Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2016: Revisions to CO_2 Emissions Estimation Methodologies

This memo describes revisions implemented for multiple segments of natural gas and petroleum systems in the 2018 Inventory of U.S. Greenhouse Gas Emissions and Sinks (GHGI). The revisions focus on CO_2 emissions calculation methodologies, but for certain sources, both the CH_4 and CO_2 calculation methodologies were revised. Previous versions of this memo were released in June and October 2017.[1,2]

The EPA made CO_2 methodological revisions for sources and segments that already rely on a subpart W-based CH_4 emission calculation methodology or where the CH_4 calculation methodology was otherwise recently revised. The subpart W methodology revisions for CH_4 emissions estimates are documented in the following memos: the 2014 HF Completion and Workover memo,[3] 2015 HF Completion and Workover memo,[4] 2016 Transmission memo,[5] 2016 Production memo,[6] 2017 Production memo,[7] and 2017 Processing memo.[8] The revisions discussed in this memo create consistency between CH_4 and CO_2 calculation methodologies. In addition, the EPA updated the GHGI to include both the CO_2 emissions and the relatively minor CH_4 emissions from flare stacks reported under subpart W in the production and transmission and storage segments.

The sources discussed in this memo include: production segment storage tanks, associated gas venting and flaring, hydraulically fractured (HF) gas well completions and workovers, production segment pneumatic controllers, production segment pneumatic pumps, liquids unloading, production segment miscellaneous flaring, most sources in the gas processing segment, transmission station flares, underground natural gas storage flares, and transmission and storage pneumatic controllers. The EPA did not consider revisions to the distribution segment CO_2 emissions calculation methodology, as discussed in Section 1.2.

1. Background and GHGI Methodology for CO_2 Emissions

This section discusses the GHGI methodology for calculating CO_2 emissions. Section 1.1 describes a CO_2-to-CH_4 gas content ratio methodology, which is the default approach used in all GHGI segments. This methodology was applied for numerous sources for the 2017 GHGI, and is still used in the 2018 GHGI for certain sources (excluding those sources with revisions in section 3). Section 1.2 describes the previous GHGI methodology to calculate CO_2

[1] See https://www.epa.gov/sites/production/files/2017-06/documents/updates_under_consideration_for_2018_ghgi_emissions_for_co2_from_natural_gas_and_petroleum_systems.pdf.
[2] See https://www.epa.gov/sites/production/files/2017-10/documents/2018_ghgi_co2_revisions_under_consideration_2017-10-25_to_post.pdf.
[3] "Overview of Update to Methodology for Hydraulically Fractured Gas Well Completions and Workovers in the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012 (2014 Inventory)," available at https://www.epa.gov/ghgemissions/natural-gas-and-petroleum-systems-ghg-inventory-updates-1990-2012-inventory-published.
[4] "Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2013: Revision to Hydraulically Fractured Gas Well Completions and Workovers Estimate," available at https://www.epa.gov/ghgemissions/natural-gas-and-petroleum-systems-ghg-inventory-updates-1990-2013-inventory-published.
[5] "Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2014: Revisions to Natural Gas Transmission and Storage Emissions," available at https://www.epa.gov/ghgemissions/natural-gas-and-petroleum-systems-ghg-inventory-additional-information-1990-2014-ghg.
[6] "Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2014: Revisions to Natural Gas and Petroleum Production Emissions," available at https://www.epa.gov/ghgemissions/natural-gas-and-petroleum-systems-ghg-inventory-additional-information-1990-2014-ghg.
[7] "Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2015: Revisions to Natural Gas and Petroleum Systems Production Emissions," available at https://www.epa.gov/ghgemissions/natural-gas-and-petroleum-systems-ghg-inventory-additional-information-1990-2015-ghg.
[8] "Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2015: Revisions to Natural Gas Systems Processing Segment Emissions," available at https://www.epa.gov/ghgemissions/natural-gas-and-petroleum-systems-ghg-inventory-additional-information-1990-2015-ghg.

emissions for certain sources that relied on emission source-specific methods. The previous GHGI CO_2 EFs are documented in Appendix A.

1.1 CO_2-to-CH_4 Gas Content Ratio Methodology

The default GHGI methodology to calculate CO_2 emission factors (EFs) relies on CH_4 emission factors and an assumed ratio of CO_2-to-CH_4 gas content. The CO_2 EF calculation is shown in equation 1:

$$CO_2 \text{ EF} = CH_4 \text{ EF} * \left(\frac{CO_2 \text{ content}}{CH_4 \text{ content}}\right) \qquad \text{Equation 1}$$

The default CH_4 and CO_2 content values for sources in natural gas systems are from the 1996 GRI/EPA study,[9] EIA,[10] and GTI's Gas Resource Database[11] and summarized in Table 1 below.

Table 1. Default Gas Content Values for Natural Gas Systems in the GHGI

Segment	CH_4 Content (vol%)	CO_2 Content (vol%)
Production – North East region	78.8	3.04
Production – Mid Central region		0.79
Production – Gulf Coast region		2.17
Production – South West region		3.81
Production – Rocky Mountain region		7.58
Production – West Coast region		0.16
Processing – Before CO_2 removal	87.0	3.45
Processing – After CO_2 removal		1.0
Transmission and Underground NG Storage	93.4	1.0
LNG Storage and LNG Import/Export	93.4	1.16
Distribution	93.4	1.0

For most of the petroleum production sources evaluated in this memo, the GHGI uses a ratio of CO_2 to CH_4 content, set at 0.017 based on the average flash gas CO_2 and CH_4 content from API TankCalc runs.

The ratio of CO_2-to-CH_4 gas content methodology is used to calculate venting and fugitive CO_2 EFs, because the CH_4 EFs that are referenced for this methodology represent venting and fugitive emissions, which are predominantly CH_4 with minimal CO_2 emissions. EPA does not use this methodology in the GHGI to calculate CO_2 EFs for combustion sources such as flares, for which the inverse is true (CO_2 is predominant, with minimal CH_4 emissions).

1.2 Emission Source-Specific CO_2 Calculation Methodologies

The previous GHGI used the following emission source-specific methodologies to calculate CO_2 emissions from oil and condensate tanks at production sites, AGR units at natural gas processing plants, and production and processing flaring.

1.2.1 Oil and Condensate Tanks at Production Sites

The previous GHGI methodology to calculate CO_2 emissions for oil and condensate tanks used CO_2 specific EFs. The EFs were developed using API TankCalc software with varying API gravities. The oil tank EF is the average from

[9] Methane Emissions from the Natural Gas Industry, Volume 6: Vented and Combustion Source Summary, Appendix A.
[10] U.S. Energy Information Administration. Emissions of Greenhouse Gases in the United States: 1987-1992, Appendix A. 1994.
[11] GRI-01/0136 GTI's Gas Resource Database: Unconventional Natural Gas and Gas Composition Databases. Second Edition. August, 2001.

API TankCalc runs for oils with API gravity less than 45, and the condensate tank EF considered data with API gravity greater than 45. Condensate tank EFs were determined for both controlled and uncontrolled tanks; the controlled tank EF assumed a control efficiency of 80%. The previous GHGI calculated oil tank CO_2 emissions by applying the oil tank emission factor (EF) to 20% of stripper well production and 100% of non-stripper oil well production. For gas production, the previous GHGI methodology estimated tank emissions by applying the condensate tank EF to condensate production in each NEMS region.

1.2.2 AGR Units at Natural Gas Processing Plants

The previous GHGI CO_2 EF for AGR units at natural gas processing plants relied on gas CO_2 content only. The difference in the default CO_2 content before and after CO_2 removal (3.45% - 1.0% = 2.45% of processing plant gas throughput) is assumed to be emitted.

1.2.3 Flaring

Flaring emissions from the production and processing segments were previously calculated under a single line item in the production segment of natural gas systems. Therefore, flaring emissions were not specifically attributed to the natural gas systems processing segment or the petroleum systems production segment. The EF was based on data from EIA's 1996 greenhouse gas emissions inventory, which estimated the amount of CO_2 released per BTU of natural gas combusted (0.055 g/BTU). The activity data were annual EIA "Vented and Flared" gas volumes (MMcf), which are reported under Natural Gas Gross Withdrawals and Production,[12] combined with the estimated national average gas heating value (averaging approximately 1,100 BTU/cf over the time series[13]). The EIA Vented and Flared data represents a balancing factor amount that EIA calculates to reconcile reported upstream and downstream gas volumes, and assumes is potentially emitted to the atmosphere during production or processing operations; the previous GHGI methodology assumed it was all flared. Details on how much of the Vented and Flared gas is potentially emitted during natural gas production, petroleum production, and processing are not available, so the previous GHGI assigned it all to natural gas production. Also, the EIA data do not account for gas that is flared prior to metering.

