April 2016

Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2014: Revisions to Natural Gas and Petroleum Production Emissions

Substantial new data are available on natural gas and petroleum systems from subpart W of the EPA's greenhouse gas reporting program (GHGRP). The data reported to subpart W include activity data (e.g., frequency of certain activities, equipment counts) and emissions. Emissions are estimated using differing methodologies depending on the emission source, including the use of emission factors (EFs) or emissions measurements. The emission sources included in subpart W are similar to those in the GHGI, but there are differences in coverage and emission estimation methods. The EPA evaluated approaches for incorporating this new data into its emission estimates for the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (GHGI). This memorandum discusses incorporation of GHGRP subpart W data for pneumatic controllers and major equipment (equipment leaks sources) in the onshore production segment into the 2016 GHGI. For purposes of simplicity in this memorandum, chemical injection pumps (CIPs) are included under the major equipment category.

Not all onshore production activity nationwide is reported to subpart W—only facilities (defined as unique combination of operator and AAPG basin of operation) that meet the reporting threshold of 25,000 metric tons of CO_2 equivalent (MT CO_2e) report data under the GHGRP subpart W. Facilities that meet this threshold have been reporting under subpart W since 2011; currently, four years of subpart W reporting data are publically available, covering reporting year (RY) 2011 through RY2014.

This memo describes on the 2016 GHGI revisions to activity data in the production segments for natural gas and petroleum systems, specifically to pneumatic controllers and equipment leaks, updates to emission factors for pneumatic controllers and CIPs, and updates to hydraulically fractured oil well completions.

In this memo, "2015 GHGI" refers to the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013*, published April 15, 2015, and "2016 GHGI" refers to the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014*, published April 15, 2016.

Background on Current GHGI Methodology and Available Data

For many sources in the GHGI, direct activity data are not available for every year of the time series. For these sources, generally, activity data drivers are used along with activity data ratios developed for the year with available data (commonly, 1992) to update activity data for each year in the GHGI. Activity data drivers currently used in the GHGI include statistics on gas production, number of wells, system throughput, miles of various types of pipeline, and other statistics that characterize the changes in the U.S. natural gas system infrastructure and operations.

For example, recent data on various types of production field equipment (e.g., heaters, separators, and dehydrators) are not available. The EPA determined that each of these types of field separation equipment relate to the number of non-associated gas wells. Using the number of each type of field separation equipment estimated by GRI/EPA in 1992, and the number of non-associated gas wells in 1992, the EPA developed a factor that is used to estimate the number of each type of field separation equipment throughout the time series based on the count of non-associated gas wells obtained for a

given year. Further information on current activity data methodology is provided in Annex 3 of the 2015 GHGI report.[1]

GHGRP Subpart W

Onshore natural gas and petroleum production facilities that are required to submit annual reports under subpart W of the GHGRP calculate methane (CH_4) and carbon dioxide (CO_2) emissions from *natural gas pneumatic device venting* (using the calculation methodology required by 40 CFR 98.233(a)), CIPs (using the calculation methodology required by 40 CFR 98.233(c)), and *equipment leaks using population counts* (using the calculation methodology required by 40 CFR 98.233(r)). Data for those two types of emission sources are reported at the facility level (i.e., unique combination of operator and AAPG basin). Data reported do not include information on production type (gas or oil).

When subpart W was originally promulgated in November 2010, the EPA deferred the reporting deadline for certain subpart W equation inputs until March 31, 2015. In October 2014, the EPA finalized the approach to collecting these deferred inputs. Subpart W reporters were required to submit both an expanded set of data elements for RY2014 and the deferred data elements for RYs 2011, 2012, and 2013 by March 31, 2015. The GHGRP subpart W data used in the analyses discussed in this memorandum are those reported to the EPA as of August 16, 2015.

There are important considerations for the incorporation of subpart W data into the GHGI. Due to the GHGRP reporting threshold, the subpart W data set is not a national total, and therefore coverage and representativeness must be taken into consideration when using the data to develop national activity or emissions estimates.

(1) Subpart W activity data need to be scaled up to national activity. Subpart W activity data could be normalized to a scalable basis. For example, subpart W equipment counts per well could be developed from the reported data, and then these counts per well could be multiplied by national well counts obtained from DrillingInfo data in each given year to obtain a national estimate of equipment counts in that year.
(2) Subpart W reports reflect activities at facilities exceeding the emission threshold. While EPA estimates that subpart W reporting covers the majority of national oil and gas production, the reporting facilities represent approximately 30% of producing wells in the U.S., located within large facilities that exceed the emissions threshold for reporting. The degree to which production segment activity data at reporting facilities is representative of all facilities (including small facilities) nationwide should be considered.
(3) Subpart W onshore production segment reports reflect activities and equipment on or associated with a single well pad. The GHGI production segment estimates have historically included emissions from centralized production (e.g., tank batteries) and gathering and boosting activities. To avoid omissions or double counting, updates to GHGI production segment data must be considered in conjunction with updates to gathering and boosting methods and data.[2]

<u>Subpart W Data for Natural Gas-driven Pneumatic Controllers</u>

[1] http://www3.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-GHGI-2015-Annex-3-Additional-Source-or-Sink-Categories.pdf

[2] A companion memo titled "GHGI of U.S. Greenhouse Gas Emissions and Sinks 1990-2014: Revisions to Natural Gas Gathering and Boosting Emissions" (April 2016) discusses revisions including updating some of the production emission calculation methodologies based on Marchese et al. (2015) measurement data for centralized production and gathering-only facilities.

