdf

GRI/EPA 1996). The pipeline leakage and blowdown CH_4 EFs are also obtained from the 1996 GRI/EPA study. The current GHGI estimates CO_2 emissions from gathering pipelines using CO_2 EFs developed by applying a default production segment ratio of CO_2-to-CH_4 gas content.

2.2 Analysis of Available Data for G&B Stations

Table 1 shows subpart W G&B station source-specific emissions and compares the total reported subpart W emissions and 2018 GHGI emissions for G&B stations for year 2016. Appendix A documents the subpart W calculation methodologies for each source. As discussed further in Section 2.4, regional variability is being evaluated for the G&B data; subpart W basin-level G&B station emissions are provided in Appendix B.

Table 1. G&B Station Source-Specific Emissions Data from Subpart W and National Totals from 2018 GHGI, Year 2016

Emission Source	Total CH_4 Emissions (mt)	Total CO_2 Emissions (mt)
AGR	n/a	1,521,325
Blowdown Vent Stacks[a]	43,974	6,373
Centrifugal Compressors	40,781	4,934
Combustion	31,822	n/a[b]
Dehydrators	55,000	657,496
Equipment Leaks[c]	102,600	11,983
Flare Stacks	10,774	2,667,154
Pneumatic Devices	182,502	12,250
Pneumatic Pumps	29,089	1,783
Reciprocating Compressors	2,654	403
Tanks	297,671	1,046,404
Subpart W Reported Total[d]	**796,868**	**5,930,105**
National Total (2018 GHGI)[e]	**2,149,065**	**233,502**

n/a – Not applicable.
a – Includes blowdown emissions reported by G&B facilities for: compressors, emergency shutdowns, facility piping, scrubbers/strainers, pig launchers and receivers, all other equipment with a physical volume greater than or equal to 50 cubic feet, and emissions reported with flow meters.
b – Excludes CO_2 emissions from engine combustion (as these emissions are included in a separate section of the GHGI).
c – Includes all emissions reported by G&B facilities under the equipment leaks reporting section, except for emissions attributed to gathering pipelines.
d – The G&B facility definition in subpart W does not delineate reporting by “station” versus "pipeline." Therefore, these emissions equal the sum of reported subpart W emissions assigned to G&B stations (see footnotes a and c), as documented in Section 1.
e – Includes normal vented and fugitive emissions plus episodic event emissions from stations; refer to 2016 G&B memo and 2017 Production memo for additional detail.

The current GHGI uses station counts (the 2018 GHGI estimates 5,241 stations for year 2016) coupled with a station-level EF to calculate emissions in each time series year. However, as discussed in Section 1, subpart W reporting is not organized around the station-level; data are reported at the basin-level, so the type and number of emission sources present at a given station cannot be inferred. Therefore, a subpart W station-level EF cannot be calculated for direct comparison to the GHGI.

EPA is considering approaches to scale subpart W data to the national level (as reported, it only represents facilities meeting the reporting threshold), to assess how national emission estimates based on subpart W compare to the current GHGI, and to consider how to potentially update the GHGI methodology to incorporate subpart W data. To estimate the degree of national coverage represented by the subpart W G&B emissions, the EPA is considering comparing the quantity of gas received (reported under subpart W by G&B facilities) to the

total amount of gas produced from wells (estimated from EPA's analysis of DrillingInfo data[4]) to assess GHGRP coverage and scale data from GHGRP to the national level. Appendix B provides volumes of gas received and gas produced for each basin in year 2016. Based on the reported quantities of gas received frequently exceeding the amount of gas produced in a basin, it appears that a given volume of gas received might be counted more than once as it moves from one system to another system (operated by the same or different operator) within the same basin (i.e., is "received" multiple times). Acknowledging this, EPA is considering assessing coverage at the basin-level, to account for certain basins where the reported gas received is less than the estimated gas produced.

An approach under consideration for scaling subpart W G&B basin-level data to estimate national emissions involves several steps: (1) EPA first compared the reported gas received to DrillingInfo gas produced in each basin; for basins where the gas produced exceeds the reported gas received, EPA adjusted the gas received to equal the gas produced value, as a reasonable maximum (to minimize impacts of the double-counting described above). (2) EPA identified basins that account for a significant fraction of reported emissions, specifically, those that contributed at least 10 percent of total annual emissions (on a CO_2 Eq. basis) from G&B sources in a given year. Three basins met this criteria: 430 – Permian Basin, 220 – Gulf Coast Basin, and 360 – Anadarko Basin. (3) For the top-emitting basins, EPA calculated a scaling factor equal to the gas produced divided by the gas received (i.e., the inverse of reporting coverage). For all other basins, EPA summed the gas produced and gas received across basins, then calculated a group scaling factor. (4) For each basin or basin group, EPA applied the scaling factor to reported emissions. Table 2 presents the subpart W G&B station data and calculated scaling factor for each basin or group. The three basins that have the highest G&B emissions each have a scaling factor of 1 for this approach, while the "all other basins group" has a factor higher than 1. The calculated national scaling factor is 1.17, which corresponds to an estimate that subpart W reporting covers approximately 85% of G&B activity in the U.S. Implicit to this approach is an assumption that all gas produced is received at G&B facilities (and basins with less than 100% coverage include G&B facilities, according to the subpart W definition, but have emissions less than the reporting threshold). National emission estimates based on this approach are presented in Section 2.5. The EPA requests comment on this approach and assumption, and other approaches that could be considered to scale subpart W G&B station emissions, in Section 7.

Table 2. Basin-Level Approach Data to Scale Subpart W G&B Station Emissions, for Year 2016

Basin	Subpart W Reported Station CH_4 (mt)	Subpart W Reported Station CO_2 (mt)	Subpart W: Quantity Gas Received (mscf)	Adjusted Quantity Gas Received (mscf)[a]	DrillingInfo: Gas Produced (mscf)	Basin Scaling Factor[b]
430 - Permian Basin	114,330	2,357,782	9,377,991,907	2,546,961,000	2,546,961,000	1.0
220 - Gulf Coast Basin (LA, TX)	180,859	1,427,659	4,671,449,082	3,061,920,423	3,061,920,423	1.0
360 - Anadarko Basin	205,913	179,505	2,378,161,495	1,712,080,076	1,712,080,076	1.0
All Other Basins	295,766	1,965,159	25,273,198,450	18,033,350,200	22,353,867,857	1.24

a – As discussed in step 1 in the paragraph preceding Table 2, for basins where the gas produced exceeds the reported gas received, EPA adjusted the gas received to equal the gas produced value.
b – As discussed in step 3 in the paragraph preceding Table 2, equals the gas produced divided by the adjusted gas received.