Flaring emissions from the transmission and storage segment were not previously calculated in the GHGI. Flaring emissions from the distribution segment are not currently calculated in the GHGI. Data are unavailable on flaring emissions in the distribution segment, but they are likely to be insignificant based on the low prevalence of this activity in the industry segment. EPA did not consider revisions to the distribution segment CO_2 emissions calculation methodology for the 2018 GHGI.

2. Available Subpart W Data

Subpart W of the EPA's Greenhouse Gas Reporting Program (GHGRP) collects annual operating 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. Onshore production facilities in subpart W are defined as a unique combination of operator and basin of operation, a natural gas processing facility in subpart W is each unique processing plant, a natural gas transmission compression facility in subpart W is each unique transmission compressor station, an underground natural gas storage facility in subpart W is the collection of subsurface storage and processes and above ground wellheads, an LNG storage facility in subpart W is the collection of storage vessels and related equipment, and an LNG import and export facility in subpart W is the collection of equipment that handles LNG received from or transported via ocean transportation. Facilities in the above-mentioned industry segments that meet the subpart W reporting threshold have been reporting since 2011;

[12] EIA Natural Gas Gross Withdrawals and Production, including the Vented and Flared category, is available at https://www.eia.gov/dnav/ng/ng_prod_sum_a_EPG0_VGV_mmcf_m.htm

[13] EIA Monthly Energy Review. Table A4 - Approximate Heat Content of Natural Gas (Btu per Cubic Feet).

currently, six years of subpart W reporting data are publicly available, covering reporting year (RY) 2011 through RY2016.[14]

Subpart W activity and emissions data have been used in recent GHGIs to calculate CH_4 emissions for several production, processing, and transmission and storage sources. CO_2 emissions data from subpart W had not yet been incorporated into the 2017 GHGI. However, facilities use an identical reporting structure for CO_2 and CH_4. Therefore, where subpart W CH_4 data have been used, the CO_2 data may be incorporated in a parallel manner. The 2014 HF Completion and Workover memo, 2016 Transmission memo, 2016 Production memo, 2017 Production memo, and 2017 Processing memo discuss in greater detail the subpart W data available for those sources.

EPA also reviewed subpart W data that could be used for CO_2 emission estimates from miscellaneous production flaring, acid gas removal (AGR) vents, and transmission and storage station flares—sources for which the emissions were not previously calculated with subpart W data in the GHGI.

Production segment flare emissions are only reported under the "flare stacks" emission source in subpart W if the flare emissions originate from sources not otherwise covered by subpart W—this emission source is referred to as "miscellaneous production flaring" for purposes of this memo. Therefore, the subpart W production flares data do not duplicate flaring emissions reported, for example, under production tank flaring or associated gas flaring. It also ensures all production flaring emissions are reported for facilities that meet the reporting threshold. Flare emissions are calculated 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.

Under subpart W, gas processing facilities calculate AGR unit CO_2 emissions using one of four methods: (1) CO_2 CEMS; (2) a vent stream flow meter with CO_2 composition data; (3) calculation using an equation with the inlet or outlet natural gas flow rate and measured inlet and outlet CO_2 composition data; or (4) simulation software (e.g., AspenTech HYSYS or API 4679 AMINECalc). CH_4 emissions for AGR units are not reported in subpart W.

Transmission and underground natural gas storage stations report emissions from all flaring under the "flare stacks" emission source as of RY2015. Prior to that, flare emissions reported under subpart W were included in the reported emissions for the specific source (e.g., reciprocating or centrifugal compressor). 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.

3. 2018 GHGI Revisions

For the 2018 GHGI, EPA calculated CO_2 EFs using the same methodologies that were developed for CH_4 EFs in recent GHGIs. For associated gas venting and flaring and production segment miscellaneous flaring, while there was an existing methodology, EPA calculated both CO_2 and CH_4 emissions using a revised methodology for the 2018 GHGI. In addition, the EPA updated the GHGI to incorporate subpart W data for CO_2 from AGR units, and both the CO_2 emissions and the relatively minor CH_4 emissions from flare stacks in the production and transmission and storage segments.

[14] The GHGRP subpart W data used in the analyses discussed in this memo are those reported to the EPA as of August 5, 2017.

3.1 Production CO_2 Emission Factors

The EPA developed CO_2 EFs for several sources in the natural gas and petroleum production segments. The CH_4 EFs for oil and condensate tanks, pneumatic controllers, and pneumatic pumps were recently revised using subpart W data, and EPA applied the same methodology to calculate CO_2 EFs. There was an existing subpart W-based CH_4 methodology for associated gas venting and flaring and gas well hydraulically fractured completions and workovers, but a revised methodology was developed for these sources. The EPA also developed a CO_2 emissions calculation methodology for miscellaneous production flaring. Each of these sources are discussed below.

3.1.1 Associated Gas Venting and Flaring

The associated gas venting and flaring emissions calculation methodology was revised in the 2017 GHGI to use subpart W data and calculated CH_4 emissions using a national-level, well count-based scaling approach.[15] However, stakeholders commented that national-level EFs and AFs would not take into account differences in associated gas venting and flaring among geographic regions. In particular, over- or under-representation in GHGRP data by geographic regions where associated gas is vented or flared more or less frequently may disproportionately contribute to national-level factors. Stakeholders also commented that associated gas emissions are more directly related to production levels, rather than well counts. In response to stakeholder comments, the EPA reassessed the associated gas venting and flaring data and finalized a basin-level, production-based scaling approach for the 2018 GHGI. The final methodology is applied for both CO_2 and CH_4 emissions and is discussed here. The October 2017 version of this memo documents the national-level approach for CO_2 (following the 2017 GHGI methodology) and presents a NEMS region-level, well-based approach that was considered but not implemented.

The EPA first reviewed the reported subpart W associated gas venting and flaring emissions for RY2011 through RY2016 to identify basins that contribute the majority of the associated gas emissions. Specifically, if a basin contributed at least 10 percent of total annual emissions (on a CO_2 Eq. basis) from associated gas venting and flaring in any year, then basin-specific EFs and AFs were developed. See Appendix B for the associated gas emissions by year for all basins. Four basins met this criteria: 220 - Gulf Coast Basin (LA, TX); 360 - Anadarko Basin; 395 - Williston Basin; and 430 - Permian Basin. Associated gas venting and flaring data in all other basins were combined, and EFs and AFs developed for the other basins as a single group.

EPA calculated EFs for RY2015 and RY2016; subpart W data in earlier years do not contain publicly available production data. The EPA calculated CO_2 and CH_4 EFs for associated gas venting and flaring by summing the reported emissions for venting and flaring and dividing by the sum of the reported volume of oil produced during associated gas venting and flaring. Table 2 and Table 3 present the emissions and oil production data for years 2015 and 2016, and Table 4 shows the resulting EFs. The 2015 EFs were applied to all prior years in the time series.

Table 2. Associated Gas Venting and Flaring Emissions and Oil Production, Subpart W RY2015

Basin	Venting CO_2 (mt)	Venting CH_4 (mt)	Volume of Oil Produced During Venting (bbl)	Flaring CO_2 (mt)	Flaring CH_4 (mt)	Volume of Oil Produced During Flaring (bbl)
220 - Gulf Coast Basin (LA, TX)	93	1,259	2,110,981	589,431	2,718	18,591,586
360 - Anadarko Basin	22	906	1,994,628	159,208	695	148,688
395 - Williston Basin	151	1,564	229,586	7,890,206	23,965	264,426,732
430 - Permian Basin	2,675	5,839	5,975,614	2,094,869	8,185	36,912,840
All Other Basins	8,520	6,303	2,522,412	390,300	1,749	27,110,014

[15] See the 2017 Production Memo for details.