For onshore production, the calculation of emissions from natural gas-driven pneumatic controller venting is based on counts (which may be estimated based on best available data for the first two RYs) of low-bleed, high-bleed, and intermittent-bleed pneumatic controllers. Counts of each type of pneumatic controller are now available for RY2011 through RY2014. These values are shown in Table 1 below. 75% of reporting onshore production facilities for RY2011, 76% for RY2012, and 81% for RY2013 reported pneumatic controller counts.

Table 1. Reported Natural Gas Pneumatic Controller Counts for RY2011-2014

Number of Reporting Facilities	RY2011	RY2012	RY2013	RY2014
Number of Onshore Production Facilities Reporting Under Subpart W	458	504	507	564
Reported Actual and Estimated Pneumatic Controller Counts, by Bleed Type:				
Low-Bleed Pneumatic Controllers	214,211	218,570	159,586	204,246
High-Bleed Pneumatic Controllers	55,846	49,707	32,939	27,615
Intermittent-Bleed Pneumatic Controllers	304,000	360,613	515,449	553,252

Reporters provide calculated emissions from each pneumatic controller bleed type category using counts of devices in the category, bleed type-specific population emission factors provided in the rule, and estimated operating time of devices in the category (default is 8,760 hours per year). As discussed below, the EPA reviewed these data and has developed revised bleed type-specific EFs used in the 2016 GHGI.

Subpart W Data for Major Equipment

Onshore production facilities have two options for calculating emissions from major equipment leaks. The first option ("Methodology 1," per 98.233(r)(2)(i), 76 FR 80554, Dec. 23, 2011) is based on estimated component counts (utilizing a table provided in the rule of typical component counts per major equipment) and includes reporting of major equipment counts for facilities using this methodology. The second option "Methodology 2," per 98.233(r)(2)(ii), 76 FR 80554, Dec. 23, 2011) uses actual component counts to calculate equipment leak emissions and does not include reporting of major equipment counts.

Major equipment counts for RY2011 through RY2014 are therefore available from those onshore production facilities that calculated equipment leak emissions using Methodology 1, which includes 83% of reporting facilities for RY2011, 85% for RY2012, 93% for RY2013, and 98% for RY2014. For wellheads, the subpart W data do not distinguish primary production type (i.e., natural gas production wells versus crude oil production wells). These reported major equipment counts are shown in Table 2 below.

Table 2. Reported Methodology 1 Equipment Leak Major Equipment Counts for RY2011-2014

Number of Reporting Facilities	RY2011	RY2012	RY2013	RY2014
Number of Onshore Production Facilities Reporting Under Subpart W	458	504	507	564
Number of Onshore Production Facilities Reporting Equipment Leak Major Equipment Counts	381	429	469	552
Reported Number of Major Equipment, By Equipment Type:				
Natural Gas and Petroleum Wellheads	375,445	406,262	425,125	499,023
Natural Gas and Petroleum Separators	204,990	230,109	243,531	269,391
Natural Gas and Petroleum Chemical Injection Pumps[a]	64,490	77,538	77,355	79,881
Natural Gas Compressors	22,232	20,986	21,318	23,740
Natural Gas Dehydrators	6,758	9,545	7,974	8,380

Petroleum Headers	32,491	29,647	32,559	44,880
Petroleum Heater-treaters	25,057	22,721	26,350	34,902
Natural Gas In-Line Heaters	51,459	56,033	49,319	48,460
Natural Gas Meters/Piping	242,074	238,174	222,802	256,340

a – As stated above, CIP data are presented within the major equipment leaks discussion for simplicity. In the GHGI, emissions from CIPs are categorized as vented emissions whereas equipment leaks are fugitive emissions.

Reporters provide calculated emissions from CIPs using counts of natural gas driven pneumatic pumps, population emission factors provided in the rule, and average estimated operating time of such pumps (default is 8,760 hours per year). As discussed below, the EPA reviewed these data and has developed revised CIP EFs used in the 2016 GHGI.

Alignment between GHGI and Subpart W Activity Data

Appendix A documents GHGI production segment emission sources in natural gas systems and petroleum systems, respectively, aligned with data collected under GHGRP subpart W for equipment leak and natural gas pneumatic controller emissions. The description of "GHGI Activity Basis" in the Appendix A table indicates whether the activity data element is obtained directly from a data source for each year in the time series (indicated by "direct") or some other methodology involving use of an activity data driver. In the current GHGI, all of the emission sources in Appendix A are driven from data elements that are available for each GHGI year: counts of wells by production type, and total oil and gas production.

Revisions to Incorporate Subpart W Data into the 2016 GHGI

As discussed in the introduction to this memorandum, subpart W provides substantial new data on oil and gas GHG-emitting activities in the U.S., but does not represent total national-level emissions due to the reporting threshold. The EPA continues to evaluate both the coverage and the representativeness of the GHGRP data for use in the GHGI. This section the approach implemented in the 2016 GHGI for scaling subpart W activity data to a national level for use in the GHGI, as well as the approaches used for revising natural gas and petroleum systems previous GHGI methodology to stratify pneumatic controller emission estimates by bleed type.

Table 3 below summarizes major equipment and pneumatic controller emission sources in the current GHGI. For natural gas systems, relevant subpart W data elements include counts of heaters, dehydrators, meters/piping, and compressors. For petroleum systems, relevant subpart W data elements include counts of heater-treaters and headers. Equipment that applies to both natural gas and petroleum production segments (according to the current GHGI structure) and for which subpart W reported activity could be allocated between production types includes counts of pneumatic controllers, wellheads, separators, and CIPs.

