Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2016: Updates Under Consideration for CO_2 Emissions

This memo discusses CO_2 emission calculation revisions being considered for multiple segments of natural gas and petroleum systems in the 2018 Inventory of U.S. Greenhouse Gas Emissions and Sinks (GHGI). The EPA is considering 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 are documented in the following memos: the 2014 HF Completion and Workover memo,[1] 2015 HF Completion and Workover memo,[2] 2016 Transmission memo,[3] 2016 Production memo,[4] 2017 Production memo,[5] and 2017 Processing memo.[6] These revisions will create consistency between CH_4 and CO_2 calculation methodologies. In addition, the EPA is considering updating 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, LNG storage flares, LNG import flares, and transmission and storage pneumatic controllers. The EPA is not considering revisions to the distribution segment CO_2 emissions calculation methodology, as discussed in Section 1.2.

1. Background and Current GHGI Methodology for CO_2 Emissions

This section discusses the current 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. Section 1.2 describes the current GHGI methodology to calculate CO_2 emissions for certain

[1] "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.

[2] "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.

[3] "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.

[4] "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.

[5] "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.

[6] "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.

sources that rely on emission source-specific methods. The current GHGI CO_2 EFs are documented in Appendix A.

1.1 CO_2-to-CH_4 Gas Content Ratio Methodology

The current GHGI methodology to calculate CO_2 emission factors (EFs) for the majority of emission sources 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:

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

The default CH_4 and CO_2 content values for sources in natural gas systems are from the 1996 GRI/EPA study,[7] EIA,[8] and GTI's Gas Resource Database[9] 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 is 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).

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

1.2 Emission Source-Specific CO_2 Calculation Methodologies

The current GHGI uses 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.

Oil and Condensate Tanks at Production Sites

The current GHGI methodology to calculate CO_2 emissions for oil and condensate tanks uses CO_2 specific EFs. The EFs were developed using API TankCalc software with varying API gravities. The oil tank EF is the average from 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 current GHGI calculates 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 current GHGI methodology estimates tank emissions by applying the condensate tank EF to condensate production in each NEMS region.

AGR Units at Natural Gas Processing Plants

The current GHGI CO_2 EF for AGR units at natural gas processing plants relies 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.

Flaring

Flaring emissions from the production and processing segments are currently calculated under a single line item in the production segment of natural gas systems. Therefore, flaring emissions are not specifically attributed to the processing segment of natural gas systems or the production segment of petroleum systems. The EF is 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 are annual EIA "Vented and Flared" gas volumes (MMcf), which are reported under Natural Gas Gross Withdrawals and Production,[10] combined with the estimated national average gas heating value (averaging approximately 1,100 BTU/cf over the time series[11]). 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 current GHGI assumes it is 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 current GHGI assigns 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 and 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. EPA is not considering revisions to the distribution segment CO_2 emissions calculation methodology for the 2018 GHGI.

[10] 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

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

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 and natural gas processing facilities 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; currently, five years of subpart W reporting data are publicly available, covering reporting year (RY) 2011 through RY2015.[12]

Subpart W activity and emissions data are used in the current GHGI to calculate CH_4 emissions for several production, processing, and transmission and storage sources. CO_2 emissions data from subpart W have not yet been incorporated into the 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 an identical 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 is also considering GHGI revisions to use subpart W data 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 are not currently 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 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, underground natural gas storage, LNG storage, and LNG import stations report emissions from all flaring under the "flare stacks" emission source as of RY2015. Prior to that, flare emissions

[12] The GHGRP subpart W data used in the analyses discussed in this memo are those reported to the EPA as of August 13, 2016.