Table 3. Associated Gas Venting and Flaring Emissions and Oil Production, Subpart W RY2016

Basin	Venting CO_2 (mt)	Venting CH_4 (mt)	Volume of Oil Produced During Venting (bbl)	Flaring CO_2 (mt)	Flaring CH_4 (mt)	Volume of Oil Produced During Flaring (bbl)
220 - Gulf Coast Basin (LA, TX)	267	2,089	1,250,441	298,967	1,187	13,547,580
360 - Anadarko Basin	6	294	175,531	1,185	5	25,735
395 - Williston Basin	140	1,356	234,720	5,035,977	14,017	208,727,344
430 - Permian Basin	216	4,281	4,135,034	1,691,562	6,767	38,294,649
All Other Basins	4,538	4,353	6,711,810	284,496	1,049	18,628,782

Table 4. Calculated Associated Gas Venting and Flaring Emission Factors (kg/bbl/yr)

Basin	Venting CO_2 EF		Venting CH_4 EF		Flaring CO_2 EF		Flaring CH_4 EF	
	2015	2016	2015	2016	2015	2016	2015	2016
220 - Gulf Coast Basin (LA, TX)	0.04	0.21	0.60	1.67	32	22	0.15	0.09
360 - Anadarko Basin	0.01	0.03	0.45	1.68	1,071	46	4.7	0.20
395 - Williston Basin	0.66	0.60	6.81	5.78	30	24	0.09	0.07
430 - Permian Basin	0.45	0.05	0.98	1.04	57	44	0.22	0.18
All Other Basins	3.38	0.68	2.50	0.65	14	26	0.06	0.08

The EPA calculated two AFs for each basin or group: the percent of oil production with either flaring or venting of associated gas and, within that subset of production, the fraction that vents and the fraction that flares. The AFs were calculated for 2015 and 2016, and the 2015 activity factors applied to all prior years. The AF data are presented in Table 5 and Table 6.

Table 5. Associated Gas Venting and Flaring Production Data and AFs, Subpart W RY2015

Basin	Volume of Oil Produced During Venting (bbl)	Volume of Oil Produced During Flaring (bbl)	Subpart W Liquids Production (bbl)	% Production with Flaring or Venting of Associated Gas	% Production with Venting	% Production with Flaring
220 - Gulf Coast Basin (LA, TX)	2,110,981	18,591,586	650,435,832[a]	3%	10%	90%
360 - Anadarko Basin	1,994,628	148,688	99,146,641	2.2%	93%	7%
395 - Williston Basin	229,586	264,426,732	447,415,171	59%	0.1%	99.9%
430 - Permian Basin	5,975,614	36,912,840	591,656,726	7%	14%	86%
All Other Basins	2,522,412	27,110,014	645,262,423	5%	9%	91%

a. Reported subpart W liquids production exceeded DrillingInfo production for basin, DrillingInfo production used to calculate AF.

Table 6. Associated Gas Venting and Flaring Production Data and AFs, Subpart W RY2016

Basin	Volume of Oil Produced During Venting (bbl)	Volume of Oil Produced During Flaring (bbl)	Subpart W Liquids Production (bbl)	% Production with Flaring or Venting of Associated Gas	% Production with Venting	% Production with Flaring
220 - Gulf Coast Basin (LA, TX)	1,250,441	13,547,580	516,246,773[a]	3%	8%	92%
360 - Anadarko Basin	175,531	25,735	94,789,700	0.2%	87%	13%
395 - Williston Basin	234,720	208,727,344	322,617,029	65%	0.1%	99.9%
430 - Permian Basin	4,135,034	38,294,649	533,358,906	8%	10%	90%
All Other Basins	6,711,810	18,628,782	1,464,067,958[a]	2%	26%	74%

a. Subpart W liquids production exceeded DrillingInfo production for basin, DrillingInfo production used to calculate AF.

EPA uses total liquids production data for each basin or group to calculate national emissions. Total liquids production data for each basin were determined from DrillingInfo, while the total national liquids production was

available from EIA (consistent with current methodologies for other GHGI sources that rely on total national production data). Therefore, the national production for all other basins equals the EIA production minus the DrillingInfo production for each of the four basins. The total liquids production data for 2015 and 2016 are provided in Table 7, and the resulting national emissions are shown in Table 8.

Table 7. Total Liquids Production (bbl), by Basin

Basin	Year 2015	Year 2016
220 - Gulf Coast Basin (LA, TX)	650,435,832	516,246,773
360 - Anadarko Basin	144,644,537	122,734,407
395 - Williston Basin	456,423,760	396,753,744
430 - Permian Basin	688,208,748	733,002,118
All Other Basins	1,494,207,123	1,464,067,958

Table 8. Calculated Total Associated Gas Venting and Flaring Emissions

Basin	Venting CO_2 (mt)		Venting CH_4 (mt)		Flaring CO_2 (mt)		Flaring CH_4 (mt)	
	2015	2016	2015	2016	2015	2016	2015	2016
220 - Gulf Coast Basin (LA, TX)	93	267	1,259	2,089	589,431	298,967	2,718	1,187
360 - Anadarko Basin	31	8	1,321	381	232,268	1,534	1,014	7
395 - Williston Basin	154	173	1,596	1,668	8,049,073	6,193,234	24,447	17,238
430 - Permian Basin	3,112	297	6,792	5,883	2,436,729	2,324,735	9,520	9,301
All Other Basins	19,728	4,538	14,596	4,353	903,802	284,496	4,049	1,049
Total	**23,119**	**5,282**	**25,564**	**14,375**	**12,211,303**	**9,102,967**	**41,749**	**28,782**

3.1.2 Miscellaneous Production Flaring

The EPA used subpart W RY2015 and RY2016 miscellaneous production flaring (reported under "flare stacks") emissions data to revise the GHGI and more fully account for flare emissions in the production segment. Subpart W data for this source were not previously considered. The EPA calculated the CO_2 and CH_4 EFs using a national-level, well count-based scaling approach for the 2018 GHGI public review draft; this methodology is documented in the previous July and October 2017 versions of this memo. However, similar to associated gas venting and flaring, stakeholders recommended a basin-level, production-based scaling approach. After evaluating the data, a basin-level, production-based scaling approach was applied for the 2018 GHGI, and is documented here.

The EPA reviewed the reported subpart W miscellaneous production flaring emissions for RY2011 through RY2016 to identify basins that contribute the majority of the associated gas emissions. Specifically, if a basin contributed at least 10 percent of total annual emissions (on a CO_2 Eq. basis) from miscellaneous production flaring in any year, then basin-specific emission factors and activity factors were developed. See Appendix C for the miscellaneous production flaring emissions by year for all basins. Three basins met this criteria: 220 - Gulf Coast Basin (LA, TX); 395 - Williston Basin; and 430 - Permian Basin. Miscellaneous production flaring data in all other basins were combined, and EFs and AFs developed for the other basins as a single group. EFs and AFs were developed using RY2015 and RY2016 data, as prior years do not contain publicly available production data.

Miscellaneous production flaring emissions are not reported separately for gas and oil production. Therefore, to use reported emissions data for separate natural gas and petroleum systems GHGI estimates, the EPA calculated the fraction of wells that were gas and oil wells for each facility, using the well counts reported in the Equipment Leaks section of subpart W.[16] The EPA then apportioned each facility's reported miscellaneous production flaring

[16] Three facilities with miscellaneous production flaring emissions did not report well counts. Therefore, for these three facilities, the EPA determined the fraction of sub-basins applicable to gas production (i.e., sub-basins with *high permeability gas*, *shale gas*, *coal seam,* or *other tight reservoir rock* formation types) and oil production (i.e., sub-basins with the *oil* formation type), and applied these fractions in the calculations.

CO_2 and CH_4 emissions by production type, and summed the facility-level CO_2 and CH_4 emissions for each production type to the basin-level to estimate total reported miscellaneous flaring CO_2 and CH_4 emissions from natural gas and oil production, for each basin or group.

Next, EPA used gas and liquids production data to develop EFs for calculating the national total emissions. The EPA calculated EFs by dividing the basin-level CO_2 and CH_4 emissions for natural gas and oil production by the summation of the reported gas produced from wells (for natural gas production EFs) and liquids produced (for oil production EFs). These emissions data, production data, and calculated EFs are provided in Table 9 through Table 12 below. The 2015 EFs were applied to all prior years in the time series.