Table 3. Summary of Activity Data Alignment between GHGI and Subpart W

Emission Source	GHGI		Subpart W Potential Allocation		
	Natural Gas	Petroleum	Allocated to NG	Allocated to Petroleum	Allocated between Prod. Types
Pneumatic Controllers	●	●			●
Wellheads	●	●			●
Separators	●	●			●
Chemical Injection Pumps	●	●			●
Heaters	●		●		

Emission Source	GHGI		Subpart W Potential Allocation		
	Natural Gas	Petroleum	Allocated to NG	Allocated to Petroleum	Allocated between Prod. Types
Dehydrators	●		●		
Meters/Piping	●		●		
Compressors	●		●		
Heater-treaters		●		●	
Headers		●		●	

Table 4 below compares reported activity data under subpart W to national activity estimates in the current GHGI for years 2011 through 2013.

Table 4. Comparison between Production Segment GHGI and Subpart W Activity Data

Equipment	2011		2012		2013		2014
	GHGI	Subpart W	GHGI	Subpart W	GHGI	Subpart W	Subpart W
Pneumatic Controllers (NG and Petro)	894,968	*574,057*	909,777	*628,890*	911,474	*707,974*	*785,113*
Wellheads (NG and Petro)	1,296,534	*375,445*	1,320,426	*406,262*	1,315,196	*425,125*	*499,023*
Separators (NG and Petro)	390,503	*204,990*	394,136	*230,109*	388,222	*243,531*	*269,391*
CIPs (NG and Petro)	66,623	*64,490*	67,256	*77,538*	66,878	*77,355*	*79,881*
Heaters (NG)	110,423	*51,459*	109,428	*56,033*	107,735	*49,319*	*48,460*
Dehydrators (NG)	65,124	*6,758*	64,753	*9,545*	62,919	*7,974*	*8,380*
Meters/piping (NG)	397,862	*242,074*	395,686	*238,174*	390,586	*222,802*	*256,340*
Compressors (NG)	36,368	*22,232*	36,052	*20,986*	35,354	*21,318*	*23,740*
Heater-treaters (Petro)	78,281	*25,057*	81,941	*22,721*	84,262	*26,350*	*34,902*
Headers (Petro)	88,708	*32,491*	91,548	*29,647*	92,395	*32,559*	*44,880*

The EPA first considered a simplistic approach to scaling subpart W data to estimate national activity. The simplified approach would not take into account how dominant production type (natural gas versus petroleum) may impact major equipment counts per well, or the degree to which major equipment counts per well reported under subpart W are representative of activity for facilities that do not report under subpart W. For year 2013, subpart W data cover 32% of active wellheads (total producing natural gas and petroleum wells) nationally. In its analysis for this memo, the EPA developed activity estimates using an assumption that the subpart W data set also represents 32% of other national equipment counts (in other words, that the ratio of each type of equipment-per-wellhead is the same for nonreporting wells as it is for reporting wells) in the onshore production segment.

The approach that the EPA implemented in the 2016 GHGI builds on the simplistic approach to allocate subpart W reported counts of pneumatic controllers, wellheads, and separators to either the natural gas or petroleum systems GHGI source categories. Each facility that reports under subpart W for onshore production reports certain data elements at the sub-basin level, which is defined as operations within a single geographic county of a common production classification. The production classifications used in subpart W are identified in Table 5 below. The EPA analyzed the sub-basin data for each facility in order to estimate the fraction of the facility's activity that is attributable to natural gas versus petroleum. For

example, if a facility reported activities in 10 total sub-basins, 4 of which are natural gas producing and 6 of which are oil producing (based on the second column in Table 5), then the EPA assigns 40% of the reported equipment to natural gas activities and 60% of equipment to petroleum activities.

Table 5. Subpart W Sub-basin Production Classification and GHGI Source Category Assignment

Subpart W Production Classification	GHGI Source Category
Shale gas	Natural gas
High permeability gas	Natural gas
Coal seam	Natural gas
Oil	Petroleum
Tight reservoir rock[a]	Natural gas or Petroleum, dependent on particular county[a]

a – Tight reservoir rock may be a gas or oil formation. The EPA's National Emissions Inventory program developed a crosswalk using 2011 production data from DrillingInfo's DI Desktop® to classify each individual county with tight reservoir rock as primarily gas-producing or oil- producing.

The EPA then analyzed counts of each type of major equipment per wellhead at each facility by production type. The EPA calculated AFs RY2014 only (since the data for previous RYs were back-reported). To calculate average AFs for each data set, EPA weighted facility-level reported activity data by facility well count. Calculated AFs are shown in Table 6 below.

The EPA's estimates of major equipment counts by this approach are presented in Table 7 and **Error! Reference source not found.** below.

Table 6. AF Calculation from Supbart W RY 2014 Data

Source Category & Major Equipment	AF
NG: Pneumatic Controllers/Well	1.83
NG: Separators/Well	0.67
NG: Chemical Injection Pumps/Well	0.18
NG: Compressors/Well	0.11
NG: Dehydrators/Well	0.04
NG: Heaters/Well	0.22
NG: Meters/piping per well	1.15
Petro: Pneumatic Controllers/Well	1.35
Petro: Separators/Well	0.43
Petro: Chemical Injection Pumps/Well	0.14
Petro: Headers/Well	0.16
Petro: Heater-treaters/Well	0.13

Table 7. Subpart W Production Segment Major Equipment Counts Scaled to National Activity Representation for Year 2013