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. Revisions Under Consideration

The EPA is considering revising CO_2 EFs for certain production, natural gas processing, and transmission and storage segment sources to use subpart W data in the exact same manner as CH_4 EFs are currently calculated in the GHGI. For purposes of this memo, EPA calculated preliminary CO_2 EFs using data from the same subpart W reporting years (RY) as were used when developing CH_4 EFs for the 2017 GHGI. For the 2018 GHGI, EPA will separately seek stakeholder feedback on potentially using data from other subpart W years to recalculate both CH_4 and CO_2 EFs.

In addition, EPA is considering updating 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.

3.1 Production CO_2 Emission Factors

The EPA developed preliminary CO_2 EFs for associated gas venting and flaring, oil and condensate tanks, gas well hydraulically fractured completions and workovers, pneumatic controllers, pneumatic pumps, and liquids unloading in the natural gas and petroleum production segments. The CH_4 EFs for these sources were recently revised using subpart W data, and EPA applied the same methodology to calculate CO_2 EFs. A brief summary of the existing methodology and the resulting CO_2 EFs are provided below for each source.

The EPA is also considering a CO_2 emissions calculation methodology for miscellaneous production flaring, which is described below.

Associated Gas Venting and Flaring

Based on the CH_4 EF methodology documented in the 2017 Production memo, the EPA calculated oil well associated gas venting and flaring CO_2 EFs using subpart W data for RY2011 through RY2015. EPA divided the reported associated gas or venting emissions by the number of reported wells with associated gas venting or flaring for each year to calculate EFs. Subpart W CO_2 data are presented in Table 2, and the calculated CO_2 EFs are presented in Table 3.

Table 2. GHGRP Subpart W CO_2 Data for Associated Gas Venting and Flaring

Year	Associated Gas Venting		Associated Gas Flaring	
	#Venting Wells	Venting CO_2 Emissions (MMT)	#Flaring Wells	Flaring CO_2 Emissions (MMT)
2011	8,863	0.012	5,628	3.72
2012	8,554	0.016	7,259	6.88
2013	6,980	0.005	8,880	9.61
2014	7,264	0.013	12,189	11.05
2015	4,286	0.011	21,606	10.31

Table 3. GHGRP Subpart W-based Associated Gas Venting and Flaring CO_2 EFs (kg/well/yr)

Year	Venting EF	Flaring EF
2011	1,336	661,723
2012	1,902	948,057
2013	773	1,081,842
2014	1,754	906,608
2015	2,675	477,254

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 RY2015 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 4 presents the resulting CO_2 EFs.

Table 4. GHGRP Subpart W-based Oil and Condensate Tank CO_2 EFs (kg/bbl/yr)

Tank Category	Oil Tanks EF	Condensate Tanks EF
Large Tanks with Flaring	7.16	8.44
Large Tanks with VRU	0.040	0.12
Large Tanks without Controls	0.016	0.020
Small Tanks with Flaring	0.26	1.95
Small Tanks without Flares	0.078	0.28
Malfunctioning Dump Valves	0.013	8.28E-05

HF Gas Well Completions and Workovers

Based on the CH_4 EF methodology documented in the 2014 HF Completion and Workover memo and 2015 HF Completion and Workover memo, the EPA calculated CO_2 EFs for four categories of HF gas well completions and workovers, using RY2011-RY2013 subpart W data: HF gas well completions and workovers that vent; flared HF gas well completions and workovers; HF gas well completions and workovers with reduced emissions completions (RECs); and HF gas well completions and workovers with RECs that flare. Average emissions per completion and workover were calculated for each category by summing the emissions in each category and dividing by the number of completions and workovers in each category using facility-level records that could be assigned to a single unambiguous category. Table 5 presents the subpart W activity and emissions data for those HF gas well completions and workovers that could be assigned to a specific category, along with the calculated CO_2 EFs.