In addition to analyzing scaled subpart W data for comparison to GHGI estimates, EPA reviewed findings from recent research studies which provide station-level EFs that can be directly compared to the current GHGI EF (in contrast to the basin-level subpart W data):

- Vaughn et al. (2017). *Comparing facility-level methane emission rate estimates at natural gas gathering and boosting stations.*

[4] The activity data methodologies for several upstream emission sources within natural gas and petroleum systems rely on EPA's analyses of the subscription-based digital DI Desktop raw data feed. This data set is referred to throughout this memo as "DrillingInfo data."

- Yacovitch et al. (2017). *Natural gas facility methane emissions: measurements by tracer flux ratio in two US natural gas producing basins*.
- Zimmerle et al. (2017). *Gathering pipeline methane emissions in Fayetteville shale pipelines and scoping guidelines for future pipeline measurement campaigns*.

The Vaughn, et al. (2017) study calculated two station-level EFs, shown in Table 3. Both EFs are higher than the current GHGI EF, the degree to which depends on whether tank venting (that was observed at two stations) is included in the EF.

The Yacovitch et al. (2017) study calculated EFs for two regions, the Fayetteville shale play and Denver-Julesburg (DJ) Basin; Table 3 presents the study results. The emission rate for the DJ Basin is lower than the Fayetteville shale play. Note that the statistical mode of the EFs were presented in the study, rather than average EFs. Yacovitch et al. (2017) also presented confidence intervals around their study data. The confidence intervals encompass the current GHGI EF. The Yacovitch et al. (2017) study also summarized results from prior studies (shown as "Multi-Basin: Tracer Sites" in Table 3), which are included for reference.

Table 3. G&B Station CH_4 Emission Rates from Recent Studies Compared to the Current GHGI

Parameter	CH_4 Emission Rate (kg/h)
Vaughn et al. 2017	
Station EF, excluding tank venting	50.4
Station EF, including tank venting	74.5
Yacovitch et al. 2017	
Multi-basin: tracer sites mode EF [95% confidence interval]	25 [12 – 3,300]
Fayetteville study area mode EF [95% confidence interval]	40 [15 – 730]
DJ study area mode EF [95% confidence interval]	11 [4.5 – 75]
2018 GHGI	
Station EF	34

EPA seeks stakeholder feedback on whether and how to incorporate data from recent studies into the 2019 or future GHGI methodologies; refer to Section 7 for specific questions. Additionally, Appendix A summarizes the general approach (e.g., measurement methods, representativeness) of each study.

2.3 Analysis of Available Data for G&B Pipelines

Table 4 compares the reported subpart W G&B pipeline source-specific emissions and activity (pipeline miles) to the 2018 GHGI emissions and pipeline miles, for year 2016. Appendix A documents the subpart W calculation methodologies for each source. Subpart W basin-level G&B pipeline emissions are provided in Appendix B.

Table 4. G&B Pipeline Source-Specific Emissions and Mileage Data from Subpart W and National Totals from 2018 GHGI, for Year 2016

Emission Source	Total CH_4 Emissions (mt)	Total CO_2 Emissions (mt)	Pipeline Miles
Equipment Leaks	**137,298**	**8,166**	**405,174**
Cast iron gathering pipeline	1,246	22	301
Plastic/composite gathering pipeline	27,100	1,268	84,299
Protected steel gathering pipeline	18,171	910	279,128
Unprotected steel gathering pipeline	90,780	5,966	41,986

Emission Source	Total CH_4 Emissions (mt)	Total CO_2 Emissions (mt)	Pipeline Miles
Blowdown Vent Stacks[a]	**14,713**	**801**	**n/a**
Subpart W Reported Total	**152,011**	**8,967**	**405,174**
National Total (2018 GHGI)	**157,798**	**18,820**	**398,554**

n/a – Not applicable.

a – Includes blowdown emissions reported by G&B facilities for pipeline venting.

To identify potential methodological updates that might improve current GHGI estimates through incorporation of subpart W data, the EPA evaluated differences between subpart W reporting and current GHGI assumptions by comparing EFs calculated from the subpart W data to those used in the current GHGI. The EFs shown in Table 5 are calculated as the total reported emissions divided by the total reported miles shown in Table 4.

Table 5. G&B Pipeline EFs Calculated from Subpart W and 2018 GHGI

Data Source	CH_4 EF (kg/mile)	CO_2 EF (kg/mile)
Subpart W	375	22
2018 GHGI[a]	396	47

a – The 2018 GHGI uses specific EFs for each NEMS region, which are adjusted for methane content. This table presents calculated EFs which represent the national average.

EPA also considered how to evaluate the subpart W reporting coverage in terms of activity (pipeline miles). As seen in Table 4, the G&B pipeline miles reported to subpart W exceed the estimated national miles from the current GHGI. PHMSA collects data for "regulated gathering lines," but this is a small subset of the total (11,494 miles were reported for 2016[5]). PHMSA does have a proposed rule, however, that would collect gathering line data, but it is not final and data are not available.[6] Year 2015 gathering pipeline miles were estimated for the proposed rule by PHMSA (355,509 miles) and industry (399,579 miles), and so while the estimates are based on more recent data than the current GHGI and are of similar magnitude, the estimates are still lower than the reported subpart W miles. If the EPA maintains an approach to estimate G&B pipeline emissions that relies on total national miles, then the subpart W data may currently provide the most complete estimate. However, national miles from PHMSA may be available in the future.

The EPA could also consider an approach to scale subpart W G&B pipeline emissions to the national level using the approach discussed in Section 2.2 for G&B stations (i.e., applying the coverage estimate of 85%). Table 6 presents the subpart W G&B pipeline data and calculated scaling factor for each basin. National emission estimates based on this approach are presented in Section 2.5.

Table 6. Basin-Level Approach to Scale Subpart W G&B Pipeline Emissions, for Year 2016

Basin	Subpart W Reported Pipeline CH_4 (mt)	Subpart W Reported Pipeline CO_2 (mt)	Basin Scaling Factor
430 - Permian Basin	47,841	2,049	1.0
220 - Gulf Coast Basin (LA, TX)	7,304	303	1.0
360 - Anadarko Basin	21,148	330	1.0
All Other Basins	75,717	6,285	1.24

[5] https://cms.phmsa.dot.gov/data-and-statistics/pipeline/annual-report-mileage-natural-gas-transmission-gathering-systems

[6] See docket PHMSA-2011-0023 at regulations.gov.

2.4 G&B Segment Regional Variability and Time Series Considerations

Stakeholders have previously suggested that differences due to regional and temporal variability should be considered when updating GHGI methodologies, particularly for sources where variation is expected. EPA reflects regional variability in the current methodologies for associated gas venting and flaring and miscellaneous production flaring by calculating basin-level emissions and activity factors. The EPA is similarly considering whether and how to represent regional variability in G&B emissions; basin-level data are presented in Appendix B, and a basin-level methodology is under consideration to estimate G&B station and pipeline emissions.

