Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2017: Updates to Natural Gas Gathering & Boosting Pipeline Emissions

This memorandum documents the updates implemented in EPA's final 2019 *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (GHGI) for natural gas gathering and boosting (G&B) emissions. Specifically, an updated emissions calculation methodology was implemented for gathering pipeline leaks and gathering pipeline blowdowns.

Additional considerations for the G&B segment, including G&B stations, were previously discussed in memoranda released in June 2018 (*Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2017: Updates Under Consideration for Incorporating GHGRP Data)* and October 2018 (*Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2017: Updates Under Consideration for Natural Gas Gathering & Boosting Emissions*).[1] During the stakeholder process for developing the 2019 GHGI, stakeholders supported making updates to the gathering pipeline calculation methodology using Greenhouse Gas Reporting Program (GHGRP) data. Stakeholders did not support updates to the G&B station calculation methodology at this time, instead requesting that EPA continue to review GHGRP data and wait for additional research findings to become available. EPA did not update the G&B station methodology as a result, and will instead consider updates to G&B station emissions for future GHGIs. The stakeholder feedback for G&B is summarized in Section 5.

1 Available GHGRP Data

This section summarizes the GHGRP data that EPA reviewed to develop the approach implemented in the 2019 final GHGI for gathering pipeline leaks and blowdowns.

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, certain sources including G&B facilities were first required to be reported in RY2016. 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 analyses in this memo, certain sources were assumed to be associated with gathering pipelines. Blowdown vent stacks from the "pipeline venting" emission source were 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 gathering pipelines, and all other equipment leak data were assigned to G&B stations.

The GHGRP data used in the analyses discussed in this memo are those reported to the EPA as of August 19, 2018. 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

[1] EPA memoranda for the 1990 to 2017 Inventory stakeholder process are available at < https://www.epa.gov/ghgemissions/stakeholder-process-natural-gas-and-petroleum-systems-1990-2017-inventory>.

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 Previous GHGI Methodology for Gathering Pipelines

While EPA made updates to the G&B segment methodology to incorporate recent study data for G&B stations in the 2016 GHGI, the methodology for gathering pipelines has been unchanged in recent years. The 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 GRI/EPA 1996 study, plus an assumed 82,600 miles of gathering pipeline owned by transmission companies (per GRI/EPA 1996). The pipeline leakage, pipeline blowdown, and pipeline mishap CH_4 EFs are also obtained from the 1996 GRI/EPA study. The 2018 (previous) GHGI estimated 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.

3 Review of GHGRP Data for Gathering Pipelines

Table 1 and Table 2 compare the reported subpart W gathering pipeline source-specific emissions and activity (pipeline miles) to the 2018 GHGI emissions and pipeline miles, for years 2016 and 2017. Appendix A documents the subpart W calculation methodologies for each source.

Table 1. Gathering Pipeline Leak Emissions and Mileage Data from Subpart W and National Totals from 2018 GHGI, for Years 2016 and 2017

Emission Source	2016			2017		
	Total CH_4 Emissions (mt)	Total CO_2 Emissions (mt)	Pipeline Miles	Total CH_4 Emissions (mt)	Total CO_2 Emissions (mt)	Pipeline Miles
Subpart W Equipment Leaks	**136,776**	**15,821**	**404,639**	**141,577**	**16,307**	**407,254**
Cast iron gathering pipeline	1,266	25	307	1,723	517	533
Plastic/composite gathering pipeline	24,135	1,265	78,119	30,675	1,369	96,073
Protected steel gathering pipeline	18,438	938	280,795	17,024	959	265,611
Unprotected steel gathering pipeline	92,937	13,593	45,418	92,155	13,462	45,037
2018 GHGI Pipeline Leaks	**157,798**	**18,820**	**398,554**	**n/a**		

n/a – Not applicable.