Table 5. GHGRP Subpart W Activity and Emissions Data and Calculated EFs for HF Gas Well Completions and Workovers

Category	# of Events			CO_2 Emissions (mt)			CO_2 EF (kg/event)
	2011	2012	2013	2011	2012	2013	
HF Completions and Workovers that Vent	3,901	2,370	1,308	11,700	2,681	7,214	**2,849**
Flared HF Completions and Workovers	1,171	538	422	1,203,235	363,631	192,235	**825,481**
HF Completions and Workovers with RECs	2,224	1,283	1,566	3,745	151	995	**964**
HF Completions and Workovers with RECs that flare	818	968	1,129	485,313	387,280	460,691	**457,387**

Pneumatic Controllers

Based on the CH_4 EF methodology documented in the 2016 Production memo, the EPA calculated pneumatic controller 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 6 presents the subpart W activity and emissions data, along with the calculated CO_2 EFs.

Table 6. 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	200,337	2,391	**12**
Intermittent Bleed	572,407	98,393	**172**
High Bleed	29,567	10,013	**339**

Pneumatic Pumps

Based on the CH_4 EF methodology documented in the 2016 Production memo, the EPA calculated a pneumatic pump 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 7 presents the subpart W activity and emissions data, along with the calculated CO_2 EF.

Table 7. 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)
79,885	11,650	**146**

Liquids Unloading

Based on the CH_4 EF methodology documented in the 2017 Production memo, the EPA calculated liquids unloading EFs using Subpart W RY2011-RY2015 data. Separate EFs were calculated for liquids unloading activities that vent with and without plunger lifts. The EPA calculated an average EF by summing the emissions reported in each category for RY2011-RY2015 and dividing by the total number of wells in each category over those years. Table 8 presents the subpart W activity and emissions data, along with the calculated CO_2 EFs.

Table 8. GHGRP Subpart W RY2011-RY2015 Activity and Emissions Data and Calculated EFs for Liquids Unloading

Year	With Plunger Lifts		Without Plunger Lifts	
	CO_2 Emissions (mt)	# Wells Vented	CO_2 Emissions (mt)	# Wells Vented
2011	17,671	42,826	20,294	26,679
2012	18,869	34,136	26,300	25,262
2013	4,233	30,922	5,617	27,723
2014	2,430	26,859	5,113	23,068
2015	1,782	30,757	3,348	20,886
Total	**44,985**	**165,500**	**60,673**	**123,618**
EF (kg CO_2/well/yr)	***272***		***491***	

Miscellaneous Production Flaring

The EPA is considering the use of subpart W RY 2015 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 the following approach.

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 for RY2015.[13] The EPA then apportioned each facility's reported miscellaneous flaring CO_2 and CH_4 emissions by production type. The EPA summed the facility-level CO_2 and CH_4 emissions for each production type to estimate total reported miscellaneous flaring CO_2 and CH_4 emissions from natural gas and oil production. The EPA then divided the reported CO_2 and CH_4 emissions for natural gas and oil production by total reported gas wells and oil wells, respectively. These emissions data, well counts, and calculated EFs are provided in Table 9 and Table 10 below. To calculate national emissions, the EFs would be multiplied by the national gas and oil well counts already estimated in the GHGI.

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

Total CO_2 Emissions (mt)	Natural Gas Production			Oil Production		
	CO_2 Emissions (mt)	Total Gas Wells	CO_2 EF (kg/well/yr)	CO_2 Emissions (mt)	Total Oil Wells	CO_2 EF (kg/well/yr)
3,779,110	1,299,672	307,737	**4,223**	2,479,438	219,433	**11,299**

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

Total CH_4 Emissions (mt)	Natural Gas Production			Oil Production		
	CH_4 Emissions (mt)	Total Gas Wells	CH_4 EF (kg/well/yr)	CH_4 Emissions (mt)	Total Oil Wells	CH_4 EF (kg/well/yr)
14,058	5,443	307,737	**17.7**	8,614	219,433	**39.3**

3.2 Processing CO_2 Emission Factors

The EPA developed preliminary 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. While AGR vent emissions are not currently calculated from subpart W data (as CH_4 emissions are not reported for this source), the EPA has calculated a subpart W-based EF and determined the corresponding activity data for this source.