Equipment	GHGI	Subpart W Reported	Subpart W Scaled	Change from GHGI Estimate
Pneumatic Controllers	911,474	*707,974*	2,025,755	+122%
Pneumatic Controllers (NG)	459,304	*371,607*	831,901	+81%
Pneumatic Controllers (Petro)	452,170	*336,367*	1,193,854	+164%
Wellheads	1,315,196	*425,125*	n/a	n/a
Wellheads (NG)	451,296	*208,991*	n/a	n/a
Wellheads (Petro)	863,900	*216,134*	n/a	n/a
Separators	388,222	*243,531*	688,465	+77%
Separators (NG)	265,586	*152,429*	305,270	+15%
Separators (Petro)	122,636	*91,102*	383,195	+212%
Chemical Injection Pumps	66,878	*77,355*	208,500	+212%
Chemical Injection Pumps (NG)	35,812	*40,501*	82,948	+132%
Chemical Injection Pumps (Petro)	31,066	*36,854*	125,552	+304%
Heaters (NG)	107,735	*49,319*	98,680	-8%
Dehydrators (NG)	62,919	*7,974*	17,064	-73%
Meters/piping (NG)	390,586	*222,802*	521,991	+34%
Compressors (NG)	35,354	*21,318*	48,342	+37%
Heater-treaters (Petro)	84,262	*26,350*	111,939	+33%
Headers (Petro)	92,395	*32,559*	143,940	+56%

Pneumatic Controller Stratification by Bleed Type and Emission Factor Revisions

As shown in Appendix A, the previous GHGI methodology did not stratify pneumatic controller emissions by bleed type within natural gas production, and stratified by high versus low bleed within petroleum production. Using reported subpart W data allowed EPA to calculate pneumatic controller emissions using activity data and EFs specific to each bleed rate category in the GHGRP: high bleed, intermittent bleed, and low bleed. This revised approach improves current GHGI estimates by providing "net" rather than "potential" emissions for each year of the time series, and therefore the calculation no longer requires incorporation of Gas STAR voluntary reductions data.

Table 8 below presents estimates of pneumatic controller counts in natural gas and petroleum production segments, nationally scaled and stratified by production type according to the approach discussed above—then stratified by bleed type based on subpart W data, for year 2013. The far-right column labeled "Change" indicates the relative difference between "Subpart W Scaled" and "2015 GHGI" values.

Table 8. Subpart W Production Segment Pneumatic Controller Counts Scaled to National Activity Representation for Year 2013

Controller Type	2015 GHGI	Subpart W Reported, and Allocated to NG and Petro	Subpart W Scaled	Change[a]
Low Bleed	-	***159,586***	**481,849**	**n/a**
Natural Gas Production	-	*69,483*	144,443	n/a
Petroleum Production	293,910	*90,103*	337,406	+15%
High Bleed	**-**	***32,939***	**92,291**	**n/a**

Natural Gas Production	-	*13,431*	42,050	n/a
Petroleum Production	158,259	*19,508*	50,241	-68%
Intermittent Bleed	**-**	***515,449***	**1,451,615**	**n/a**
Natural Gas Production	-	*209,508*	645,408	n/a
Petroleum Production	-	*305,941*	806,207	n/a
Natural Gas Prod. Total	**459,304**	***292,422***	**831,901**	**+81%**
Petroleum Prod. Total	**452,170**	***415,552***	**1,193,854**	**+164%**
Production Segment Total	**911,474**	***707,974***	**2,025,755**	**+122%**

a – Relative difference between "Subpart W Scaled" and "2015 GHGI" values.
"-" means not estimated.
"n/a" means not applicable.

The EPA developed EFs using subpart W reported data for pneumatic controllers stratified by bleed type to be used in conjunction with revised activity data. These EFs are presented in Table 9 below and compared to current GHGI EFs.

Table 9. Production Segment Pneumatic Controller Methane EF Comparison (scfd/device)

Data Source	Data Source Base Year	Low-Bleed	High-bleed	Intermittent Bleed	Population Average
Subpart W RYs 2011-2014[a]	2011–2014	23	617	215	183
Subpart W RY 2014[a]	2014	23	622	218	182
Current GHGI: Natural Gas Production[b]	1992	-	654	323	345[d]
Current GHGI: Petroleum Production[c]	2002	52	330	-	149

a – Subpart W EFs are calculated as a weighted average based on the number of devices of the given type at each reporting facility.
b – The previous GHGI methodology used the population EF from the 1996 GRI/EPA report. This population EF represents an observed mix of 65% intermittent bleed and 35% continuous bleed natural gas-driven pneumatic controllers; the bleed type-specific EFs from the GRI/EPA report (which are not directly used in the current GHGI) are shown for comparison to other data sources. The continuous bleed EF from the GRI/EPA report is most appropriately compared to the high-bleed subcategorization for purposes of this analysis (versus low-bleed continuous).
c – The previous GHGI methodology used high bleed and low bleed EFs developed in 2002 in conjunction with an assumed mix of 65% low bleed and 35% high bleed natural gas-driven pneumatic controllers. The petroleum systems production segment average EF (which is not directly used in the current GHGI) is shown for comparison to other data sources.
d – Potential factor. In the previous GHGI methodology, Gas STAR reductions are subtracted from potential emissions to reflect net emissions from the actual mix of controllers in place. This is further discussed below under "Impact on National Emission Estimates."

Pneumatic Pump Emission Factor Revision

The EPA developed an EF using subpart W reported data for pneumatic pumps to be used in conjunction with revised activity data. The revised CH_4 EF is 216 scfd/pump, compared to the previous EF of 248 scfd/pump.

