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Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2013: Potential Revisions to Pneumatic Controller Emissions Estimate (Production Segment)

Overview of Current Inventory Method

EPA calculates emissions for pneumatic controllers in the production segment for natural gas and petroleum systems using a national estimate for counts of pneumatic controllers, potential emission factors, and Natural Gas STAR data on reductions.

Activity Data

To calculate national emissions for these sources for the GHG Inventory, a set of industry activity data drivers was developed and is used to update activity data, as a time series of activity data are not available for this source. Pneumatic controllers are estimated each year by applying a regional factor for the number of pneumatic controllers per well (GRI/EPA 1996) to annual regional data on gas well population. The EPA-GRI study surveyed equipment data from 28 companies that included information on almost 7,000 pneumatic devices from over 11,000 gas wells and over 3,000 oil wells. The EPA-GRI study was focused on all methane sources across the oil and gas production industry, and therefore included wells without pneumatic devices. These factors range from 0.5 to 1.6 pneumatic controllers per well. For the petroleum production segment, pneumatic controllers are estimated each year by applying a factor for the number of pneumatic controllers per heater/treater (4), and pneumatic controller per battery without a heater/treater (3). The activity counts for pneumatic controllers in the GHG Inventory include emergency shutdown devices.

Potential Methane Factors

The basis for the GHG Inventory's potential methane emission factors for pneumatic controllers in the natural gas and petroleum production industry segment is the 1996 GRI/EPA report. The factor for natural gas systems represents a mix of the average emissions from continuous bleed and intermittent natural gas-driven pneumatic controllers in the 1996 GRI/EPA report. The region-specific factors are developed using the GRI/EPA factor and regional gas composition data. For petroleum systems, it was then assumed that 65% of pneumatic controllers in the petroleum production segment are low bleed pneumatic controllers, and 35% of controllers are high bleed. The GRI/EPA factors are applied to these populations.

Emission Reductions

The calculated potential emissions estimates are reduced using data on voluntary emission reductions reported by industry partners to the Natural Gas STAR Program. The reductions undergo quality assurance and quality control checks to identify errors, inconsistencies, or irregular data before being incorporated into the GHG Inventory.

This approach of calculating potential CH_4 emissions and then applying reductions data to calculate net emissions is used to ensure an accurate time series that reflects real emission trends. Key data on emissions from many sources in the Inventory are from data collected in 1992 (EPA/GRI 1996). Since the time of this study, practices and technologies have changed. While the study still represents best available data for some emission sources, using these emission factors alone to represent actual emissions without adjusting for emissions controls would in many cases overestimate emissions. As updated emission factors reflecting changing practices are not available for most sources, the 1992 emission factors continue to be used for many sources for all years of the Inventory, but they are

considered to be potential emissions factors, representing what emissions would be if practices and technologies had not changed over time.

In previous Inventories, all production segment reductions related to pneumatic controllers reported to Natural Gas STAR were assigned to the natural gas systems category. Since some portion of these reductions would be more appropriately assigned to the petroleum systems category, in the public review draft of the 2015 Inventory, the total reductions were apportioned by the potential emissions for pneumatic devices in petroleum versus natural gas. This update resulted in an increase in natural gas CH_4 emissions (increase of around 8 MMT CO_2e from the previous inventory estimate for 2012) and a decrease in petroleum systems CH_4 emissions.

The revision to the well count methodology (see memo Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2013: Revision to Well Count Data) resulted in a large increase in the number of petroleum wells, and therefore a large increase in the calculated number of controllers and in the calculated potential emissions. Due to a spreadsheet error, the Natural Gas STAR reductions from pneumatics in petroleum systems are miscalculated in this Inventory across all years, and will be updated in the final Inventory. The impact of the update is anticipated to show a further decrease in net emissions from the production segment. Please see the Tables 1 and 2 below.

Table 1. Year 2012 Pneumatic Controller Emissions in Previous (2014) Inventory, Public Review draft of 2015 Inventory, and Corrected for 2015 Final Inventory for the Production Segment of Petroleum and Petroleum Systems.

Data Element	2012 in 2014 Inventory	2012 in Public Review draft 2015 Inventory	Corrected 2012 in final 2015 Inventory (Estimate)
Petroleum Systems			
# of Pneumatic Controllers	414,797	724,184	724,184
Potential CH_4 (kt)	435	760	760
Reductions of CH_4 (kt)	0	*69*	341
Net CH_4 (kt)	435	*691*	419
Natural Gas Systems			
# of Pneumatic Controllers	477,606	468,303	468,303
Potential CH_4 (kt)	1,208	1,185	1,185
Reductions of CH_4 (kt)	873	532	532
Net CH_4 (kt)	335	653	653
Natural Gas and Petroleum Systems Total Net CH4 (kt)	**770**	**1,344**	**1,072**

Table 2. Overview of GHG Inventory Emission Factors for Year 2012

Inventory/Factor type	Average Device Methane Emission Rates (scf/h)	Basis
2014 GHG Inventory: Gas Wells, Potential[1]	Ranging from 14.1 to 16.8 (dependent on region); averaging 15.0	EF is a weighted average from GRI, based on device populations observed in EPA-GRI study and regional field gas compositions.
2014 GHG Inventory: Gas Wells, Net	Ranging from 3.9 to 4.7 (dependent on region); averaging 4.2	2014 Inventory method assigns all Gas STAR reductions for pneumatic devices to gas segment.