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 RY2015 data (the purpose of the plant grouped EF is

[13] RY2015 is the first year in which total oil and gas well counts are reported. However, six facilities did not report these data. Therefore, for these six 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).

discussed in Section 3.4). Subpart W data and calculated CO_2 EFs for the plant grouped sources are presented in Table 11.

Table 11. 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	7,818	2,662	compressors	2,937
Centrifugal compressors with wet seals	1,259	264	compressors	4,768
Centrifugal compressors with dry seals	20	214	compressors	400
Dehydrators	7,433	467	plants	15,916
Flares	4,503,224	467	plants	9,642,878
Plant fugitives	2,291	467	plants	4,906
Plant Grouped Sources	**4,522,046**	**467**	**plants**	**9,683,181**

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 RY2015 data. Subpart W data and the calculated CO_2 EF for blowdowns and venting are presented in Table 12.

Table 12. GHGRP Subpart W RY2015 Emissions and Activity Data and Calculated EF for Gas Processing Blowdown and Venting

CO2 Emissions (mt)	Activity Count (plants)	CO_2 EF (kg/plant/yr)
11,084	467	**23,733**

For AGR vent emissions, the existing CH_4 EF methodology does not rely on subpart W, but the EPA is considering applying 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 emissions for gas processing plants and divided by the total reported count of plants for each RY from 2011 to 2015 to calculate CO_2 EFs. Note, the current GHGI methodologies for gas processing segment sources that use subpart W-based CH_4 EFs rely on RY2015 only. To calculate national CO_2 emissions, the CO_2 EF would be multiplied by the number of gas plants each year. Subpart W data and the calculated CO_2 EFs for AGR vents are presented in Table 13.

Table 13. GHGRP Subpart W RY2015 Emissions and Activity Data and Calculated EF for Gas Processing AGR Vents

Year	CO_2 Emissions (mt)	Activity Count (plants)	CO_2 EF (kg/plant/yr)
2011	16,093,040	374	**43,029,519**
2012	15,692,240	403	**38,938,561**
2013	13,201,139	438	**30,139,587**
2014	12,559,555	479	**26,220,366**
2015	10,048,285	467	**21,516,669**

3.3 Transmission and Storage CO_2 Emission Factors

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 - RY2015 data. The EPA divided the reported emissions by the number of reported controllers for each controller type to calculate EFs. Table 14 and Table 15 present the subpart W activity and emissions data, along with the calculated CO_2 EFs.

Table 14. GHGRP Subpart W Activity and Emissions Data and Calculated EFs for Transmission Station Pneumatic Controllers

Controller Type	Data Element	2011	2012	2013	2014	2015
High Bleed	Total Count	2,203	1,114	1,158	1,173	1,483
	CO_2 Emissions (mt)	203	106	106	107	120
	CO_2 EF (kg/controller/yr)	**92**	**95**	**91**	**91**	**81**
Intermittent Bleed	Total Count	8,343	9,114	9,903	11,141	10,857
	CO_2 Emissions (mt)	673	736	747	134	103
	CO_2 EF (kg/controller/yr)	**81**	**81**	**75**	**12**	**10**
Low Bleed	Total Count	644	880	857	1,078	1,032
	CO_2 Emissions (mt)	4.6	6.2	6.2	6.7	4.3
	CO_2 EF (kg/controller/yr)	**7.1**	**7.0**	**7.3**	**6.2**	**4.2**

Table 15. 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
High Bleed	Total Count	1,253	1,100	1,089	1,271	1,024
	CO_2 Emissions (mt)	116	118	116	117	64
	CO_2 EF (kg/controller/yr)	**92**	**107**	**106**	**92**	**63**
Intermittent Bleed	Total Count	1,391	1,539	1,601	2,045	2,098
	CO_2 Emissions (mt)	16	21	21	24	22
	CO_2 EF (kg/controller/yr)	**12**	**13**	**13**	**12**	**10**
Low Bleed	Total Count	250	319	366	319	320
	CO_2 Emissions (mt)	1.9	2.4	2.8	2.2	1.4
	CO_2 EF (kg/controller/yr)	**7.5**	**7.4**	**7.6**	**7.0**	**4.4**