The EPA is also considering temporal variability, and ways to reflect emissions changes over the time series. However, limited historical data are available for G&B stations and pipelines. Subpart W data are only available for a single year (2016), and the current GHGI approach and other recent studies only examined data at a single recent point in time. The current GHGI methodology applies the same EFs for all years of the time series, and the activity data vary with changes in gas production or gas wells. For the updates under consideration, the year 2016 subpart W data could be used for all prior years in the time series, and activity could vary with gas production or pipeline miles. Notably, the updates being considered that rely on subpart W data would be able to reflect future trends, as year-specific updates would be applied for 2016 and forward. The EPA requests additional data and information that could inform time series trends.

2.5 G&B Segment Preliminary National Emissions Estimates

Table 7 and Table 9 show national CH_4 and CO_2 emissions for 2016 based on the updates under consideration described above for G&B stations and pipelines.
Table 8 and Table 10 present the national G&B emissions by source.

Table 7. Comparison of National-Level CH_4 and CO_2 Emissions Estimates for G&B Station Emissions, for Year 2016

Basin	Subpart W Emissions, as Reported		Subpart W Basin-Level Scale Up Approach[a]		2018 GHGI	
	CH_4 (mt)	CO_2 (mt)	CH_4 (mt)	CO_2 (mt)	CH_4 (mt)	CO_2 (mt)
430 - Permian Basin	114,330	2,357,782	114,330	2,357,782	NE	NE
220 - Gulf Coast Basin (LA, TX)	180,859	1,427,659	180,859	1,427,659		
360 - Anadarko Basin	205,913	179,505	205,913	179,505		
All Other Basins	295,766	1,965,159	366,627	2,435,981		
Total	**796,868**	**5,930,105**	**867,729**	**6,400,927**	**2,149,065**	**233,502**

NE – Not estimated.
a – Emissions calculated using the basin-level emissions and scaling factors in Table 2.

Table 8. Subpart W Scaled-Up G&B Station Emission Source-Specific Emissions, for Year 2016

Emission Source	Subpart W Scaled-Up Emissions[a]	
	CH_4 (mt)	CO_2 (mt)
AGR	0	1,642,111
Blowdown Vent Stacks[a]	47,885	6,879
Centrifugal Compressors	44,407	5,326
Combustion	34,652	0
Dehydrators	59,891	709,698
Equipment Leaks[c]	111,724	12,934
Flare Stacks	11,733	2,878,914
Pneumatic Devices	198,731	13,222
Pneumatic Pumps	31,676	1,924
Reciprocating Compressors	2,890	435
Tanks	324,141	1,129,483

Emission Source	Subpart W Scaled-Up Emissions[a]	
	CH_4 (mt)	CO_2 (mt)
Total	**867,729**	**6,400,927**

a – To develop national-level scaled up estimates at the emission source-level for this table, ratios of scaled subpart W emissions to reported subpart W emissions (from Table 7) were calculated for CH_4 and CO_2 and applied to the reported total for each emissions source (from Table 1).

Table 9. Comparison of National-Level CH_4 and CO_2 Emissions Estimates for G&B Pipeline Emissions, for Year 2016

Basin	Subpart W Basin-Level Approach[a]		Subpart W Pipeline Mileage Approach[b]		2018 GHGI	
	CH_4 (mt)	CO_2 (mt)	CH_4 (mt)	CO_2 (mt)	CH_4 (mt)	CO_2 (mt)
430 - Permian Basin	47,841	2,049	NE	NE	NE	NE
220 - Gulf Coast Basin (LA, TX)	7,304	303				
360 - Anadarko Basin	21,148	330				
All Other Basins	93,858	7,791				
Total	**170,152**	**10,473**	**152,011**	**8,967**	**157,798**	**18,820**

NE – Not estimated.

a – Emissions calculated using the basin-level emissions and scaling factors in Table 6.

b – Emissions calculated using the subpart W pipeline EFs in Table 5 and the reported subpart W pipeline miles in Table 4.

Table 10. Subpart W Scaled-Up G&B Pipeline Emission Source-Specific Emissions, for Year 2016

Emission Source	Subpart W Scaled-Up Emissions[a]	
	CH_4 (mt)	CO_2 (mt)
Cast iron gathering pipeline	1,395	26
Plastic/composite gathering pipeline	30,334	1,481
Protected steel gathering pipeline	20,340	1,063
Unprotected steel gathering pipeline	101,614	6,968
Blowdown vent stacks[a]	16,468	935
Total	**170,152**	**10,473**

a – To develop national-level scaled up estimates at the emission source-level for this table, ratios of scaled subpart W emissions to reported subpart W emissions (from Table 9) were calculated for CH_4 and CO_2 and applied to the reported total for each emissions source (from Table 4).

Comparing the G&B station subpart W scaled emissions using the basin-level approach that is under consideration to the 2018 GHGI emissions, the subpart W scaled station CH_4 emissions are approximately 40% of the 2018 GHGI station CH_4 emissions, and the subpart W scaled station CO_2 emissions are approximately 27 times the 2018 GHGI station CO_2 emissions. As discussed in Section 2.1, the current GHGI does not fully account for station CO_2 emissions from flaring, and the subpart W data addresses this issue. However, the EPA seeks stakeholder feedback on whether the G&B emission source estimates reported under subpart W accurately represent U.S. emissions from G&B stations, and if not, whether external data sources might be used to supplement reported data for purposes of GHGI updates and/or perform further assessments. As an example, the subpart W G&B compressor methodology relies on G&B compressor counts paired with an EF that is the same as the EF prescribed for the subpart W onshore production segment, when gathering segment compressors may be larger—as a result, the EPA might consider an approach such as applying the GHGI compressor EFs from the natural gas processing segment (currently calculated from subpart W data) to G&B segment reported activity.

For G&B pipeline emissions, the subpart W-based approaches that are being considered both have a similar magnitude of emissions compared to the 2018 GHGI emissions. However, the subpart W basin-level approach

results in some scale-up compared to the reported subpart W emissions (based on the currently available data for RY2016), whereas the pipeline mileage approach assumes 100% reporting coverage of gathering pipeline equipment/activity.

3 HF Oil Well Completions and Workovers Updates Under Consideration

In the 2018 GHGI Additional Revisions memo, EPA stated that subpart W data would be considered for the GHGI and requested stakeholder feedback on certain items—specifically including updating the GHGI to use GHGRP data on HF oil well completions and workovers and considerations toward developing national-level estimates. This section presents the subpart W data that are available, compares these data to the current GHGI basis, and discusses options for updating estimates of national total emissions for HF oil well completions and workovers.

3.1 Current GHGI Methodology

In the current GHGI methodology for HF oil well completions, controlled and uncontrolled CH_4 EFs were developed using data analyzed for the 2015 NSPS OOOOa proposal. The current GHGI estimates CO_2 emissions using CO_2 EFs developed by applying a default production segment ratio of CO_2-to-CH_4 gas content. As such, this approach for does not fully account for CO_2 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 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.