Table 9. GHGRP Subpart W RY2015 Natural Gas Production CO_2 and CH_4 Emissions and Activity Data and Calculated EFs for Miscellaneous Production Flaring

Basin	Gas CO_2 (mt)	Gas CH_4 (mt)	Gas Produced from Wells (mscf)	Gas CO_2 EF (kg/mscf/yr)	Gas CH_4 EF (kg/mscf/yr)
220 - Gulf Coast Basin (LA, TX)	324,079	1,157	3,161,594,496	1.03E-01	3.66E-04
395 - Williston Basin	56	0	645,705,949[a]	8.61E-05	3.14E-07
430 - Permian Basin	673,592	2,992	2,367,810,821[a]	2.84E-01	1.26E-03
All Other Basins	310,453	1,337	20,352,492,312[a]	1.53E-02	6.57E-05

a. Subpart W production exceeded DrillingInfo production for basin, DrillingInfo production used.

Table 10. GHGRP Subpart W RY2015 Oil Production CO_2 and CH_4 Emissions and Activity Data and Calculated EFs for Miscellaneous Production Flaring

Basin	Oil CO_2 (mt)	Oil CH_4 (mt)	Liquids Produced (bbl)	Oil CO_2 EF (kg/bbl/yr)	Oil CH_4 EF (kg/bbl/yr)
220 - Gulf Coast Basin (LA, TX)	859,858	3,548	652,726,411[a]	1.32E+00	5.44E-03
395 - Williston Basin	856,957	2,145	447,415,171	1.92E+00	4.79E-03
430 - Permian Basin	424,156	1,626	591,656,726	7.17E-01	2.75E-03
All Other Basins	540,935	1,861	743,813,115[a]	7.27E-01	2.50E-03

a. Subpart W production exceeded DrillingInfo production for basin, DrillingInfo production used.

Table 11. GHGRP Subpart W RY2016 Natural Gas Production CO_2 and CH_4 Emissions and Activity Data and Calculated EFs for Miscellaneous Production Flaring

Basin	Gas CO_2 (mt)	Gas CH_4 (mt)	Gas Produced from Wells (mscf)	Gas CO_2 EF (kg/mscf/yr)	Gas CH_4 EF (kg/mscf/yr)
220 - Gulf Coast Basin (LA, TX)	213,698	584	2,661,846,306	8.03E-05	2.19E-07
395 - Williston Basin	206	0	649,228,154[a]	3.18E-07	5.28E-10
430 - Permian Basin	438,567	1,939	2,356,640,169	1.86E-04	8.23E-07
All Other Basins	339,247	1,573	19,553,610,690[a]	1.73E-05	8.05E-08

a. Subpart W production exceeded DrillingInfo production for basin, DrillingInfo production used.

Table 12. GHGRP Subpart W RY2016 Oil Production CO_2 and CH_4 Emissions and Activity Data and Calculated EFs for Miscellaneous Production Flaring

Basin	Oil CO_2 (mt)	Oil CH_4 (mt)	Liquids Produced (bbl)	Oil CO_2 EF (kg/bbl/yr)	Oil CH_4 EF (kg/bbl/yr)
220 - Gulf Coast Basin (LA, TX)	389,281	1,630	518,218,649[a]	7.51E-04	3.15E-06
395 - Williston Basin	274,154	778	322,617,029	8.50E-04	2.41E-06
430 - Permian Basin	563,672	1,991	533,358,906	1.06E-03	3.73E-06
All Other Basins	414,762	1,035	689,536,735[a]	6.02E-04	1.50E-06

a. Subpart W production exceeded DrillingInfo production for basin, DrillingInfo production used.

EPA calculated national emissions using the appropriate national production (i.e., total gas production or liquids production) for each basin or group. Total gas production data for each basin and for the nation were determined from DrillingInfo. Total liquids production data for each basin were determined from DrillingInfo, while the total national liquids production was available from EIA (consistent with current methodologies for other GHGI sources that rely on total national production data). Therefore, the national liquids production for all other basins equals the EIA production, minus the DrillingInfo production for each of the three basins. The production data and resulting national emissions for 2015 and 2016 are shown in Table 13 and Table 14.

Table 13. Total Production Data and Miscellaneous Production Flaring Emissions for Natural Gas and Petroleum Systems, Reporting Year 2015

Basin	Total Gas Production (mscf)	Total Liquids Production (bbl)	Gas CO_2 (mt)	Gas CH_4 (mt)	Oil CO_2 (mt)	Oil CH_4 (mt)
220 - Gulf Coast Basin (LA, TX)	3,519,664,923	652,726,411	360,782	1,288	859,858	3,548
395 - Williston Basin	645,705,949	456,442,746	56	0	874,248	2,188
430 - Permian Basin	2,367,810,821	688,752,179	673,592	2,992	493,763	1,893
All Other Basins	24,940,124,177	1,635,998,664	380,431	1,639	1,189,773	4,094
Total	**31,473,305,870**	**3,433,920,000**	**1,414,861**	**5,918**	**3,417,643**	**11,724**

Table 14. Total Production Data and Miscellaneous Production Flaring Emissions for Natural Gas and Petroleum Systems, Reporting Year 2016

Basin	Total Gas Production (mscf)	Total Liquids Production (bbl)	Gas CO2 (mt)	Gas CH4 (mt)	Oil CO2 (mt)	Oil CH4 (mt)
220 - Gulf Coast Basin (LA, TX)	3,061,920,423	518,218,649	245,817	672	389,281	1,630
395 - Williston Basin	649,228,154	396,772,982	206	0	337,170	957
430 - Permian Basin	2,546,961,000	733,544,659	473,985	2,095	775,235	2,738
All Other Basins	23,551,484,913	1,584,268,710	408,609	1,895	952,951	2,378
Total	**29,809,594,491**	**3,232,805,000**	**1,128,617**	**4,662**	**2,454,637**	**7,703**

3.1.2 Production Tanks

Based on the CH_4 EF methodology documented in the 2017 Production memo, the EPA calculated oil and condensate tank CO_2 EFs for several tank categories, using subpart W data: large tanks with flaring; large tanks with a vapor recovery unit (VRU); large tanks without controls; small tanks with flaring; small tanks without flaring; and malfunctioning separator dump valves. EPA applied several steps described in the 2017 Production memo to apportion the reported subpart W data to each of the categories. EPA then summed the emissions and divided by the throughput for each tank category. Table 15 presents the resulting CO_2 EFs for RY2015 (which are applied for 2015 and all prior years in the time series) and RY2016.

Table 15. GHGRP Subpart W-based Oil and Condensate Tank CO_2 EFs (kg/bbl/yr)

Tank Category	Oil Tanks EF		Condensate Tanks EF	
	2015	2016	2015	2016
Large Tanks with Flaring	7.21	6.98	8.33	10.90
Large Tanks with VRU	0.037	0.025	0.11	0.12
Large Tanks without Controls	0.016	0.019	0.019	0.026
Small Tanks with Flaring	0.27	1.64	1.96	4.46
Small Tanks without Flares	0.078	0.066	0.28	0.46
Malfunctioning Dump Valves	0.013	0.012	8.19E-05	6.98E-05

3.1.4 Pneumatic Controllers

Based on the CH_4 EF methodology documented in the 2016 Production memo, the EPA calculated pneumatic controller CO_2 EFs for low, intermittent, and high bleed controllers using Subpart W RY2014 data. EPA divided the reported emissions by the number of reported controllers for each controller type to calculate EFs. All pneumatic controllers data were considered together, and thus pneumatic controller EFs for natural gas and petroleum systems are identical. Table 16 presents the subpart W activity and emissions data, along with the calculated CO_2 EFs.