2014 GHG Inventory: Oil Wells	Averaging 6.2 (independent of region)	Assumption of 65% of pneumatic controllers in the petroleum production segment are low bleed, and 35% of controllers are high bleed; use of GRI factors
2014 GHG Inventory: All Wells, Effective Net	Averaging 5.1	Recognizing that some Gas STAR reductions are likely at oil wells, this value represents the potential emissions for oil and gas reduced by the total Gas STAR reductions.
2015 GHG Inventory: All Wells, Effective Net	Averaging 5.3	The 2015 Inventory allocates Gas STAR reductions to both gas and oil wells

Table 2 footnotes:

[1] This factor represents *potential* emissions. 2014 GHG Inventory methodology subtracts Gas STAR reductions from this emission source, resulting in total net emissions that are approximately one-third of potential emissions.

Potential Revisions to Pneumatic Controller Estimates

Several recent studies and upcoming data from GHGRP provide new information on pneumatic controllers. Below is a brief overview of the data and potential uses of the data to update the GHG Inventory estimates.

Allen et al. 2014

Allen et al. 2014 measured emissions from 377 pneumatic controllers at 65 oil and gas production sites, operated by 10 participating companies, across 4 regions of the United States.[1] Of the three studies discussed in this section, the Allen et al. study is the most comparable to U.S. national emissions estimate and it is described in the most detail.

In addition to measuring methane emission from each device, the study collected data on each device's design, application and operating characteristics. The pneumatic controllers included the full range of pneumatic controller types used at oil and gas production sites in a range of applications. Device types included low, high or intermittent bleed pneumatic controllers. Application characteristics included liquid level, temperature and, pressure control.

For each controller, measurements were made over a 15-minute period and included the number of actuation events, the duration of each event, and the flow rate during each event. This information was used to calculate the average emission rate from the device over a given time period.

For most measurements, Allen et al. used a gas supply line meter for testing wherever situations allowed. However, for 44 device tests they were not able to use a supply line meter, and instead monitored the exhaust port of the actuator with a Hi Flow® sampler. The impact of the use of different methods is discussed in detail in Allen et al.

The average emission factors from Allen et al. were generally in agreement with average emission factors from the GHG Inventory. However, the study observed great variability in emissions that is not reflected in the average factors used by the GHG Inventory. In addition, Allen et al. data indicate that the population of pneumatic controllers may be from 50% to 100% greater than the population assumed in the GHG Inventory.

[1] Allen, D.T., Pacsi, A., Sullivan, D., Zavala-Araiza, D., Harrison, M., Keen, K., Fraser, M., Hill, A.D., Sawyer, R.F., and Seinfeld, J.H. Methane Emissions from Process Equipment at Natural Gas Production Sites in the United States: Pneumatic Controllers, Environmental Science & Technology, 10.1021/es5040156. Available online: http://pubs.acs.org/doi/pdf/10.1021/es5040156

Allen et al. 2014 Emission Data

Of the 377 devices measured in the Allen et al. study, 241 devices had no measurable emissions due to no observed emissions (136 devices) or due to emissions below the measurement threshold of the instrument (105 devices). Since the measurement period was only 15 minutes, devices which vented less frequently would typically have undetected emissions. This would be typical of a separator level controller at a well producing little condensate, a plunger lift valve actuated once a day, or an emergency shutdown valve that is rarely actuated. To estimate the high-end impact of correcting the emission data for infrequently actuating devices, the study assumed that all of these infrequently actuating devices were actuated at frequency intervals just greater than the 15 minute test period. This high-end assumption increases the estimated emission factor by 11%. A statistical analysis by Allen et al. on the actuation patterns of the measured emissions indicated that the average emission factor would likely be increased by 2% to 6% if the test period had been extended indefinitely. Allen et al. did not adjust their emission factor of 4.9 scf CH_4/hr for this likely error due to its small value relative to other uncertainties.