3.2 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 3.1). 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 reduced emissions completion (REC) use, venting, and flaring).[7]

Additionally, as summarized in Section 3.1, the current GHGI HF oil well completion CO_2 EF is calculated by applying an associated gas CO_2-to-CH_4 content ratio, which does not account for CO_2 conversion during hydrocarbon combustion. This current methodological limitation would be obviated by using subpart W data to directly calculate CH_4 and CO_2 EFs, parallel to the current methodology for HF gas well events.

[7] 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.

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 11 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 12 shows AFs for each event type/control category.

Table 11. 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

Table 12. 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 3.4, DrillingInfo-based activity data are used in conjunction with the EFs and AFs in Table 11 and Table 12, 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 3.4, 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).

3.3 Regional Variability and Time Series Considerations

For HF oil well completions and workovers, this memo presents preliminary emissions estimates (see Section 3.4) 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.

3.4 Preliminary National Emissions Estimates

Table 13 below shows national total activity data and CH_4 emissions for select time series years based on the updates under consideration described above.

Table 13. 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 CH_4 emissions (kt)	128	101	180	222	95	46
2018 GHGI CH_4 emissions (kt)[a]	21	15	31	52	79	79
Total CO_2 emissions (kt)	100	79	142	688	2,179	2,402
2018 GHGI CO_2 emissions (kt)[a]	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).

4 Flaring N_2O Emissions Updates Under Consideration

The current GHGI does not estimate N_2O emissions for natural gas and petroleum systems. However, with recent updates that use GHGRP data to estimate CH_4 and CO_2 flaring emissions, the EPA is considering updates to incorporate N_2O emissions for the same flaring sources. The EPA would apply the existing source-specific methodology for using GHGRP CH_4 data to develop N_2O EFs.

For purposes of presenting preliminary national total flaring N_2O emission estimates, EPA calculated a ratio of the GHGRP reported N_2O emissions to CO_2 emissions and then multiplied the N_2O-to-CO_2 ratio by the 2018 GHGI CO_2 emissions, for each emission source. Table 14 presents reported GHGRP N_2O and CO_2 flaring emissions, the calculated N_2O-to-CO_2 ratio, 2018 GHGI CO_2 emissions, and the resulting scaled N_2O 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 14. Preliminary National N_2O Emissions Estimates for Flaring Sources in Natural Gas and Petroleum Systems, Year 2016

Emission Source	GHGRP N_2O (as reported)[a] (mt)	GHGRP Flaring CO_2 (as reported) (mt)	Ratio of N_2O:CO_2 (x100,000)	2018 GHGI CO_2 (mt)	Estimated National Total N_2O (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[b]	+
HF Completions - REC with Flaring	17.9	618,126	2.9	16[b]	+
HF Workovers - Non-REC with Flaring	+	2,024	0.1	NE[b]	+
HF Workovers - REC with Flaring	0	218	0	NE[b]	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**	**1.0**
Gathering and Boosting Stations	25.9	5,930,105[c]	0.4	225,373[b,c]	1.0

Emission Source	GHGRP N_2O (as reported)[a] (mt)	GHGRP Flaring CO_2 (as reported) (mt)	Ratio of N_2O:CO_2 (x100,000)	2018 GHGI CO_2 (mt)	Estimated National Total N_2O (mt)
Offshore Production	**10.9**	**457,617**	-	-	-
Offshore Flaring	10.9	457,617	2.4	368,840[d]	10.9[d]
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	+
LNG Storage Station Flare Stacks	+	2,506	-[e]	NE	+[e]
LNG Import/Export Station Flare Stacks	0.2	97,940	-[e]	NE	0.2[e]
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 – For gas well and oil well completions and workovers, access to flaring N_2O data via EPA's Envirofacts portal is not working correctly and is being fixed.

b – Current GHGI does not rely on subpart W data for this source, and 2018 GHGI estimated CO_2 emissions shown in this table do not fully account for combustion. Using CO_2 emissions estimates developed under the draft subpart W-based approaches discussed in this memo, national N_2O emissions would be approximately 53 mt for flared oil well HF completions and workovers and 28 mt for G&B station flaring.

c – CO_2 includes vented and fugitive sources, in addition to flared sources.

d – Current GHGI does not rely on subpart W data for this source. As the GHGRP reported CO_2 emissions exceed the current GHGI estimate, the as-reported GHGRP N_2O emissions are shown.

e – Current GHGI does not estimate flaring CO_2 from these sources. Therefore, as-reported GHGRP N_2O emissions are shown as surrogate for national estimates. Section 6 discusses updates under consideration for this segment to use GHGRP data, but EPA has not yet developed updated draft estimates of national CO_2 emissions.

5 Transmission Pipeline Blowdowns Updates Under Consideration

As discussed in Section 1, 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.

5.1 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 CH_4 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). CO_2 emissions are calculated from the CH_4 emission factor and a default downstream gas profile of 93.4% CH_4 and 1.0% CO_2.

5.2 Analysis of Available Data

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 15 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 15. 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

6 Liquefied Natural Gas (LNG) Facility Updates Under Consideration

GHGI emissions estimates for LNG facilities have not been updated in recent years. Below, EPA summarizes the current methodology and available subpart W data that might be used to improve the current GHGI estimates.

6.1 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.[8] 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.[9] 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 Analysis of Available Data

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 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

[8] 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.

[9] FERC. "North American LNG Import/Export Terminals – Existing." Available at http://www.ferc.gov/industries/gas/indus-act/lng/lng-existing.pdf.

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*.[10]
    - 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. Comparisons of the current GHGI and reported subpart W CH_4 and CO_2 emissions, including average emissions per station, are presented in Table 16 and Table 17. Subpart W CO_2 emissions are higher starting in 2015 due to the new flare stacks reporting requirements, as discussed in Section 1.

Table 16. LNG Storage and LNG Import/Export Terminal CH_4 Emissions Comparison

Source	2011	2012	2013	2014	2015	2016
LNG Storage						
2018 GHGI						
CH_4 Emissions (mt)	73,124	73,124	73,124	73,124	73,124	73,124
# Stations[a]	70	70	70	70	70	70
CH_4 EF (mt/station)	1,041	1,041	1,041	1,041	1,041	1,041
Subpart W (as reported)						
CH_4 Emissions (mt)	67	10	31	17	70	152
# Stations	4	4	3	4	5	5
CH_4 EF (mt/station)	17	2	10	4	14	30
LNG Import/Export Terminals						
2018 GHGI (Import Terminals)						
CH_4 Emissions (mt)	15,681	12,377	10,902	10,190	10,801	10,741
# Terminals	8	8	8	8	8	8
CH_4 EF (mt/terminal)	2,036	1,607	1,416	1,323	1,403	1,395

[10] 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	2016
Subpart W – Import Terminals (as reported)[b]						
CH_4 Emissions (mt)	2,481	2,151	1,249	6,939	650	18,470
# Terminals	7	7	7	6	6	4
CH_4 EF (mt/terminal)	354	307	178	1,156	108	4,618
Subpart W – Export Terminals (as reported)[c]						
CH_4 Emissions (mt)	1,826	1,990	1,572	1,067	801	2.0
# Terminals	1	1	1	1	1	1
CH_4 EF (mt/terminal)	1,826	1,990	1,572	1,067	801	2.0

a – 2003 estimate is carried forward for all years. This number reflects all complete storage stations (57) and one-third of the count of satellite stations (39).
b – Includes an unknown amount of emissions from export terminals, because two subpart W facilities have both import and export operations, and emissions from both operations are reported together.
c – Emissions from the one facility that has only LNG export operations.