Table 16. GHGRP Subpart W RY2014 Activity and Emissions Data and Calculated EFs for Pneumatic Controllers

Controller Type	# Controllers	Total CO_2 Emissions (mt)	CO_2 EF (kg/controller/yr)
Low Bleed	198,941	2,382	**12**
Intermittent Bleed	561,283	98,269	**175**
High Bleed	27,208	9,790	**360**

3.1.5 Pneumatic Pumps

Based on the CH_4 EF methodology documented in the 2016 Production memo, the EPA calculated a pneumatic pump CO_2 EF using Subpart W RY2014 data. EPA divided the reported emissions by the number of reported pneumatic pumps to calculate the EF. All pneumatic pumps data were considered together, and thus the EF for natural gas and petroleum systems is identical. Table 17 presents the subpart W activity and emissions data, along with the calculated CO_2 EF.

Table 17. GHGRP Subpart W RY2014 Activity and Emissions Data and Calculated EF for Pneumatic Pumps

# Pumps	Total CO_2 Emissions (mt)	CO_2 EF (kg/pump/yr)
79,760	11,647	**146**

3.1.3 HF Gas Well Completions and Workovers

EPA calculated CO_2 emissions for the 2018 GHGI public review draft using the CH_4 EF methodology documented in the 2014 HF Completion and Workover memo and 2015 HF Completion and Workover memo. See the earlier versions of this memo from June and October 2017 for the resulting EFs. However, both the CO_2 and CH_4 calculation methodologies for this source were revised for the final 2018 GHGI, and these revisions are documented in the *2018 Year-Specific Emissions memo*.[17]

3.1.6 Liquids Unloading

EPA calculated CO_2 emissions for the 2018 GHGI public review draft using the CH_4 EF methodology documented in the 2017 Production memo. See the earlier versions of this memo from June and October 2017 for the resulting EFs. However, both the CO_2 and CH_4 calculation methodologies for this source were revised for the final 2018 GHGI, and these revisions are documented in the *2018 Year-Specific Emissions memo*.

3.2 Processing CO_2 Emission Factors

The EPA developed gas processing CO_2 EFs for the plant grouped emission sources (reciprocating compressors, centrifugal compressors with wet seals, centrifugal compressors with dry seals, dehydrators, flares, and plant fugitives), blowdowns and venting, and AGR vents. The CH_4 EFs for the grouped sources and blowdowns and venting were recently revised using subpart W data, and the EPA applied the same methodology to calculate CO_2 EFs. AGR vent emissions were not previously calculated from subpart W data (as CH_4 emissions are not reported for this source), but the EPA calculated a subpart W-based CO_2 EF and determined the corresponding activity data for this source.

[17] "Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2016: Revisions to Create Year-Specific Emissions and Activity Factors," available online at https://www.epa.gov/ghgemissions/natural-gas-and-petroleum-systems-ghg-inventory-additional-information-1990-2016-ghg.

Based on the CH_4 EF methodology documented in the 2017 Processing memo, the EPA calculated the plant grouped source CO_2 EFs using subpart W data (the purpose of the plant grouped EF is discussed in Section 3.4). Subpart W RY2015 and RY2016 data and calculated CO_2 EFs for the plant grouped sources are presented in Table 18 and Table 19.

Table 18. GHGRP Subpart W RY2015 Emissions and Activity Data and Calculated EFs for Gas Processing Plant Grouped Sources

Emission Source	CO_2 Emissions (mt)	Activity Count (plants or compressors)		CO_2 EF (kg/compressor/yr or kg/plant/yr)
Reciprocating compressors	7,618	2,678	compressors	2,845
Centrifugal compressors with wet seals	1,259	264	compressors	4,768
Centrifugal compressors with dry seals	21	215	compressors	400
Dehydrators	7,430	466	plants	15,944
Flares	4,231,009	466	plants	9,079,418
Plant fugitives	2,244	466	plants	4,816
Plant Grouped Sources	**4,249,580**	**466**	**plants**	**9,119,411**

Table 19. GHGRP Subpart W RY2016 Emissions and Activity Data and Calculated EFs for Gas Processing Plant Grouped Sources

Emission Source	CO_2 Emissions (mt)	Activity Count (plants or compressors)		CO_2 EF (kg/compressor/yr or kg/plant/yr)
Reciprocating compressors	7,275	2,737	compressors	2,658
Centrifugal compressors with wet seals	839	226	compressors	3,711
Centrifugal compressors with dry seals	39	228	compressors	474
Dehydrators	4,467	447	plants	9,994
Flares	3,621,791	447	plants	8,102,440
Plant fugitives	2,599	447	plants	5,813
Plant Grouped Sources	**3,637,009**	**447**	**plants**	**8,136,640**

Based on the CH_4 EF methodology documented in the 2017 Processing memo, the EPA also calculated the blowdown and venting CO_2 EF using subpart W data. Subpart W RY2015 data and the calculated CO_2 EF for blowdowns and venting are presented in Table 20.

Table 20. GHGRP Subpart W RY2015 Emissions and Activity Data and Calculated EF for Gas Processing Blowdown and Venting

RY	CO2 Emissions (mt)	Activity Count (plants)	CO_2 EF (kg/plant/yr)
2015	11,059	466	**23,731**
2016	7,817	447	**17,487**

For AGR vent emissions, the existing CH_4 EF methodology does not rely on subpart W, but the EPA applied a similar methodology as the other processing sources to develop CO_2 EFs and activity data from subpart W data. The EPA summed the reported AGR vent CO_2 emissions for gas processing plants and divided by the total reported count of plants for each RY to calculate CO_2 EFs. Subpart W RY2015 and RY2016 data and the calculated CO_2 EFs for AGR vents are presented in Table 21. To calculate national CO_2 emissions, the CO_2 EF was multiplied by the number of gas plants each year.

Table 21. GHGRP Subpart W Emissions and Activity Data and Calculated EFs for Gas Processing AGR Vents

Year	CO_2 Emissions (mt)	Activity Count (plants)	CO_2 EF (kg/plant/yr)
2015	10,441,754	466	**22,407,197**
2016	11,101,161	447	**24,834,813**

3.3 Transmission and Storage CO_2 Emission Factors

3.3.1 Pneumatic Controllers

Based on the CH_4 EF methodology documented in the 2016 Transmission memo, the EPA calculated transmission station and storage station pneumatic controller CO_2 EFs for low, intermittent, and high bleed controllers using Subpart W RY2011 - RY2016 data. The EPA divided the reported emissions by the number of reported controllers for each controller type to calculate EFs. Table 22 and Table 23 present the subpart W activity and emissions data, along with the calculated CO_2 EFs. The RY2011 EFs were applied for all prior years in the time series.

Table 22. GHGRP Subpart W Activity and Emissions Data and Calculated EFs for Transmission Station Pneumatic Controllers

Controller Type	Data Element	2011	2012	2013	2014	2015	2016
High Bleed	Total Count	2,203	1,114	1,158	1,173	1,508	1,000
	CO_2 Emissions (mt)	203	106	106	107	121	85
	CO_2 EF (kg/controller/yr)	**92**	**95**	**91**	**91**	**80**	**85**
Intermittent Bleed	Total Count	8,343	9,114	9,903	11,160	10,891	11,122
	CO_2 Emissions (mt)	673	736	747	134	105	120
	CO_2 EF (kg/controller/yr)	**81**	**81**	**75**	**12**	**10**	**11**
Low Bleed	Total Count	644	880	857	1,078	1,033	943
	CO_2 Emissions (mt)	4.6	6.2	6.2	6.7	4.3	4.5
	CO_2 EF (kg/controller/yr)	**7.1**	**7.0**	**7.3**	**6.2**	**4.2**	**4.8**

Table 23. GHGRP Subpart W Activity and Emissions Data and Calculated EFs for Underground Natural Gas Storage Station Pneumatic Controllers

Controller Type	Data Element	2011	2012	2013	2014	2015	2016
High Bleed	Total Count	1,253	1,100	1,089	1,271	1,024	1,051
	CO_2 Emissions (mt)	116	118	116	117	64	97
	CO_2 EF (kg/controller/yr)	**92**	**107**	**106**	**92**	**63**	**92**
Intermittent Bleed	Total Count	1,391	1,539	1,601	2,045	2,098	2,288
	CO_2 Emissions (mt)	16	21	21	24	22	50
	CO_2 EF (kg/controller/yr)	**12**	**13**	**13**	**12**	**10**	**22**
Low Bleed	Total Count	250	319	366	319	320	289
	CO_2 Emissions (mt)	1.9	2.4	2.8	2.2	1.4	1.6
	CO_2 EF (kg/controller/yr)	**7.5**	**7.4**	**7.6**	**7.0**	**4.4**	**5.5**

3.3.2 Flares

The EPA developed GHGI flare CO_2 EFs for transmission stations and underground natural gas storage using subpart W data. As discussed in Section 1.3, the GHGI CO_2 emissions calculation methodology did not previously calculate CO_2 emissions from flares. Therefore, the EPA updated the methodology to calculate CO_2 emissions with new line items for transmission and storage flares.