Flares

The EPA is considering developing updated GHGI flare CO_2 EFs for transmission station, underground natural gas storage, LNG storage, and LNG import stations using subpart W data. As discussed in Section 1.3, the GHGI CO_2 emissions calculation methodology does not calculate CO_2 emissions from flares. Therefore, the EPA is considering supplementing the current methodology to calculate CO_2 emissions with new line items for station flares.

The EPA divided the reported flare CO_2 and CH_4 emissions by the number of reported stations for RY2015 to calculate the EFs. Subpart W transmission station, underground natural gas storage, LNG storage, and LNG import station flare data are presented in Table 16 through Table 19. The applicable activity data to calculate national emissions are the national number of stations, which are already calculated in the GHGI.

Table 16. GHGRP Subpart W RY2015 Emissions and Activity Data and Calculated EFs for Transmission Station Flares

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)
521	16	24	28,511	54,723	124	238

Table 17. GHGRP Subpart W RY2015 Emissions and Activity Data and Calculated EFs for Underground Natural Gas Storage Flares

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)
53	8	21	3,576	67,479	34	650

Table 18. GHGRP Subpart W RY2015 Emissions and Activity Data and Calculated EFs for LNG Storage Flares

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)
7	2	2	259	37,042	1.9	266

Table 19. GHGRP Subpart W RY2015 Emissions and Activity Data and Calculated EFs for LNG Import Flares

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)
7	2	3	77,420	11,059,970	268	38,238

3.4 Time Series Considerations

For the production segment sources discussed in Section 3.1, the EPA would apply the same methodology to calculate CO_2 over the time series as used for calculating CH_4 emissions over the time series.[14] For oil and condensate tanks, the EPA applies category-specific EFs for every year of the time series; for associated gas venting and flaring, the EPA applies the subpart W 2011 EFs for years prior to 2011 and year-specific subpart W EFs are applied for 2011 and forward; for liquids unloading, the average 2011-2015 EFs developed from subpart W data are applied to each year of the time series; for pneumatic controllers and pumps, category-specific EFs are applied for each year of the time series; and for HF gas well completions and workovers, category-specific EFs are applied for each year of the time series. EPA will separately seek stakeholder feedback on considerations for time series calculations for both CH_4 and CO_2 emissions in the 2018 GHGI.

For the production miscellaneous flaring time series, the current GHGI flare emission estimate (representing both production and processing), fluctuates 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 flaring emissions per well do not show a clear trend. See Requests for Stakeholder Feedback section for more information. In a revised approach to use subpart W-based CO_2 EFs (kg/well), the EF could be held constant for each year and flare emission estimates would fluctuate with active gas or oil well count over the time series.

[14] 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.

For certain processing sources discussed in Section 3.1, the EPA would apply the same methodology to calculate CO_2 over the time series as used for calculating CH_4 emissions over the time series.[15] 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. For AGR vents, the EPA is considering adopting 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 is evaluating the prevalence of flares over the 1990–2016 time series. 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 16 through Table 19). Therefore, the 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.

4. National Emissions Estimates

The EPA calculated national CO_2 emissions using each of the subpart W-based approaches discussed in Section 3 in conjunction with activity data for year 2015 from the 2017 GHGI. These emissions are compared against 2015 emissions from the 2017 GHGI in Table 20 and Table 21.