Table 17. LNG Storage and LNG Import/Export Terminal CO_2 Emissions Comparison

Source	2011	2012	2013	2014	2015	2016
LNG Storage						
2018 GHGI						
CO_2 Emissions (mt)	2,409	2,409	2,409	2,409	2,409	2,409
# Stations[a]	70	70	70	70	70	70
CO_2 EF (mt/station)	34	34	34	34	34	34
Subpart W (as reported)						
CO_2 Emissions (mt)	0.5	8	84	74	260	2,507
# Stations	4	4	3	4	5	5
CO_2 EF (mt/station)	0.1	2	28	19	52	501
LNG Import/Export Terminals						
2018 GHGI (Import Terminals)						
CO_2 Emissions (mt)	300	300	300	300	300	300
# Terminals	8	8	8	8	8	8
CO_2 EF (mt/terminal)	39	39	39	39	39	39
Subpart W – Import Terminals (as reported)[b]						
CO_2 Emissions (mt)	36	6	5	8	77,432	98,753
# Terminals	7	7	7	6	6	4
CO_2 EF (mt/terminal)	5	1	1	1	12,905	24,688
Subpart W – Export Terminals (as reported)[c]						
CO_2 Emissions (mt)	58	45	31	23	0	58
# Terminals	1	1	1	1	1	1
CO_2 EF (mt/terminal)	58	45	31	23	0	58

a – 2003 estimate is carried forward for all years. This number reflects all complete storage stations (57) and one-third of the count of satellite stations (39).
b – Includes an unknown amount of emissions from export terminals, because two subpart W facilities have both import and export operations, and emissions from both operations are reported together.
c – Emissions from the one facility that has only LNG export operations.

The EPA reviewed the subpart W activity data and calculated activity factors for reciprocating and centrifugal compressors. A comparison of the 2018 GHGI and subpart W activity data for years 2015 and 2016 are presented in Table 18. Note, the subpart W compressor data below includes counts for all compressors, even if the compressor did not operate (e.g., was in standby pressurized mode all year).

Table 18. LNG Storage and LNG Import/Export Terminal Activity Data Comparison

Source	2015		2016	
	2018 GHGI	Subpart W (as reported)	2018 GHGI	Subpart W (as reported)
LNG Storage				
# Stations	70	5	70	5
# Recip. Compr.	270	10	270	6
# Recip. Compr. per Station	3.8	2.0	3.8	1.2
Recip. Compr., MMhphr per Compr.	2.1	1.3	2.1	1.1
# Centr. Compr.	64	2	64	1
# Centr. Compr. per Station	0.9	0.4	0.9	0.2
Centr. Compr., MMhphr per Compr.	1.8	12.2	1.8	14.8
LNG Import/Export Terminals				
# Terminals	8	7	8	5
# Recip. Compr.	37	17	37	16
# Recip. Compr. per Terminal	4.9	2.4	4.9	3.2
Recip. Compr., MMhphr per Compr.	11.6	7.8	11.6	8.2
# Centr. Compr.	7	10	7	9
# Centr. Compr. per Terminal	0.9	1.4	0.9	1.8
Centr. Compr., MMhphr per Compr.	14.1	10.4	14.1	1.2

The EPA might calculate EFs based on the subpart W data for each of the 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 update in the 2017 GHGI. The EPA retained the existing GHGI EF, but updated the AD to use an activity factor developed from subpart W data. The EPA is considering implementing a similar approach involving developing an updated 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[11], and for scaling LNG import/export emissions include the national LNG import/export activity database maintained by EIA.[12] EPA plans to investigate these two sources of activity data for use in calculating LNG facility emissions over the 1990–2017 time period.

The GHGI does not currently include LNG export terminals while subpart W does require reporting from LNG export terminals. EPA may update the GHGI methodology to include LNG export terminals. FERC identifies three LNG export terminals;[13] one that only exports LNG and two that import and export LNG. In addition, several LNG

[11] http://www.phmsa.dot.gov/pipeline/library/data-stats/distribution-transmission-and-gathering-lng-and-liquid-annual-data
[12] http://energy.gov/fe/downloads/lng-annual-report-2015
[13] FERC. "North American LNG Import/Export Terminals – Existing." Available at http://www.ferc.gov/industries/gas/indus-act/lng/lng-existing.pdf.

export terminals are under construction, are approved for construction, or are proposed to be constructed.[14,15] 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 Requests for Stakeholder Feedback

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

General

1. What other new or upcoming studies might provide useful data to consider for the GHGI, to use as a quality check against GHGRP-based estimates, and/or to supplement GHGRP data? For example, EPA is aware of several DOE-funded field studies being conducted by researchers including GSI Environmental, Inc., Utah State University, Colorado State University, and Houston Advanced Research Center; focused on topics such as component-specific measurements to develop gathering compressor emission factors[16]; developing nationally representative emission factors for equipment at G&B stations[17]; and methane emissions rate quantification for natural gas storage wells and fields[18].
2. EPA seeks feedback or suggestions on the general approach for incorporating GHGRP data into recently updated GHGI estimates, which has been:
    - Apply existing historical EFs and AFs (e.g., control category splits) for early time series years
    - Apply GHGRP-based EFs and AFs for GHGRP years
    - Develop intermediate EFs and AFs through linear interpolation
    - Apply a basin-level approach for sources with large regional variability and where national-level emissions estimates are impacted by a basin-level versus national level approach (e.g., associated gas venting and flaring, miscellaneous production flaring)

Gathering & Boosting Segment (Section 2)

3. What data source(s) and methodology are most appropriate to develop national G&B station and pipeline emissions (both steady-state and episodic) in light of newly available data (GHGRP subpart W and studies)? EPA seeks feedback on whether additional data sources or methods should be considered for specific equipment types for gathering stations (e.g. compressors).
4. For subpart W, which reported G&B activity data elements should be evaluated to assess the fraction of national activity represented in the reporting data (for considerations toward developing appropriate emissions factors that can be combined with available national-level activity data to develop national emission estimates for the GHGI)?
    a. Does the fraction of national activity represented in subpart W vary by equipment type due to the G&B facility definition (e.g., is it possible that close to 100% of G&B pipeline mileage is represented, but equipment such as G&B compressors or G&B tanks have different coverage)?
    b. EPA seeks feedback on data sources that provide national-level totals for purposes of considering G&B 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).
5. EPA seeks feedback on how to consider regional and temporal variability specifically for G&B.