The EPA divided the reported flare CO_2 and CH_4 emissions by the number of reported stations to calculate the EFs. Subpart W transmission station and underground natural gas storage flare data are presented in Table 24 and Table 25. The applicable activity data to calculate national emissions are the national number of stations, which are already calculated in the GHGI. The RY2015 EFs were applied for all prior years in the time series.

Note these flaring emissions estimates were developed from reported GHGRP data, wherein transmission compressor stations that service underground storage fields might be classified as transmission compression as the primary function. Therefore, a fraction of the transmission station flaring emissions may occur at stations that service storage facilities; such stations typically require flares, compared to a typical transmission compressor station used solely for mainline compression that does not require liquids separation, dehydration, and flaring.

Table 24. GHGRP Subpart W RY2015 Emissions and Activity Data and Calculated EFs for Transmission Station Flares

Year	Total # Stations	# Stations With Flares	# Flares	Total CO_2 Emissions (mt)	CO_2 EF (kg/station/yr)	Total CH_4 Emissions (mt)	CH_4 EF (kg/station/yr)
2015	524	18	30	23,833	45,483	93	177
2016	529	17	26	25,116	47,479	112	212

Table 25. GHGRP Subpart W RY2015 Emissions and Activity Data and Calculated EFs for Underground Natural Gas Storage Flares

Year	Total # Stations	# Stations With Flares	# Flares	Total CO_2 Emissions (mt)	CO_2 EF (kg/station/yr)	Total CH_4 Emissions (mt)	CH_4 EF (kg/station/yr)
2015	53	9	23	3,587	67,676	35	651
2016	53	9	21	2,343	44,214	30	572

3.4 Time Series Considerations

For the production segment sources discussed in Section 3.1, in general, the EPA applied the same methodology to calculate CO_2 over the time series as used for calculating CH_4 emissions over the time series.[18] For oil and condensate tanks, the EPA applies category-specific EFs for every year of the time series and for pneumatic controllers and pumps, category-specific EFs are applied for each year of the time series.

For associated gas venting and flaring, for CH_4, the EPA applied the subpart W 2015 EFs for years prior to 2015 and year-specific subpart W EFs were applied for 2015 and forward.

For the miscellaneous production flaring time series, the previous GHGI flare emission estimate (representing both production and processing), fluctuated based on activity data (EIA's estimated annual vented and flared volumes). Assessment of subpart W CO_2 data over the time series for this source indicates that miscellaneous production flaring emissions do not show a clear trend. See the Requests for Stakeholder Feedback section for more information. In the revised approach to use subpart W-based EFs (kg/mscf or kg/bbl), the EF was held constant for years prior to 2015 and flare emission estimates fluctuated with gas and liquids production data over the time series.

For certain processing sources discussed in Section 3.2, the EPA applied the same methodology to calculate CO_2 over the time series as used for calculating CH_4 emissions over the time series.[19] For plant grouped emission sources and blowdowns and venting, GRI/EPA 1996 EFs are used for 1990 through 1992; EFs calculated from subpart W are used for 2011 forward; and EFs for 1993 through 2010 are developed through linear interpolation.

[18] Additional details on current time series calculations for production segment sources are provided in the 2014 HF Completion and Workover memo, 2015 HF Completion and Workover memo, 2016 Production memo, and 2017 Production memo.

[19] Additional details on current time series calculations are provided in the 2017 Processing memo.

For CO_2 from AGR vents, the EPA adopted a similar methodology as the other processing sources (maintain the current GRI/EPA 1996 EFs for 1990 through 1992, apply the subpart W-based EFs for 2011 forward, and develop EFs for 1993 through 2010 using linear interpolation).

For transmission and storage flares, the EPA applied the 2015 subpart W-based EF (kg/station) for all prior years of the time series and year-specific EFs for 2015 and forward.

4. National Emissions Estimates

For sources with the largest contribution to CO_2 emissions (e.g., flaring sources), national CO_2 emissions for year 2015 using the subpart W-based approaches discussed in Section 3 (and implemented in the 2018 GHGI) are compared against the 2017 GHGI in Table 26 and Table 27.

Table 26. Natural Gas Systems Year 2015 National CO_2 Emissions (MMT) for 2018 GHGI Compared to 2017 GHGI

Industry Segment and Emission Source	2017 GHGI (Year 2015)	2018 GHGI (Year 2015)
Exploration	***NA***	***0.29***
HF Completions	0.07	0.28
Production	***17.6***	***3.40***
Miscellaneous Flaring	17.6[a]	1.41
Tanks	0.03	1.09
HF Workovers	0.03	0.08
Processing	***23.7***	***21.04***
AGR Vents	23.6	14.95
Plant Grouped Sources	0.1	6.08
Transmission & Storage	***0***	***0.15***
Transmission Flares	0	0.11
Underground Storage Flares	0	0.02
Distribution	***0***	***0.01***
Natural Gas Systems Total	**42.4**	**24.9**

NA (Not Applicable)

a. Also represents flaring from petroleum production and gas processing.

Table 27. Petroleum Systems Year 2015 National CO_2 Emissions (MMT) for 2018 GHGI Compared to 2017 GHGI

Industry Segment and Emission Source	2017 GHGI (Year 2015)	2018 GHGI (Year 2015)
Exploration	***NA***	***0.26***
Well Testing	NE	0.26
Production	***0.64***	***24.48***
Associated Gas	NE	12.23
Tanks	0.52	8.72
Miscellaneous Flaring	NE[a]	3.42
Transportation	***NE***	***NE***
Refining	***2.93***	***4.01***
Petroleum Systems Total	**3.57**	**28.75**

NA (Not Applicable)

NE (Not Estimated)

a. In the 2017 GHGI, emissions were generally included within the natural gas systems production flaring estimate.

The CO_2 revisions resulted in an overall shift of CO_2 emissions from Natural Gas systems to Petroleum systems. This is due to the availability of industry segment-specific and emission source-specific data in subpart W, whereas previous data sources were not as granular. The previous GHGI accounted for all onshore production and gas processing flaring emissions under a single line item in the production segment of natural gas systems. Using the revised approaches, flaring emissions are now specifically calculated for natural gas production, petroleum production, and gas processing (within the plant grouped emission sources). The shift in CO_2 emissions from Natural Gas systems to Petroleum systems is also due to the inclusion of associated gas flaring as a specific line item under Petroleum systems; this is the largest source of CO_2 emissions for the revisions.

5. October 2017 Requests for Stakeholder Feedback

The EPA initially sought feedback on the questions below in the version of this memo released in October 2017. The questions below were minimally altered to specifically cite the October 2017 memo. The EPA discusses feedback received, and further planned improvements to the GHGI methodology, in Chapter 3.8 of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016* (April 2018). The EPA continues to welcome additional stakeholder feedback on these questions for potential updates to future GHGIs.

General

1. EPA seeks stakeholder feedback on the general approach of using subpart W reported CO_2 emissions data to revise the current CO_2 emissions calculation methodology (described in Section 1) in the GHGI.

2. EPA seeks feedback on using consistent calculation methodologies for both CH_4 and CO_2, when GHGI relies on subpart W data. Are there sources where the CH_4 and CO_2 methodologies based on subpart W should differ?

Associated Gas Venting and Flaring (Section 3.1.1)

3. EPA seeks feedback on the methodology to calculate national emissions from associated gas venting and flaring. In particular, which methodology discussed in Section 3.1.1 of the October 2017 memo (national-level, or NEMS region-level) or other approach best reflects national-level emissions from associated gas venting and flaring by taking into account variability of this source?

4. What scale-up assumptions should EPA make regarding associated gas venting or flaring for regions that do not report any oil well data to GHGRP? Should EPA assume that these regions have no such activity, or should EPA assign surrogate EF and AF values (e.g., average from all other reported regions, or some other methodology)?