Table 2. Gathering Pipeline Blowdown Emissions from Subpart W and National Totals from 2018 (Previous) GHGI, for Years 2016 and 2017

Emission Source	2016		2017	
	Total CH_4 Emissions (mt)	Total CO_2 Emissions (mt)	Total CH_4 Emissions (mt)	Total CO_2 Emissions (mt)
Subpart W Blowdown Vent Stacks[a]	**14,713**	**801**	**19,777**	**718**
2018 GHGI Venting Sources	**3,874**	**462**	**n/a**	
Pipeline blowdowns	2,513	300		
Pipeline mishaps	1,360	162		

n/a – Not applicable.

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

EPA calculated EFs from the subpart W and GHGI data by dividing the total reported emissions from Table 1 and Table 2 by the total reported miles shown in Table 1. Table 3 and Table 4 compare the resulting EFs calculated from the subpart W data to those used in the 2018 GHGI.

Table 3. Gathering Pipeline Leak EFs Calculated from Subpart W and 2018 GHGI

Data Source	CH_4 EF (kg/mile)	CO_2 EF (kg/mile)
Subpart W – Year 2016	338	39
Subpart W – Year 2017	348	40
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.

Table 4. Gathering Pipeline Blowdown EFs Calculated from Subpart W and 2018 GHGI

Data Source	CH_4 EF (kg/mile)	CO_2 EF (kg/mile)
Subpart W – Year 2016	36	2
Subpart W – Year 2017	49	2
2018 GHGI[a]	10	1

a – The 2018 GHGI uses specific EFs for each NEMS region, which are adjusted for methane content. This table presents calculated EFs that 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 1, the gathering pipeline miles reported to subpart W exceed the estimated national miles from the previous GHGI for year 2016. PHMSA collects data for "regulated gathering lines," but this is a small subset of the total (11,494 miles were reported for 2016[2]). PHMSA does have a proposed rule, however, that would collect gathering line data, but it is not final and data are not available.[3] 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 previous GHGI and are of similar magnitude, the estimates are still lower than the reported subpart W miles. EPA is maintaining an approach to estimate gathering pipeline emissions that relies on total national miles, and based on the available data, the subpart W data provides the most complete estimate for recent years and will be used as-is (i.e., the subpart W gathering pipeline miles will not be scaled up and will represent the national total for 2016 and forward). National miles from PHMSA may be available in the future, and EPA will compare that data to the subpart W data should it become available.

4 Time Series Considerations for Gathering Pipelines

The EPA also considered temporal variability, and ways to reflect emissions changes over the time series. However, limited historical data are available for gathering pipelines. Subpart W data are only available for two years (2016 and 2017), and the previous GHGI approach and other recent studies only examined data at a single point in time. The previous GHGI methodology applied the same EFs for all years of the time series, and the activity data vary with changes in gas production or gas wells (which is used to drive estimates of pipeline mileage).

5 Updated Methodology and National Emissions Estimates for Gathering Pipelines in the 2019 GHGI

For the gathering pipelines updates implemented in the 2019 GHGI, EPA applied the subpart W year-specific EFs for pipeline leaks and pipeline blowdowns (as shown in Table 3 and Table 4) for year 2016 and 2017, and then applied the year 2016 EFs to all prior years of the time series. EPA also maintained the GHGI methodology to

[2] https://cms.phmsa.dot.gov/data-and-statistics/pipeline/annual-report-mileage-natural-gas-transmission-gathering-systems
[3] See docket PHMSA-2011-0023 at regulations.gov.

calculate pipeline miles for 1990-2015, and then used the reported subpart W miles to represent the national total for 2016 and 2017. Using the reported subpart W miles as-is results in the national emissions equaling the reported subpart W emissions for 2016 and 2017. The use of subpart W data allows the GHGI to reflect trends, as year-specific subpart W EFs and pipeline miles will be applied for 2016 and forward.