Impact on National Emission Estimates

Table 12 below presents activity and emissions estimates from the most recent previous GHGI (2015 GHGI) compared to the approach implemented in the 2016 GHGI using subpart W data.

The AFs derived from subpart W data result in generally higher equipment counts per well (for example, approximately twice as high as the 2015 GHGI for separators and meters), though dehydrator counts per well are less than calculated in the 2015 GHGI. Subpart W reporting does not cover centralized production facilities which may lead to underrepresentation of dehydrators population; however, revisions implemented to gathering and boosting sources in the 2016 GHGI (see companion memo titled "GHGI of U.S. Greenhouse Gas Emissions and Sinks 1990-2014: Revisions to Natural Gas Gathering and Boosting Emissions" (April 2016)) would help mitigate this discrepancy because emissions from dehydrators at centralized gathering locations would be included within the gathering stations EF. The revision using subpart W activity and emissions data to update GHGI pneumatic controller estimates resulted in significant increases to current emissions estimates. The revision using subpart W activity and emissions data to update CIP estimates resulted in approximately doubling the previous estimates.

The 2015 and previous GHGIs calculated potential emissions for pneumatic controllers and major equipment fugitives (column 2 in Table 12), then subtracts Gas STAR reductions (column 3) to obtain net emission estimates (column 4). Gas STAR reductions for pneumatic controllers were applied to the pneumatic controller categories, but the previous GHGI methodology did not assign Gas STAR reductions specifically to major equipment fugitive sources. The revised 2016 GHGI approach relies on subpart W data which reflect net emissions, and therefore it is no longer be appropriate to subtract Gas STAR reductions for these source estimates.

The activity data from the 2016 GHGI approach shown in Table 12 below are consistent with values shown in Table 7 above. The "revised net" emissions shown for use bleed rate-specific activity stratification from Table 8 (pneumatics stratified by bleed type) and associated EFs from Table 9; this approach is comparable to the 2015 GHGI's approach of calculating potential emissions then subtracting Gas STAR reductions to account for increased adoption of lower bleed rate controllers in 2013 compared to the 1992 base year. For major equipment fugitives, the "revised net" emissions in Table 12 use GHGI EFs unchanged.

Time Series Considerations

Subpart W annual reporting data are available beginning in year 2011. The EPA revised the GHGI time series (1990–2014) to create consistency between earlier years' estimates that generally rely on studies conducted in the 1990s, and more recent years' estimates that rely on subpart W data.

Activity Data

For natural gas systems major equipment and natural gas-driven pneumatic controller counts in each year after the current GHGI base year (1992) and before the first year of subpart W data (2011), the EPA applied an interpolation approach that reflects dynamics of well development activity. The inherent assumption is that equipment counts in each such year are directly dependent on active well counts in the given year. For each year between the base year and 2011, the EPA used the percent of "Δ active wells" as the assumed percent of "Δ equipment", where:

- Δ active wells = difference in count of active wells in 2011 compared to base year (all years are directly calculated from DrillingInfo data); and
- Δ equipment = difference in count of each type of major equipment in 2011 compared to base year (counts in base year are taken from existing GHGI, and counts in 2011 are developed using AFs developed from subpart W data).

For petroleum systems, major equipment and natural gas-driven pneumatic controller counts derived from subpart W data for recent time series years have increased compared to base year estimates (1993 for major equipment and 1995 for pneumatic controllers) whereas the count of active wells and oil production have decreased over the same time frame. This might reflect the evolution of unconventional production and decrease in conventional oil production over time, and/or might reflect high uncertainties in the early 1990s data. Therefore, an interpolation approach that uses an independent parameter as a driver (e.g., active well count) such as that implemented for natural gas systems cannot be applied. The EPA therefore used simple linear interpolation to develop activity data for these sources between the base year and 2011.

For natural gas-driven pneumatic controllers, the EPA developed a bleed rate categorization for each time series year. The previous GHGI natural gas production segment methodology assumed the controller population comprises 35% high bleed and 65% intermittent bleed controllers in year 1992, and this stratification was carried forward to represent potential emissions in all years. In the 2016 GHGI, the EPA linearly interpolated from these to the proportions observed in 2011 GHGRP, which represent net emissions in each year. The EPA retained the existing GHGI methodology for years 1990–1992. Similarly, the previous GHGI petroleum production segment methodology assumed the controller population comprises 35% high bleed and 65% low bleed controllers for all years. The activity data methodology for calculating total pneumatic controller count was based on consensus of an industry review panel for base year 1995. In the 2016 GHGI, the EPA linearly interpolated from the 1995 subpopulations to the proportions observed in 2011 GHGRP. The EPA retained the existing GHGI methodology for years 1990–1995.

To develop national activity estimates for major equipment and total pneumatic controller counts for year 2011 and beyond, the EPA applied AFs (count of each type of equipment and total natural gas-driven pneumatic controllers per well) developed using the approach discussed above. This approach could be refined in future GHGIs to use AFs developed from RY2014 data to calculate activity data in the GHGI for recent years, use an average of RY2011–2014 data, or use year-specific data from GHGRP for these years in the GHGI. As shown in Table 6 above, AFs do not significantly vary over this time period based on reported data. For the 2016 GHGI, the EPA used AFs from RY2014 data, but as future years of subpart W data become available, the EPA will reconsider at what frequency it is appropriate to recalculate AFs. The EPA calculated pneumatic controller bleed rate stratification for each year of available data to allow the GHGI to reflect changes in these populations and resulting emissions—including changes resulting from NSPS OOOO implementation. See Table 10 below.