5. Should EPA consider an approach not presented in Section 3.1.1 of the October 2017 memo?
    a. For example, scaling subpart W-based estimates using production rather than oil well counts?
    b. For example, disaggregating to the AAPG basin-level?

GHGI Sources that Are Not Currently Estimated Using Subpart W data

6. In the October 2017 memo, Section 3.1.7 discusses considerations for developing EFs and associated activity data for miscellaneous production flaring that facilitate scaling reported subpart W data to a national level. The EPA has presented a preliminary approach that develops an EF in units of emissions per well. National active well counts would be paired with such EF to calculate emissions in the GHGI. The EPA seeks feedback on this approach, or suggestions of other approaches that would facilitate scaling to a national level and time series population.

7. For sources discussed in the October 2017 memo that do not currently estimate CH_4 emissions using subpart W, EPA is considering which year(s) of subpart W data to use in developing the CO_2 emissions methodologies. For miscellaneous production flaring, the EPA reviewed reported emissions and activity data for RY2011 - RY2014. However, wellhead counts for RY2011 - RY2014 are only reported by those facilities that calculated equipment leak emissions using Methodology 1, and as such, are not comprehensive. At the time of the 2016 Production memo, 83% of reporting facilities for RY2011, 85% of RY2012 reporting facilities, 93% of RY2013 facilities, and 98% of RY2014 reporting facilities reported wellhead counts under Methodology 1. In addition, facilities only reported total wellheads and did not report gas and oil wellhead counts separately for RY2011 - RY2014. The EPA calculated the CO_2 EFs under consideration using RY2015 only, because well counts from all reporting facilities are reported. However, the EPA requests feedback on whether it is appropriate to consider data from prior reporting years, which would have more uncertainty due to incomplete coverage, in order to show a trend over the time series. Table 28 provides the reported subpart W emissions and activity data for RY2011-RY2015.

Table 28. GHGRP Subpart W Emissions and Activity Data for Miscellaneous Production Flaring

Year	CO_2 Emissions (mt)	# Flares	# Wells (a)	CO_2 EF (kg/well)
2011	2,252,297	13,509	371,604	6,061
2012	3,616,326	16,356	398,137	9,083
2013	4,596,329	21,098	415,355	11,066
2014	4,841,116	22,155	502,391	9,636
2015	3,779,110	20,293	527,170	7,169

a. Total gas and oil wellheads. Wellhead counts for RY2011 through RY2014 are available from those onshore production facilities that calculated equipment leak emissions using Methodology 1.

For transmission and storage segment flares, the EPA relies on RY2015 data for the revisions under consideration, because all flaring emissions are reported under the flare stacks source. Whereas, for RY2011 - RY2014, flare emissions are reported under flare stacks and each individual emission source.

8. Section 3.4 in the October 2017 memo discusses time series considerations for transmission and storage flares. The EPA is considering applying a subpart W-based EF (kg/station) for all years of the time series. However, few transmission and storage stations reported flares for RY2015 (see Table 24 and Table 25). Therefore, EPA might alternatively assume that flares did not operate in 1990 (i.e., an EF of 0), apply the subpart W-based EF for 2011 forward, and apply linear interpolation from 1991 through 2010. The EPA seeks feedback on these approaches, or suggestions of other approaches to time series population.

Appendix A – Current (2017) GHGI CO_2 Emission Factors

All EFs are presented in the same units as the EFs under consideration for the 2018 GHGI; kg/[unit].

Emission Source	GHGI CO_2 EF	EF Units
Natural Gas & Petroleum Production		
Stripper Wells (for Associated Gas Venting)	2.47	kg/well
Condensate Tank Vents - Without Control Devices	0.18	kg/bbl
Condensate Tank Vents - With Control Devices	0.037	kg/bbl
Oil Tanks	0.18	kg/bbl
HF Gas Well Completions and Workovers	18,367[a]	kg/event
Pneumatic Controllers, all bleed types (Natural Gas)	144[a]	kg/controller
Low Bleed Pneumatic Controllers (Petroleum)	8.8	kg/controller
Intermittent Bleed Pneumatic Controllers (Petroleum)	83.9	kg/controller
High Bleed Pneumatic Controllers (Petroleum)	238.9	kg/controller
Pneumatic Pumps (Natural Gas)	168.4[a]	kg/pump
Pneumatic Pumps (Petroleum)	82.8	kg/pump
Liquids Unloading with Plunger Lifts	613[a]	kg/well
Liquids Unloading without Plunger Lifts	678[a]	kg/well
Onshore Production & Processing - Flaring Emissions	40,624	kg/well
Natural Gas Processing		
Reciprocating compressors - before CO2 removal	4,764	kg/compressor
Reciprocating compressors - after CO2 removal	1,058	kg/compressor
Centrifugal compressors with wet seals - before CO2 removal	21,859	kg/compressor
Centrifugal compressors with wet seals - after CO2 removal	4,854	kg/compressor
Centrifugal compressors with dry seals - before CO2 removal	10,719	kg/compressor
Centrifugal compressors with dry seals - after CO2 removal	2,380	kg/compressor
Plant fugitives - before CO2 removal	3,364	kg/plant
Plant fugitives - after CO2 removal	747	kg/plant
Kimray pumps	859	kg/plant
Dehydrator vents	5,291	kg/plant
Plant Grouped Sources	**95,303**	**kg/plant**
AGR vents	35,394,396	kg/plant
Blowdowns and venting	8,363	kg/plant
Transmission		
High Bleed Pneumatic Controllers	84.43	kg/controller
Intermittent Bleed Pneumatic Controllers	10.95	kg/controller
Low Bleed Pneumatic Controllers	6.22	kg/controller
Underground NG Storage		
High Bleed Pneumatic Controllers	82.21	kg/controller
Intermittent Bleed Pneumatic Controllers	10.74	kg/controller
Low Bleed Pneumatic Controllers	6.34	kg/controller

a. Average EF based on data from all NEMS regions.

Appendix B – GHGRP Subpart W Associated Gas Venting and Flaring Emissions, by basin, for RY2011-2016