Table 5 shows national total CH_4 and CO_2 emissions for 2016 and 2017 based on the update described above for gathering pipelines compared to previous GHGI estimates (also shown in Table 1 and Table 2). The subpart W-based update implemented for the 2019 GHGI has a similar magnitude of emissions compared to the 2018 GHGI emissions.

Table 5. Comparison of National-Level CH_4 and CO_2 Emissions Estimates for Gathering Pipeline Emissions, for Year 2016 and 2017

Emissions Source/Approach	2016		2017	
	CH_4 (mt)	CO_2 (mt)	CH_4 (mt)	CO_2 (mt)
Gathering Pipeline Leaks				
2019 GHGI (Subpart W-based Update[a])	136,776	15,821	141,577	16,307
2018 (Previous) GHGI	157,798	18,820	n/a	n/a
Gathering Pipeline Blowdowns				
2019 GHGI (Subpart W-based Update[a])	14,713	801	19,777	718
2018 (Previous) GHGI	3,874	462	n/a	n/a

n/a – Not applicable.
a – Estimates use subpart W data-as reported.

6 Requests for Stakeholder Feedback

EPA sought stakeholder feedback on the approaches under consideration discussed in the June and October 2018 memos, including the particular questions below. In response to those memos and public review draft emissions for the 2019 GHGI, stakeholders provided specific feedback on the G&B station and gathering pipeline approaches, and their feedback is summarized here:

- A stakeholder supported the use of subpart W data for gathering pipelines, including showing the emissions for each pipeline type. The stakeholder did not support using the mileage estimate from the proposed PHMSA rule, but did recommend comparing the subpart W mileage to the PHMSA data once PHMSA begins collecting this data.
- Stakeholders did not support the proposed approach of using component-level data reported under subpart W for G&B stations. Instead, stakeholders supported the current GHGI approach, which relies on the station-level EF from Marchese et al. 2015. Stakeholders recommended the following to update the G&B station methodology:
    - Wait for results from additional research on G&B station emissions.
    - Scale up component-level data from GHGRP to the Marchese et al. 2015 station-level estimates or using the component-level data from GHGRP but adding an uncategorized source of emissions that makes up the difference between Marchese et al. and the GHGRP.
    - Apply the G&B station facility-level EF presented in an Alvarez et al. 2018 study to better account for high emitting sites.

G&B Segment-Specific

1. 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 peer-reviewed studies)?

   a. EPA seeks feedback on whether additional data sources or methods should be considered for specific equipment types for gathering stations (e.g. compressors).
   b. 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[4]; developing nationally representative emission factors for equipment at G&B stations[5]; and methane emissions rate quantification for natural gas storage wells and fields[6].

2. 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).

3. In addition to reciprocating compressors, are there other specific G&B emission sources that EPA should examine to assess the difference between the subpart W-based estimates and the current GHGI estimates, for example episodic events (blowdowns)?

4. For G&B reciprocating compressor seal and valve leakage emissions, is the GHGI EF for gas processing or transmission reciprocating compressors more appropriate for calculating emissions from G&B in the GHGI than the current subpart W EF? EPA seeks feedback on the considerations and approaches discussed in Section 2.3.2.1 (of the Oct. 2018 memo) for this source (wherein the GHGI gas processing or transmission segment EF is used as a surrogate), or other methodologies to consider.

5. EPA is considering using the current GHGI EF for processing or transmission to calculate G&B reciprocating compressor exhaust emissions (refer to Section 2.3.2.2 (of the Oct. 2018 memo) for additional detail). EPA seeks feedback on the approach discussed in Section 2.3.2.2 (of the Oct. 2018 memo) wherein it is assumed that reported emissions from reciprocating compressor drivers fueled by natural gas indicate use of the subpart C EF. EPA acknowledges a limitation in this approach: that the subpart C EF would only have been applied for use of *pipeline quality* natural gas—but believes the potential over-estimate of activity due to this limitation is minimal, based on the similarity in the ratios of CO_2 to CH_4 between reported emissions and the subpart C prescribed EFs.