[14] FERC. "North American LNG Import/Export Terminals – Approved." Available at https://www.ferc.gov/industries/gas/indus-act/lng/lng-approved.pdf
[15] FERC. "North American LNG Export Terminals – Proposed." Available at https://www.ferc.gov/industries/gas/indus-act/lng/lng-proposed-export.pdf
[16] https://www.netl.doe.gov/research/oil-and-gas/project-summaries/natural-gas-midstream-projects/fe0029084-gsi
[17] https://www.netl.doe.gov/research/oil-and-gas/project-summaries/natural-gas-midstream-projects/fe0029068-csu
[18] https://www.netl.doe.gov/research/oil-and-gas/project-summaries/natural-gas-midstream-projects/fe0029085-gsi

6. EPA seeks feedback on how to consider the subpart W definition of the G&B segment which includes equipment that serves more than one well pad (e.g., tank batteries) that might generally be considered production equipment. EPA notes that the current GHGI approach for developing activity estimates for the production segment relies on data from production segment facilities that report under subpart W, so incorporating data from the subpart W G&B segment facilities should theoretically avoid double-counting.
7. EPA seeks feedback on the level of detail for presenting emissions from gathering and boosting in the GHGI. For example, emissions could be presented by equipment type (similar to how other production segment equipment emissions are presented) or could be presented at the station-level (as in the current GHGI) or at the basin level (as presented in Section 2.5).

HF Oil Well Completions and Workovers (Section 3)

Note, EPA's 2018 Well-related Activity Data companion memo details further considerations for potentially updating activity data for sources including HF oil well completions and workovers and includes additional stakeholder questions.

8. 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).
9. EPA seeks feedback on how to consider regional and temporal variability for HF oil well completions and workovers.
10. 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 3.2). 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.
11. 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 set any events seemingly conducted at oil wells? develop factors specific to oil well events prior to RY2016?)?

N_2O Emissions (Section 4)

12. EPA seeks feedback on updating the GHGI to include N_2O from flaring, based on GHGRP data.
13. EPA seeks feedback on other available data sources for N_2O emissions.

Transmission Pipeline Blowdowns (Section 5)

14. EPA seeks feedback on the use of subpart W data to update the current GHGI methodology for this source.
15. Are the EFs calculated from RY2016 subpart W data (shown in Table 15) nationally representative,?
16. EPA seeks feedback on time series calculations; e.g., on whether GHGI EFs be retained for early time series years or if subpart W EFs should be applied for all years.

LNG Facilities (Section 6)

17. EPA seeks feedback on time series calculations; e.g., on whether GHGI EFs (which are based on data from transmission and storage stations) should be retained for early time series years or if subpart W EFs should be applied for all years.
18. EPA seeks feedback on how LNG storage blowdown emissions should be incorporated into the GHGI; e.g., maintain the current GHGI EFs or use data from subpart W LNG import/export terminals.
19. EPA seeks feedback on an approach that maintains the current GHGI EF for compressor exhaust, but using subpart W compressor hp-hr data.

Appendix A – Measurement Methodologies from Data Sources Considered for Updates

Emission Source	Measurement and/or Calculation Type	# Sources	Location & Representativeness	EF Calculation Method
GHGRP Subpart W				
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
G&B Acid gas removal (AGR) vents	Emissions calculated from the available methods: (1) CEMS for CO_2 with volumetric flow rate monitors, (2) Vent meter for CO_2 and annual volume of vent gas, (3) measured inlet (or outlet) gas flow rate and inlet and outlet volumetric fraction of CO_2, or (4) simulation software.	Emissions data (for 2016) are available from only 49 facilities.	Facilities in the U.S. that exceed 25,000 mt CO2e reporting threshold.	For this memo, the EPA evaluated the reported data at the basin-level to scale to the national-level.
G&B Centrifugal Compressors	Emissions calculated using the count of centrifugal compressors that have wet seal oil degassing vents multiplied by default EF (annual volumetric flow per unit).	Emissions data (for 2016) are available from 25 facilities.	Facilities in the U.S. that exceed 25,000 mt CO2e reporting threshold.	For this memo, the EPA evaluated the reported data at the basin-level to scale to the national-level.
G&B Combustion	Emission calculations depend on the type of fuel burned: • If burning pipeline quality natural gas or the identified fuels and blends (i.e., coal, coke, natural gas, petroleum products, certain other solids and gaseous fuels, solids/gaseous/liquid biomass fuels) then use default EFs. • If burning field gas, process vent gas, or a gas blend then determine volume of fuel combusted from company records and use a continuous gas composition analyzer to measure mole fraction of gas. • These sources are exempt: (1) external fuel combustion sources with rated heat capacity ≤ 5 MMBtu/hr, (2) internal combustion sources, not compressor-drivers, with a rated heat capacity ≤ 1 MMBtu/hr (equal to 130 HP).	Emissions data (for 2016) are available from 289 facilities.	Facilities in the U.S. that exceed 25,000 mt CO2e reporting threshold.	For this memo, the EPA evaluated the reported data at the basin-level to scale to the national-level.

Emission Source	Measurement and/or Calculation Type	# Sources	Location & Representativeness	EF Calculation Method
G&B Dehydrators	Emissions calculations depend on the daily throughput: • If daily throughput is ≥ 0.4 million scf then use simulation software. • If daily throughput is ≤ 0.4 million scf then use EFs and a dehydrator count • For dessicant dehys, use the amount of gas vented from the dessicant vessel when it is depressurized • When a flare or a regenerator fire-box/fire tube is used adjust the emissions to reflect the control efficiency.	Emissions data (for 2016) are available from 242 facilities.	Facilities in the U.S. that exceed 25,000 mt CO2e reporting threshold.	For this memo, the EPA evaluated the reported data at the basin-level to scale to the national-level.
G&B Equipment Leaks	Emissions calculated using: (1) default EFs, by source type; (2) source type counts (rule provides default counts e.g., valves per wellhead) including miles of gathering pipelines by material type; (3) estimated time the source was operational; and (4) concentration of CO_2 and CH_4.	Emissions data (for 2016) are available from 297 facilities.	Facilities in the U.S. that exceed 25,000 mt CO2e reporting threshold.	For this memo, the EPA evaluated the reported data at the basin-level to scale to the national-level.
G&B Pneumatic Devices	Emissions calculated using: (1) counts of continuous high bleed, continuous low bleed, and intermittent bleed devices, (2) default EFs for each device type, (3) annual operating hours, and (4) GHG concentrations in vented gas.	Emissions data (for 2016) are available from 263 facilities.	Facilities in the U.S. that exceed 25,000 mt CO2e reporting threshold.	For this memo, the EPA evaluated the reported data at the basin-level to scale to the national-level.
G&B Pneumatic Pumps	Emissions calculated using: (1) counts of pneumatic pumps, (2) default EF, (3) annual operating hours, and (4) GHG concentrations in vented gas.	Emissions data (for 2016) are available from 194 facilities.	Facilities in the U.S. that exceed 25,000 mt CO2e reporting threshold.	For this memo, the EPA evaluated the reported data at the basin-level to scale to the national-level.
G&B Reciprocating Compressors	Emissions calculated using the count of reciprocating compressors multiplied by default EF (annual volumetric flow per unit).	Emissions data (for 2016) are available from 291 facilities.	Facilities in the U.S. that exceed 25,000 mt CO2e reporting threshold.	For this memo, the EPA evaluated the reported data at the basin-level to scale to the national-level.
G&B Tanks	Emissions calculations depend on the daily throughput: • If oil throughput is ≥10 bbl/d and the gas and liquid passes through non-separator equipment (e.g., stabilizers, slug catchers) before flowing to the tank, calculate CO2 and CH4 emissions	Emissions data (for 2016) are available from 215 facilities.	Facilities in the U.S. that exceed 25,000 mt CO2e reporting threshold.	For this memo, the EPA evaluated the reported data at the basin-level to scale to the national-level.