Table 10. Subpart W Production Segment Pneumatic Controller Bleed Rate Stratification

Controller Type	RY2011	RY2012	RY2013	RY2014
Natural Gas Production				
Low Bleed	33%	28%	17%	27%
High Bleed	10%	9%	5%	3%
Intermittent Bleed	57%	62%	78%	69%
Petroleum Production				
Low Bleed	44%	42%	28%	25%
High Bleed	9%	7%	4%	4%
Intermittent Bleed	47%	51%	68%	72%

Emission Factors

The revised pneumatic controller EFs were similarly developed from RY 2014 subpart W data and were applied for all years of the time series in the 2016 GHGI. As discussed above, the previous GHGI methodology relied on Gas STAR reductions to account for industry advancements in adoption of lower bleed rate controllers over time. The 2016 GHGI revision takes this dynamic into account through EFs stratified by bleed type and development of bleed type-specific activity data.

The revised CIP EF was also developed from RY 2014 subpart W data and was applied for years 2011 and beyond. For years 1990 through 1992, the EPA retained existing estimates of the CIP EF. For intermediate years, the EPA linearly interpolated between the existing CIP EF and the revised CIP EF developed from subpart W data. The 2016 GHGI revision for this source aims to take into account shifts in practices over time.

Revisions to Subpart W Effective RY2015

Revisions to subpart W that became effective January 1, 2015 (79 FR 70352, Nov. 25, 2014) include additional data elements related to equipment leaks that onshore production facilities must begin reporting in RY2015. Onshore petroleum and natural gas production facilities must report the following separately by component type, service type, and geographic location (i.e., Eastern U.S. or Western U.S.) for both calculation methods (Methodology 1 and Methodology 2):

- total number of the emission source type at the facility (e.g., valves, connectors, PRVs, etc.) (note, this is already reported for facilities using Methodology 1 as of RY2014);
- average estimated time that the emission source type was operational in the calendar year; and
- calculation method used (i.e., Methodology 1 using major equipment counts or Methodology 2 using actual component counts).

Additionally, for each major equipment type, production type (i.e., natural gas or crude oil) and geographic location combination in Tables W-1B and W-1C of subpart W, facilities must report an indication of whether the facility contains the major equipment type and if the facility does contain the equipment type, the count of the major equipment type.

Gas STAR Reductions Revisions

As discussed above, the 2016 GHGI revision obviates the need to apply Gas STAR reductions data for certain production segment sources. Table 11 below presents production segment emissions by source in the 2015 GHGI. There are significant Gas STAR reductions in the production segment that are not classified as applicable to specific emission sources ("Other voluntary reductions" are 16 MMT CO_2e CH_4 in year 2013). Some portion of the "other voluntary reductions" might apply to the emission sources for which the EPA is considering revising the activity data basis to reflect the subpart W definition of an onshore production facilities (excluding centralized production and gathering-only facilities). The EPA is continuing to investigate potential disaggregation of "other voluntary reductions." For the 2016 GHGI, the EPA developed and applied a scaling factor to the "other voluntary reductions" to reduce this reported amount based upon the fraction of the overall production segment emissions that now rely on net emission factor approaches (e.g., hydraulically fractured gas well workovers and completions, liquids unloading, pneumatic controllers, and gathering facilities). The scaling factor for year 2013 used in the 2016 GHGI was 0.464, bringing "other voluntary reductions" to 7.6 MMT CO_2e.

Table 11. Year 2013 Natural Gas and Petroleum Production Segment CH_4 Emissions by Source in the Previous (2015) GHGI Inventory

All Production Emission Sources	Potential Emissions (MMT CO_2e)	Reduction (MMT CO_2e)	Net Emissions (MMT CO_2e)

Pneumatic Controllers (Vented)	40.8	22.6	18.2
Major Equipment (Fugitive)	12.0	-	12.0
Chemical Injection Pumps (Vented)	3.0	0.1	2.9
Other Vented	36.6	0.01[a]	36.5
Other Fugitive	6.9	-	6.9
Engine, turbine exhaust	9.0	3.5[b]	5.5
Offshore	8.4	-	8.4
Upsets	0.1	-	0.1
Other Voluntary Reductions	n/a	16.5	n/a
Regulatory Reductions	n/a	3.0[c]	n/a
Total	**116.9**	**45.7**	**71.2**

a – Natural gas systems, compressor starts.

b – Natural gas systems, compressor gas engine exhaust.

c – Due to NESHAP regulations addressing condensate storage tanks and dehydrators, in effect for year 1999 forward.

Table 12. Year 2013 Production Segment CH_4 Emissions from Pneumatic Controllers and Equipment Leaks in the 2015 and 2016 GHGI

Emission Source (Production Type)	2015 GHGI **Potential** Estimate (MMT CO_2e)	2015 GHGI **Reduction** Estimate (MMT CO_2e)	2015 GHGI **Net** Estimate (MMT CO_2e)	2015 GHGI Activity	2016 GHGI Activity	2016 GHGI **Revised Net** Estimate (MMT CO_2e)
Pneumatic Controllers (NG)	29.0	15.5	13.5	459,304	831,901	31.5
Pneumatic Controllers (Petro)	11.9	7.1	4.7	452,170	1,193,854	37.8
Wellheads (NG)	1.3	-	1.3	451,296	454,491	1.3
Wellheads (Petro)	1.5	-	1.5	863,900	884,652	1.5
Separators (NG)	2.6	-	2.6	265,586	305,270	3.0
Separators (Petro)	0.3	-	0.3	122,636	383,195	0.8
Chemical Injection Pumps (NG)	1.6	-	1.6	35,812	82,948	3.2
Chemical Injection Pumps (Petro)	1.4	-	1.4	31,066	125,552	4.8
Heaters (NG)	0.8	-	0.8	107,735	98,680	0.6
Dehydrators (NG)	0.8	-	0.8	62,919	17,064	0.2
Meters/piping (NG)	2.6	-	2.6	390,586	521,991	2.7
Wellpad Compressors (NG)	1.7	-	1.7	35,354	48,342	2.4
Heater-treaters (Petro)	0.3	-	0.3	84,262	111,939	0.4
Headers (Petro)	0.1	-	0.1	92,395	143,940	0.2