6. EPA seeks feedback on how to consider regional and temporal variability for G&B stations.
   a. Specifically, EPA seeks feedback on the detailed basin-level approach for scaling and estimating emissions at the basin-level, compared with the simplified scaling approach (which involves analyzing basin-level throughput to develop a national scaling factor) as discussed in Section 2.3.1

[4] https://www.netl.doe.gov/research/oil-and-gas/project-summaries/natural-gas-midstream-projects/fe0029084-gsi
[5] https://www.netl.doe.gov/research/oil-and-gas/project-summaries/natural-gas-midstream-projects/fe0029068-csu
[6] https://www.netl.doe.gov/research/oil-and-gas/project-summaries/natural-gas-midstream-projects/fe0029085-gsi

(of the Oct. 2018 memo). Note that national estimates presented in Section 5 and Appendix C (of the Oct. 2018 memo) were developed using the detailed basin-level approach.

b. Specifically, EPA seeks feedback on an activity data element and data source that is appropriate to estimate emissions in time series years before subpart W data are available for the G&B segment (i.e., 1990 through 2015). EPA seeks feedback on the use of basin-level DrillingInfo well production data, described in Section 4 (of the Oct. 2018 memo) and used to develop time series estimates presented in Appendix C (of the Oct. 2018 memo).

7. EPA seeks feedback on which of Scenarios 1, 2, and 3 presented in Section 5 (of the Oct. 2018 memo) for calculating national G&B station emissions is most appropriate for incorporation in the GHGI—or another approach that addresses considerations discussed in Section 2 (of the Oct. 2018 memo). Note that all three scenarios presented use the detailed basin-level approach for scaling and estimating emissions at the basin-level, but EPA is also considering using a simplified scaling approach (refer to Question #6) which could be combined with other elements of these three scenarios. For example, EPA might use a simplified scaling approach to scale up reported subpart W station emissions by a factor of 1.17 combined with surrogate EF methodology for reciprocating compressor sources.

8. EPA seeks feedback on the most appropriate EF to use over the time series for G&B pipelines. Table 3 and Table 4 compare the previous GHGI EFs and the subpart W EFs. Because the EFs are similar, EPA applied the subpart W EFs to all years of the time series for the update implemented for the 2019 GHGI. However, EPA could apply the previous GHGI EF for early time series year, apply the subpart W EF to recent time series years, and interpolate between the two EFs for intermediate years.

9. 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 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.

10. 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.

General (might impact other GHGI segments)

11. Stakeholders have suggested that CH_4 emissions from compressor exhaust in the GHGI (which are currently based on the 1996 GRI/EPA EFs for all segments except G&B, which uses a facility-level measurement) might be improved by developing activity data and EFs specific to rich burn versus lean burn modes of operation and by reflecting control technologies. The current GHGI CH_4 EFs for compressor exhaust were originally developed in the 1996 GRI/EPA study from an industry survey that weighted various operating characteristics of compressors to develop average EFs representative of the natural gas value chain. EPA is evaluating available data (e.g., from GHGRP, AP-42, EPA's Nonpoint Oil and Gas Emission Estimation Tool (NEI O&G Tool), background analyses for engine NSPS and NESHAP rules) to consider developing a revised methodology that reflects the fraction of reciprocating compressors that are rich burn versus lean burn and use of control technologies. EPA seeks stakeholder input on specific data sources that distinguish the prevalence of rich versus lean burn and controlled versus uncontrolled engines—for each industry segment, and across the time series.

12. 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)

Appendix A – GHGRP Measurement Methodologies

Emission Source	Measurement and/or Calculation Type	# Sources	Location & Representativeness	EF Calculation Method
GHGRP Subpart W				
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.	Reported emissions divided by reported pipeline miles.
G&B - 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.	Emissions data (for 2016) are available from 236 facilities.	Facilities in the U.S. that exceed 25,000 mt CO2e reporting threshold.	Reported emissions divided by reported pipeline miles.