Emission Source	Measurement and/or Calculation Type	# Sources	Location & Representativeness	EF Calculation Method
	using simulation software or by assuming all CO2 and CH4 is emitted. • If oil throughput is ≥10 bbl/d and the gas and liquid flows directly to a tank without passing through a separator, assume all CO2 and CH4 is emitted. • If oil throughput is <10 bbl/d then calculate CO2 and CH4 emissions from (1) counts of separators, wells, or non-separator equipment that feed oil directly to the storage tank and multiply by EF (annual volumetric flow per unit). • Subtract emissions if a VRU is used and if a flare is used then use the flare calculation methodology.			
G&B, LNG Storage, & LNG Import/Export - Flare Stacks	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.	G&B: Emissions data (for 2016) are available from 140 facilities. LNG Storage: Emissions data (for 2016) are available from 1 station and a total of 1 flare stack. LNG Import/Export: Emissions data (for 2016) are available from 2 stations and a total of 6 flare stacks.	Facilities in the U.S. that exceed 25,000 mt CO2e reporting threshold.	G&B: For this memo, the EPA evaluated the reported data at the basin-level to scale to the national-level.
G&B & LNG Import/Export - Blowdown Vent Stacks	Emissions calculated from the available methods: (1) use blowdown volumes, the number of blowdowns, and the ideal gas law modified with a compressibility factor, or (2) used a flowmeter to directly measure emissions for each equipment type or all equipment associated with a blowdown event.	G&B: Emissions data (for 2016) are available from 236 facilities. LNG Import/Export: Emissions data (for 2016) are available from 5 stations and a total of 5 blowdown vent stacks.	Facilities in the U.S. that exceed 25,000 mt CO2e reporting threshold.	G&B: For this memo, the EPA evaluated the reported data at the basin-level to scale to the national-level.
LNG Storage & LNG Import/Export – Equipment Leaks	Emissions calculated using: • Population counts and EF approach, estimate time emission source was operational, and • Leak surveys (>1 per year) to identify leaking components, estimate time assumed to be leaking, and use component type EFs in the rule.	LNG Storage: Emissions data (for 2016) are available from 5 stations and a total of 5 leak surveys and population counts. LNG Import/Export: Emissions data (for 2016) are available from 5 stations and a total of 5 leak surveys and population counts.	Facilities in the U.S. that exceed 25,000 mt CO2e reporting threshold.	EFs not currently calculated.

Emission Source	Measurement and/or Calculation Type	# Sources	Location & Representativeness	EF Calculation Method
LNG Storage & LNG Import/Export – Centrifugal Compressors	Direct measurement of emissions from: • Wet seals, blowdown vents, and isolation valves; or • Manifolded groups of compressor sources.	LNG Storage: Emissions data (for 2016) are available from 1 station and a total of 1 centrifugal compressor. LNG Import/Export: Emissions data (for 2016) are available from 2 stations and a total of 9 centrifugal compressors.	Facilities in the U.S. that exceed 25,000 mt CO2e reporting threshold.	EFs not currently calculated.
LNG Storage & LNG Import/Export – Reciprocating Compressors	Direct measurement of emissions from: • Blowdown valves, rod packing, and isolation valves; or • Manifolded groups of compressor sources.	LNG Storage: Emissions data (for 2016) are available from 2 stations and a total of 6 reciprocating compressors. LNG Import/Export: Emissions data (for 2016) are available from 4 stations and a total of 16 reciprocating compressors.	Facilities in the U.S. that exceed 25,000 mt CO2e reporting threshold.	EFs not currently calculated.
Transmission Blowdown Vent Stack	Emissions calculated using: • Blowdown volumes, number of blowdowns, and the ideal gas low 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.	EFs calculated as a straight average of all available data.
Vaughn et al. 2017				
G&B facilities	Dual-tracer measurements, aircraft measurements, and on-site component-level measurements (direct measurements and simulated direct measurements) coupled with engineering estimates using Monte Carlo model.	36 gathering stations	• Measurements conducted September–October 2015 • Eastern portion of the Fayetteville shale play (Arkansas)	Dual-tracer measurements, including and excluding significant tank venting
Yacovitch et al. 2017				
Production, gathering, processing, and transmission facilities	Dual tracer flux ratio method	• DJ study area: 12 gathering stations, 5 wellpads, and 4 processing plants measured. FV study area: 31 gathering stations, 18 wellpads, and 4 transmission stations measured.	• Two natural gas production regions: Denver-Julesberg (DJ) basin and Fayetteville shale play (FV) in Arkansas • Nov 2014 for DJ basin Sep-Oct 2015 for FV play	Dual-tracer measurements to calculate facility-level emission rates and throughput-weighted emissions

Emission Source	Measurement and/or Calculation Type	# Sources	Location & Representativeness	EF Calculation Method
Zimmerle et al. 2017				
Gathering pipelines	• Detect and localize pipeline leaks using vehicle-based measurement and handheld equipment Measure leaks: INDACO high flow (using above-ground enclosure for pipelines based on Lamb 2015 study methods)	• Pigging facilities: 56 locations screened, 50% with measurable emissions • Block valves: 39 locations screened, 15% with measurable emissions Pipeline leaks: 96 km screened, 1 leak detected	• Measurements conducted September–October 2015 • Fayetteville shale play (Arkansas)	• Measured leaks from underground pipelines and above-ground auxiliary equipment Monte Carlo approach used to estimate total study area methane emissions

Appendix B – Subpart W Reported Basin-Level G&B Data, for Year 2016 (descending by quantity gas received)