HF Oil Well Completions and Workovers

In addition to the updates using GHGRP data discussed above, the EPA also updated its estimates for oil well completions in the 2016 inventory, after receiving stakeholder feedback supporting updates to include this source.

The Inventory previously did not distinguish between oil well completions and workovers with hydraulic fracturing (HF) and oil well completions and workovers without hydraulic fracturing. The previous Inventory emission factors for all oil well completions and workovers were developed using an assumption that all oil well workovers and completions are flared. In the 2016 GHGI, an estimate for the subcategories of oil well completions with hydraulic fracturing with and without controls was included. This estimate was developed using an uncontrolled emission factor developed as part of the analysis supporting the OOOOa NSPS proposal (7.5 tons CH_4/completion)[3], and a controlled emission factor that assumes 95% control efficiency (0.4 tons CH_4/completion). For the OOOOa proposal analysis, EPA extracted gas production data from oil well records in DrillingInfo, and developed average daily gas production rates (over the first month of production) for wells that were determined to have been completed with hydraulic fracturing in 2012. The average value for these wells was 255.47 Mcf/day. This was then multiplied by a 3 day completion duration, and a methane content value of 47% to develop the uncontrolled factor. Total annual national HF oil well completion data were developed from DrillingInfo data (DrillingInfo 2015). The GHG inventory uses the NSPS OOOOa proposal value for the percentage of oil well completions that are controlled due to state regulations, 7%, and applies that value beginning in 2008. It is assumed in the Inventory estimate that prior to 2008, all oil well completions with HF are uncontrolled. The inventory continues to use one estimate for workover emissions for completions of all types (i.e. both hydraulically fractured and non-hydraulically fractured). This recalculation results in a 3 MMT CO_2e increase from the previous 2013 estimate for completions and workovers, and an average increase of 1 MMT CO_2e over the 1990-2013 time series.

Table 13. Methane Emissions from Oil Well Completions and Workovers, MMT CO2e

Activity	1990	2005	2010	2013	2014
Non-HF Completions	+	+	+	+	+
Workovers (HF and non-HF)	+	+	+	+	+
HF Completions	0.6	0.9	1.7	3.0	3.0
TOTAL Completions &Workovers	**0.6**	**0.9**	**1.7**	**3.0**	**3.0**
Previous TOTAL Completions &Workovers	***+***	***+***	***+***	***+***	***N/A***

Requests for Stakeholder Feedback

The EPA initially sought feedback on the following questions in the version of this memo released February 2016. The EPA discusses feedback received thus far through the 2016 GHGI public review process, and further planned improvements to 2016 GHGI methodology, in Chapter 3.5 and Chapter 3.6 of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014* (April 2016). The EPA welcomes additional seek stakeholder feedback on the following questions.

[3] The value presented in the NSPS proposal, 9.72 short tons was the average emissions calculated for the subset of HF oil well completions with GOR >300 scf/bbl. The GHG Inventory averaged emissions from the same base data set, without the GOR >300 scf/bbl exclusion, so that the emission factor can be applied to all HF oil well completions in the U.S., including those with lower GOR.

General use of Subpart W data

1) The EPA seeks feedback on how to take into account the reporting threshold when using subpart W data, and the appropriateness of using subpart W-based AFs for the national population of major equipment and pneumatic controllers.
    a. Are other data sources available that would help the EPA determine characteristics of the non-reporting population?
    b. Are other approaches available for scaling up this data for use in the GHGI?

2) The EPA seeks feedback on other data sources (e.g., Allen et al. 2013 and 2014, the Prasino Group 2013) that could be considered for the development of emission factors for equipment leaks and/or pneumatic controllers.
    a. Allen et al. 2014 study did not differentiate between controller types. Is it possible to disaggregate the Allen emissions data in a way that would allow the EPA to calculate emissions for various control types?

3) The EPA seeks feedback on how to take into account reported emissions data under subpart W for major equipment fugitives in the GHGI. For reporters using equipment leak methodology 1 (98% of reporters in RY2014), emissions data are reported at the facility level based on use of component-level EFs specified in the rule, not at the equipment level. The EPA seeks feedback on how to use such data in developing equipment-specific fugitive EFs that could be applied in the natural gas and petroleum systems segments of the GHGI. The subpart W specified EF for reporting vented emissions from CIPs uses the same basis (GRI/EPA) as the current GHGI. The EPA is considering adjusting the GHGI emission factor for CIP using subpart W reported data, which takes into account operating hours.

Calculations using Subpart W data

4) The EPA seeks feedback on the methodology for allocating subpart W data between the natural gas and petroleum production segments. Are other approaches available for allocating subpart W equipment and pneumatic controller counts between production types? For example, one limitation in the current methodology is that for facilities covering both oil and gas sub-basins and having separators, the count of separators-per-gas well is equivalent to separators-per-oil well.