Table 20. Natural Gas Systems Estimated Year 2015 National CO_2 Emissions (mt) Using Subpart W-based EFs Compared to 2017 GHGI

Industry Segment and Emission Source	2017 GHGI	Scaled Up Subpart W (Draft Update)
Production	***18,585,048***	***4,855,904***
Tanks	**30,426**	**1,108,346**
Large Tanks w/Flares		1,059,701
Large Tanks w/VRU		2,840
Large Tanks w/o Control		632
Small Tanks w/Flares		35,173
Small Tanks w/o Flares		9,984
Malfunctioning Separator Dump Valves		15
Miscellaneous Flaring (a)	**17,628,522**	**1,860,355**
Gas HF Completions/Workovers	**91,965**	**1,129,883**
Non-REC with Venting		397
Non-REC with Flaring		281,489
REC with Venting		3,203
REC with Flaring		844,794
Liquids Unloading	**39,485**	**9,282**
w/Plunger Lifts	13,780	4,169
w/o Plunger Lifts	25,705	5,112
Pneumatic Controllers	**119,970**	**79,608**
Low-Bleed		1,842
Intermittent Bleed		71,177

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

Industry Segment and Emission Source	2017 GHGI	Scaled Up Subpart W (Draft Update)
High-Bleed		6,589
Pneumatic Pumps	**14,021**	**7,770**
Other Production Sources (b)	**660,659**	**660,659**
Processing	***23,712,956***	***20,826,478***
AGR Vents	23,643,456	14,351,618
Plant Grouped Sources	63,662	6,458,775
Blowdowns/Venting	5,586	15,830
Pneumatics	250	255
Transmission & Storage	***38,694***	***250,095***
Transmission Flares	0	100,357
Underground Storage Flares	0	23,542
LNG Storage Flares	0	2,603
LNG Import Flares	0	85,162
Pneumatic Controllers	1,649	1,386
Other Transmission & Storage Sources (b)	37,045	37,045
Distribution (b)	***13,988***	***13,988***
Natural Gas Systems Total	**42,350,685**	**25,946,465**

a. Also represents flaring from petroleum production and gas processing.
b. Set 2018 GHGI value equal to 2017 GHGI value.

Table 21. Petroleum Systems Estimated Year 2015 National CO_2 Emissions (mt) Using Subpart W-based EFs Compared to Current GHGI

Industry Segment and Emission Source	2017 GHGI	Scaled Up Subpart W (Draft Update)
Production	***640,443***	***44,233,703***
Tanks	**519,934**	**8,643,876**
Large Tanks w/Flares		8,576,672
Large Tanks w/VRU		17,229
Large Tanks w/o Control		5,928
Small Tanks w/Flares		10,581
Small Tanks w/o Flares		8,271
Malfunctioning Separator Dump Valves		25,194
Miscellaneous Flaring	**incl. w/NG**	**6,864,989**
Associated Gas (a)	**826**	**28,582,015**
Flaring		28,550,273
Venting		31,742
Pneumatic Controllers	**87,576**	**109,857**
Low-Bleed	2,697	2,252
Intermittent Bleed	74,341	100,265
High-Bleed	10,538	7,339
Pneumatic Pumps	**10,779**	**11,639**
Other Production Sources (b)	**21,327**	**21,327**
Refining (b)	***2,926,666***	***2,926,666***
Petroleum Systems Total	**3,567,110**	**47,160,369**

a. 2017 GHGI is estimate for stripper well venting.
b. Set 2018 GHGI value equal to 2017 GHGI value.

The CO_2 revisions under consideration will result 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 current

GHGI accounts 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 approach, these flaring emissions would be 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 under consideration.

5. Requests for Stakeholder Feedback

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?

3. Section 3.1 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.

4. For sources discussed in this 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 have more uncertainty due to incomplete coverage, in order to show a trend over the time series. Table 22 provides the reported subpart W emissions and activity data for RY2011-RY2015.

Table 22. 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.

5. Section 3.4 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 16 through Table 19). 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 GHGI CO_2 Emission Factors

All EFs are presented in the same units as the EFs under consideration; 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.