Basin	2011		2012		2013		2014		2015		2016	
	Total CO_2 + CH_4 Emissions (mt CO_2e)	% of Total	Total CO_2 + CH_4 Emissions (mt CO_2e)	% of Total	Total CO_2 + CH_4 Emissions (mt CO_2e)	% of Total	Total CO_2 + CH_4 Emissions (mt CO_2e)	% of Total	Total CO_2 + CH_4 Emissions (mt CO_2e)	% of Total	Total CO_2 + CH_4 Emissions (mt CO_2e)	% of Total
160 - Appalachian Basin	256	0%	267	0%	272	0%	208	0%	183	0%	6,061	0%
160A - Appalachian Basin (Eastern Overthrust Area)	16,224	0%	23,477	0%	27,119	0%	15,055	0%	36,404	0%	18,016	0%
210 - Mid-Gulf Coast Basin	22,825	0%	14,535	0%	32,584	0%	68,569	1%	95,521	1%	103,081	1%
220 - Gulf Coast Basin (LA, TX)	773,401	10%	944,157	9%	1,411,635	12%	990,875	8%	688,957	6%	381,131	5%
230 - Arkla Basin	5,306	0%	3,354	0%	3,552	0%	3,551	0%	17,847	0%	12,171	0%
260 - East Texas Basin	2,434	0%	325,252	3%	48,131	0%	130	0%	1,134	0%	3,560	0%
305 - Michigan Basin	103,228	1%	159,425	2%	130,168	1%	124,802	1%	101,424	1%	73,317	1%
345 - Arkoma Basin	18,059	0%	18,152	0%	2,824	0%	6,220	0%	5,950	0%	3,614	0%
350 - South Oklahoma Folded Belt	0	0%	4,580	0%	17,422	0%	47,665	0%	38,627	0%	25,359	0%
355 - Chautauqua Platform	39,207	1%	23,253	0%	13,910	0%	9,559	0%	5,357	0%	2,692	0%
360 - Anadarko Basin	1,951,932	26%	1,079,360	10%	79,744	1%	194,986	2%	199,248	2%	8,674	0%
375 - Sedgwick Basin	0	0%	661,828	6%	0	0%	234	0%	3,033	0%	0	0%
385 - Central Kansas Uplift	71,586	1%	90,656	1%	101,570	1%	93,974	1%	28,525	0%	19,500	0%
395 - Williston Basin	3,316,405	45%	5,746,941	55%	7,863,150	67%	9,691,472	76%	8,528,583	68%	5,420,456	66%
415 - Strawn Basin	0	0%	0	0%	0	0%	6,291	0%	0	0%	0	0%
420 - Fort Worth Syncline	39,882	1%	50,428	0%	2,186	0%	4,907	0%	28	0%	25	0%
430 - Permian Basin	677,415	9%	779,460	8%	1,229,008	11%	1,051,295	8%	2,448,137	20%	1,967,988	24%
435 - Palo Duro Basin	19,829	0%	19,510	0%	3	0%	62	0%	1,866	0%	0	0%
515 - Powder River Basin	39,890	1%	77,435	1%	197,564	2%	106,907	1%	69,643	1%	41,490	1%
520 - Big Horn Basin	0	0%	0	0%	0	0%	1,088	0%	944	0%	0	0%
535 - Green River Basin	294	0%	3,626	0%	8,404	0%	3,191	0%	2	0%	0	0%
540 - Denver Basin	267,533	4%	313,901	3%	383,261	3%	228,937	2%	82,878	1%	24,899	0%
545 - North Park Basin	0	0%	0	0%	0	0%	0	0%	26,989	0%	40,151	0%
575 - Uinta Basin	22,251	0%	31,682	0%	115,014	1%	48,026	0%	34,872	0%	28,416	0%
580 - San Juan Basin	9,910	0%	10,470	0%	22,593	0%	8,536	0%	13,959	0%	13,795	0%
595 - Piceance Basin	0	0%	0	0%	0	0%	0	0%	124	0%	451	0%
745 - San Joaquin Basin	10,487	0%	3,248	0%	9,836	0%	2,557	0%	34,723	0%	7,499	0%
820 - AK Cook Inlet Basin	0	0%	0	0%	0	0%	0	0%	83	0%	1	0%
TOTAL	**7,408,353**	**100%**	**10,384,996**	**100%**	**11,699,948**	**100%**	**12,709,097**	**100%**	**12,465,041**	**100%**	**8,202,349**	**100%**

Appendix C – GHGRP Subpart W Miscellaneous Production Flaring Emissions, by basin, for RY2011-2016

Basin	2011		2012		2013		2014		2015		2016	
	Total CO2 + CH4 Emissions (mt CO2e)	% of Total	Total CO2 + CH4 Emissions (mt CO2e)	% of Total	Total CO2 + CH4 Emissions (mt CO2e)	% of Total	Total CO2 + CH4 Emissions (mt CO2e)	% of Total	Total CO2 + CH4 Emissions (mt CO2e)	% of Total	Total CO2 + CH4 Emissions (mt CO2e)	% of Total
140 - Florida Platform	0	0%	31	0%	0	0%	316	0%	95	0%	2,905	0%
160 - Appalachian Basin	0	0%	9,474	0%	156,596	3%	1,508	0%	439	0%	3,091	0%
160A - Appalachian Basin (Eastern Overthrust Area)	10,059	0%	21,295	1%	68,263	1%	44,956	1%	51,167	1%	66,029	2%
200 - Black Warrior Basin	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
210 - Mid-Gulf Coast Basin	58,779	2%	70,807	2%	129,025	2%	150,254	3%	142,160	3%	107,848	4%
220 - Gulf Coast Basin (LA TX)	347,141	14%	625,252	16%	1,313,767	25%	1,311,265	25%	1,301,568	30%	658,331	23%
230 - Arkla Basin	2,447	0%	1,204	0%	79,635	2%	19,459	0%	24,286	1%	2,035	0%
260 - East Texas Basin	43,960	2%	25,802	1%	26,203	1%	15,192	0%	17,847	0%	12,968	0%
305 - Michigan Basin	4,949	0%	14,923	0%	4,402	0%	3,210	0%	3,230	0%	5,215	0%
345 - Arkoma Basin	13	0%	12	0%	12	0%	0	0%	24	0%	9	0%
350 - South Oklahoma Folded Belt	1,075	0%	1,552	0%	1,324	0%	2,418	0%	5,856	0%	7,982	0%
355 - Chautauqua Platform	424	0%	30,371	1%	15,108	0%	29,880	1%	3,408	0%	584	0%
360 - Anadarko Basin	142,911	6%	70,685	2%	145,823	3%	85,971	2%	232,793	5%	143,872	5%
375 - Sedgwick Basin	51	0%	0	0%	0	0%	1,394	0%	0	0%	254	0%
385 - Central Kansas Uplift	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
395 - Williston Basin	913,695	38%	488,554	12%	708,243	14%	1,473,619	28%	910,642	21%	293,829	10%
400 - Ouachita Folded Belt	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
415 - Strawn Basin	5,967	0%	5,587	0%	2,269	0%	7,491	0%	2,365	0%	0	0%
420 - Fort Worth Syncline	6,326	0%	8,690	0%	23,043	0%	35,343	1%	38,969	1%	568	0%
425 - Bend Arch	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
430 - Permian Basin	374,182	16%	2,108,306	54%	1,962,876	38%	1,508,848	29%	1,213,197	28%	1,100,472	38%
435 - Palo Duro Basin	0	0%	0	0%	0	0%	354	0%	390	0%	71	0%
450 - Las Animas Arch	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
455 - Las Vegas-Raton Basin	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
507 - Central Western Overthrust	625	0%	925	0%	701	0%	111	0%	112	0%	120	0%
515 - Powder River Basin	28,534	1%	52,245	1%	105,528	2%	125,437	2%	102,594	2%	34,839	1%
520 - Big Horn Basin	4,122	0%	2,494	0%	177	0%	1,954	0%	1,165	0%	0	0%
530 - Wind River Basin	0	0%	373	0%	528	0%	621	0%	129	0%	28	0%
535 - Green River Basin	84,576	4%	158,743	4%	255,830	5%	59,517	1%	55,234	1%	54,918	2%
540 - Denver Basin	61,760	3%	13,454	0%	10,950	0%	89,192	2%	118,692	3%	153,414	5%
545 - North Park Basin	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
575 - Uinta Basin	4,588	0%	16,025	0%	2,702	0%	12,325	0%	8,066	0%	14,383	1%
580 - San Juan Basin	394	0%	71	0%	39,238	1%	70,284	1%	28,342	1%	187	0%
585 - Paradox Basin	236,981	10%	146,578	4%	113,924	2%	161,528	3%	61,032	1%	55,460	2%
595 - Piceance Basin	14,247	1%	5,043	0%	5,828	0%	4,507	0%	3,257	0%	4,828	0%
730 - Sacramento Basin	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%

Basin	2011		2012		2013		2014		2015		2016	
	Total CO2 + CH4 Emissions (mt CO2e)	% of Total	Total CO2 + CH4 Emissions (mt CO2e)	% of Total	Total CO2 + CH4 Emissions (mt CO2e)	% of Total	Total CO2 + CH4 Emissions (mt CO2e)	% of Total	Total CO2 + CH4 Emissions (mt CO2e)	% of Total	Total CO2 + CH4 Emissions (mt CO2e)	% of Total
740 - Coastal Basins	0	0%	0	0%	0	0%	136	0%	136	0%	0	0%
745 - San Joaquin Basin	16,360	1%	13,884	0%	15,494	0%	8,547	0%	16,082	0%	26,941	1%
750 - Santa Maria Basin	0	0%	0	0%	2,204	0%	864	0%	232	0%	277	0%
760 - Los Angeles Basin	933	0%	2,486	0%	2,191	0%	1,591	0%	1,548	0%	0	0%
820 - AK Cook Inlet Basin	1,716	0%	2,118	0%	3,263	0%	2,151	0%	514	0%	490	0%
890 - Arctic Coastal Plains Province	35,172	1%	25,434	1%	26,837	1%	11,040	0%	11,188	0%	119,898	4%
TOTAL	**2,401,985**	**100%**	**3,922,418**	**100%**	**5,221,983**	**100%**	**5,241,284**	**100%**	**4,356,758**	**100%**	**2,871,844**	**100%**