Subpart W: Basin	Subpart W: Station - CO_2 (mt)	Subpart W: Station - CH_4 (mt)	Subpart W: Pipeline - CO_2 (mt)	Subpart W: Pipeline - CH_4 (mt)	Subpart W: % of Total Reported Emissions (CO_2e basis)	Subpart W: Pipeline Miles	Subpart W: Quantity Gas Received (mscf)	DrillingInfo: Gas Produced (mscf)
430 - Permian Basin	2,357,782	114,330	2,049	47,841	22%	88,779	9,377,991,907	2,546,961,000
160A - Appalachian Basin (Eastern Overthrust Area)	237,240	43,632	64	9,330	5%	21,491	9,085,887,678	6,963,307,185
220 - Gulf Coast Basin (LA, TX)	1,427,659	180,859	303	7,304	21%	77,306	4,671,449,082	3,061,920,423
890 - Arctic Coastal Plains Province	282,030	8,988	440	1,013	2%	466	2,631,488,269	0
360 - Anadarko Basin	179,505	205,913	330	21,148	20%	79,855	2,378,161,495	1,712,080,076
230 - Arkla Basin	78,662	15,870	77	675	2%	5,473	1,572,948,899	1,383,010,956
345 - Arkoma Basin	91,957	42,829	166	3,169	4%	9,485	1,446,997,239	1,152,833,455
535 - Green River Basin	38,600	12,137	102	2,767	1%	7,367	1,217,043,594	1,320,824,691
580 - San Juan Basin	33,580	27,635	313	2,270	3%	12,654	1,117,052,404	950,371,313
415 - Strawn Basin	92,667	7,816	13	212	1%	3,057	1,112,322,086	790,688,219
260 - East Texas Basin	27,507	26,385	213	2,933	3%	14,157	1,088,736,072	1,231,438,252
595 - Piceance Basin	22,749	5,520	1,140	2,293	1%	3,483	921,296,725	572,215,719
160 - Appalachian Basin	29,102	7,777	169	18,288	2%	11,710	678,462,313	327,688,787
395 - Williston Basin	556,431	12,340	189	3,046	3%	14,102	649,086,818	649,228,154
420 - Fort Worth Syncline	29,816	7,451	83	779	1%	8,657	601,323,784	596,143,279
540 - Denver Basin	82,700	12,371	40	1,065	1%	9,069	600,318,419	654,717,466
210 - Mid-Gulf Coast Basin	13,705	634	16	31	0%	50	586,701,993	266,348,942
350 - South Oklahoma Folded Belt	11,420	9,867	116	3,990	1%	6,194	385,990,762	196,332,085
575 - Uinta Basin	24,127	10,889	165	6,085	2%	4,502	334,179,136	330,771,548
507 - Central Western Overthrust	87	916	0	52	0%	744	324,760,269	144,840,092
355 - Chautauqua Platform	9,010	6,726	32	2,318	1%	8,344	227,037,752	167,058,005
745 - San Joaquin Basin	137,854	5,223	2,243	4,423	1%	2,282	192,211,752	146,297,127
515 - Powder River Basin	21,014	4,843	449	5,811	1%	6,404	177,702,150	276,528,876
305 - Michigan Basin	4,883	10,543	83	245	1%	1,185	70,799,977	114,012,350
820 - AK Cook Inlet Basin	2,323	666	0	14	0%	172	67,195,723	69,286,251
455 - Las Vegas-Raton Basin	91,527	2,543	16	885	1%	1,286	59,160,425	102,155,261
425 - Bend Arch	196	1,495	18	1,195	0%	4,335	39,409,305	35,370,315
375 - Sedgwick Basin	117	1,131	5	743	0%	1,498	38,192,792	56,061,331
730 - Sacramento Basin	36	3,929	8	1,291	0%	540	16,453,024	67,915,824
740 - Coastal Basins	181	121	64	118	0%	59	6,974,637	1,919,724
450 - Las Animas Arch	30	243	0	24	0%	360	6,089,722	8,200,509
530 - Wind River Basin	6	142	0	3	0%	45	5,731,782	166,238,346
760 - Los Angeles Basin	19,331	607	15	71	0%	58	5,360,745	58,536,331
755 - Ventura Basin	25,813	419	43	490	0%	266	3,178,610	6,139,904

Subpart W: Basin	Subpart W: Station - CO_2 (mt)	Subpart W: Station - CH_4 (mt)	Subpart W: Pipeline - CO_2 (mt)	Subpart W: Pipeline - CH_4 (mt)	Subpart W: % of Total Reported Emissions (CO_2e basis)	Subpart W: Pipeline Miles	Subpart W: Quantity Gas Received (mscf)	DrillingInfo: Gas Produced (mscf)
365 - Cherokee Basin	457	4,054	2	88	0%	232	3,103,595	23,594,565
845 - Bristol Bay Basin	0	0	0	0	0%	0	0	2,777,440,868
585 - Paradox Basin	0	0	0	0	0%	0	0	500,632,196
445 - Sierra Grande Uplift	0	0	0	0	0%	0	0	97,122,899
200 - Black Warrior Basin	0	0	0	0	0%	0	0	55,702,726
400 - Ouachita Folded Belt	0	0	0	0	0%	0	0	46,874,613
520 - Big Horn Basin	0	0	0	0	0%	0	0	13,359,240
750 - Santa Maria Basin	0	0	0	0	0%	0	0	8,202,838
500 - Sweetgrass Arch	0	0	0	0	0%	0	0	7,773,963
435 - Palo Duro Basin	1	24	0	2	0%	47	0	5,317,449
510 - Central Montana Uplift	0	0	0	0	0%	0	0	4,048,704
385 - Central Kansas Uplift	0	0	0	0	0%	0	0	2,872,248
250 - Upper Mississippi Embayment	0	0	0	0	0%	0	0	1,053,875
630 - Overthrust&Wasatch Uplift	0	0	0	0	0%	0	0	803,882
300 - Cincinnati Arch	0	0	0	0	0%	0	0	762,456
710 - Western Columbia Basin	0	0	0	0	0%	0	0	581,536
545 - North Park Basin	0	0	0	0	0%	0	0	387,513
720 - Eel River Basin	0	0	0	0	0%	0	0	356,368
405 - Kerr Basin	0	0	0	0	0%	0	0	160,190
315 - Illinois Basin	0	0	0	0	0%	0	0	99,929
370 - Nemaha Anticline	0	0	0	0	0%	0	0	70,568
335 - Forest City Basin	0	0	0	0	0%	0	0	57,665
590 - Black Mesa Basin	0	0	0	0	0%	0	0	51,567
140 - Florida Platform	0	0	0	0	0%	0	0	33,177
725 - Northern Coast Range Prov	0	0	0	0	0%	0	0	22,803
625 - Great Basin Province	0	0	0	0	0%	0	0	2,858
640 - Mojave Basin	0	0	0	0	0%	0	0	589
650 - Sierra Nevada Province	0	0	0	0	0%	0	0	273
Total	**5,930,105**	**796,868**	2,049	47,841	**100%**	**405,714**	**41,700,800,934**	**29,674,829,356**