5) The EPA seeks feedback on whether and how to use subpart W data to reflect geographic variation of activity factors and/or emission factors. In the current GHGI, emissions from natural gas systems are calculated separately for six NEMS regions, and emissions from petroleum systems do not have geographic variation. The update under consideration is applied at the national level. The EPA plans to explore options to reflect geographic variation in future GHGIs.

6) The EPA seeks stakeholder feedback on year-to-year trends in reported subpart W data, and whether it is more appropriate to recalculate activity factors and/or emission factors separately for each RY, or to use another approach (e.g., combine data from multiple early RYs such as the current methodology for hydraulically fractured gas well completions which uses combined RY2011 through RY2013 data to calculate the emission factor).

7) The EPA seeks feedback on how to address time series consistency in using AFs derived from subpart W data—i.e., calculating activity in years between the early 1990s base year and recent

subpart W-era years. As discussed under "Time Series Considerations" the EPA used the count of active production wells as an activity data driver for major equipment and total pneumatic controller counts in natural gas systems, and simple linear interpolation for petroleum systems. The EPA could consider taking into account other factors (e.g., year to year production changes). The EPA seeks stakeholder feedback on other factors that impact equipment counts and potential methods to incorporate these factors into the GHGI calculations.

Other Emission Sources

8) The EPA discusses revisions to the GHGI production segment structure in a companion memo titled "GHGI of U.S. Greenhouse Gas Emissions and Sinks 1990-2014: Revisions under Consideration for Natural Gas Gathering and Boosting Emissions" (April 2016). Revisions included updating some of the production emission calculation methodologies based on Marchese et al. (2015) measurement data for centralized production and gathering-only facilities. With such revisions, storage tank emission estimates may overlap with the Marchese et al. facility-level EF based on current methodology. The EPA seeks feedback on how to improve GHGI activity, emissions, and controls data for these sources located at non-gathering production sites based on available subpart W data.

9) The EPA seeks stakeholder feedback on production segment sources not discussed in this memorandum.
    a. For sources where GHGRP data are currently available, the EPA seeks stakeholder feedback on how GHGRP data may be used to revise current GHGI methodologies. For example, the EPA seeks stakeholder feedback on whether similar methods to those discussed in this memorandum could be used to scale up subpart W activity data for sources such as liquids unloading and hydraulically fractured (HF) gas well completions
    b. For sources where GHGRP data are not currently available, the EPA seeks stakeholder feedback on data sources available for updates to those methodologies. The EPA specifically seeks stakeholder feedback on any currently available or upcoming activity and/or emissions data on abandoned wells.

10) Recent production segment studies have detected the presence of superemitters in the production segment. The EPA seeks stakeholder feedback on how to incorporate information on superemitters into estimates for the production segment. The EPA also seeks stakeholder feedback on which GHGI sources are more likely than others to act as superemitters and whether and how to apply a superemitter factor or other methodology to those sources.

APPENDIX A
Table A-1. Alignment of GHGI and Subpart W Activity Data Elements

GHGI Emission Source	GHGI Activity	GHGI Activity Basis	Corresponding Subpart W Data Element
Natural Gas Systems			
Natural Gas-driven Pneumatic Controllers			
Pneumatic Controllers	Controllers	Calculated using 1992 data on pneumatic controller counts per gas well	Annual counts of low-bleed, high-bleed, and intermittent bleed NG pneumatic controllers from reporting facilities
Equipment Leaks/Fugitives			
Associated Gas Wells	Wells	direct	Annual count of wellheads from reporting facilities using EL Methodology 1
Non-associated Gas Wells (less fractured wells)	Wells	direct	
Gas Wells with Hydraulic Fracturing	Wells	direct	
Heaters	Heaters	Calculated using 1992 data on heaters per non-associated gas well	Annual count of in-line heaters from reporting facilities using EL Methodology 1
Separators	Separators	Calculated using 1992 data on separators per non-associated gas well	Annual count of separators from reporting facilities using EL Methodology 1
Dehydrators	Dehydrators	Calculated using 1992 data on dehydrators per non-associated gas well	Annual count of dehydrators from reporting facilities using EL Methodology 1
Meters/Piping	Meters	Calculated using 1992 data on meters per all gas wells	Annual count of meters/piping from reporting facilities using EL Methodology 1
Petroleum Systems			
Natural Gas-driven Pneumatic Controllers			
Pneumatic Controllers, High Bleed	controller	Calculated based on total number of separators + heater/treaters and assumed percent of population that is high bleed versus low bleed	Annual count of high-bleed NG pneumatic controllers
Pneumatic Controllers, Low Bleed	controller		Annual count of low-bleed NG pneumatic controllers
Pneumatic Controllers, Intermittent Bleed	N/A	N/A	Annual count of intermittent-bleed NG pneumatic controllers
Equipment Leaks/Fugitives			
Oil Wellheads (heavy crude)	Oil well	Calculated based on total producing oil wells (less 80% of stripper wells) and ratio of heavy crude wells to total crude wells	Annual count of wellheads from facilities using EL Methodology 1
Oil Wellheads (light crude)	Oil well		
Separators (heavy crude)	separator	Calculated using 1993 base year factor; scaled using annual domestic production and total producing oil wells	Annual count of separators from facilities using EL Methodology 1
Separators (light crude)	separator		
Heater-Treaters (light crude)	heater	Calculated using 1993 base year factor; scaled using annual domestic production and total producing oil wells	Annual count of heater/treaters from facilities using EL Methodology 1
Headers (heavy crude)	header	Calculated based on total producing oil wells and ratio of heavy crude production wells to total crude production wells	Annual count of headers from facilities using EL Methodology 1
Headers (light crude)	header		