There were 49 emergency shutdown pneumatic devices (ESD) in the Allen et al. study of 377 pneumatic controllers (13%). Of the 49 ESD, 31 had no detectable emissions and 5 had well-defined actuations during the 15 minute test period. Allen et al. also noted that the measured emissions for some of the ESD included device leaks rather than actuations. Because some studies of pneumatics exclude ESD from their analysis, Allen et al. considered the impact excluding of ESD on the pneumatic controller emission factor. When Allen et al. excluded ESD data from the emission tests, the resulting emission factor for non-ESD pneumatics was 5.5 scf CH_4/hr.

The Allen et al. study included 26 measurements on pneumatic controllers at sites that identify as oil production sites, out of their 377 measurements. Allen et al. treated the data from oil and gas wells as a single data set due to variability in the definitions of oil and gas wells vary, largely depending on gas to oil production ratios.

The study found that 19% of controllers were responsible for 95% of emissions.

Allen et al. 2014 Activity Data

The Allen et al. study observed 2.7 controllers per well surveyed. Only sites with venting pneumatic controllers were visited for the study. However, the study notes that some sites use non-venting and/or non-pneumatic controllers, and that therefore 2.7 controllers per well represents an upper bound. To develop rough estimates of national emissions, in one scenario Allen et al. assumed that 75% of all controllers were pneumatic-style controllers, of which 75% would be actively venting methane. This assumption results in an estimated average of 1.5 venting pneumatic controllers per well.

Potential Applicability of Allen et al. 2014 to Revising GHG Inventory Emission Factors

Emission factors calculated with the Allen et al. data set are compared to the GHG Inventory emission factors in Table 3. The first column of values presents the 2014 GHG Inventory factors for potential emissions from gas wells in the year 2012. The second column presents the 2014 GHG Inventory emission factors for net emissions from wells when adjusted for voluntary reductions provided by companies converting high bleed devices to lower bleed devices in 2012. The voluntary reductions were only applied to gas wells in the 2014 GHG Inventory. The same emission factor was applied to all oil wells, regardless of region. The third column presents the 2015 GHG Inventory net emission factors for all wells. The 2015 Inventory distributed the voluntary emission reductions to both gas and oil wells

based on estimated population of devices for each well type. The last column presents the net emission factor developed by the Allen et al. study for gas wells and oil wells, combined. Allen et al. noted that there was close agreement between their net emission factor and the 2014 GHG Inventory net factor when compared at the national level.

A review of the GRI-EPA 1996 study which provided the activity data used in the GHG Inventory indicates that ESD valves were included in their survey of pneumatic devices. Therefore the comparison below includes ESD values in the Allen et al. emission factors.

Table 3. Comparison of GHG Inventory Emission Factors for 2012 to Allen et al. Emission Factors (scf CH_4/device-hour)

Region/Well Type	2014 GHG Inventory Potential Emissions	2014 GHG Inventory Net Emissions[1]	2015 GHG Inventory Net Emissions[2]	Allen et al. All well types, Net Emissions
Gas Wells				
Northeast	15.5	4.3	8.5	1.7
Mid Continent	15.1	4.2	8.3	4.9
Southwest	14.7	4.1	8.1	
Rocky Mountain	14.1	3.9	7.9	0.7
West Coast	16.8	4.7	9.3	
Gulf Coast	16.1	4.5	8.9	10.6
National Average	15.0	4.2	8.2	4.9
Oil Wells Average	6.2	6.2	3.4	-
National Average		**5.1**	**5.3**	**4.9**

Table 3 footnotes:
[1] Attributing all Gas STAR reductions to gas wells in the natural gas systems source category, none to oil wells in the petroleum systems source category.
[2] Apportioning Gas STAR reductions to both gas and oil wells according to their respective well populations.

There are a number of ways the Allen et al. study results could be used to update emission factors in the GHG Inventory. A key finding of the study is that a small fraction of controllers emit a large fraction of emissions. It may be possible to stratify the Inventory activity data in way that would allow calculation of emissions for the high-emitting population separately from emissions from the lower emitting population. EPA is seeking comment on how to quantify this population throughout the time series. Please see Request for Stakeholder Feedback.

The Allen et al. emission data could be organized into device type (i.e., high bleed, intermittent, and low bleed) to develop emission factors based on device type. However, almost half of the devices in the sample could not be classified by the company. Similarly, the Allen et al. data could be organized by application of the controller, such as on separator level control or on emergency shutdown devices (ESD). However, EPA is unaware of a source for activity data on the national populations of pneumatic device by application.

There is a very high degree of regional variation in the Allen et al. study emission factors (a factor of 10, as seen in Table above) which is distinctly different than the findings of the original EPA-GRI study.

Potential Applicability of Allen et al. 2014 to Revising GHG Inventory Activity Data

The activity factors (number of pneumatic devices per well) observed and calculated in the Allen et al. study are compared to the activity factors used in the 2014 GHG Inventory for the year 2012 in Table 4.

Table 4. Comparison of 2014 GHG Inventory Activity Factors for 2012 to Allen et al.
(average number of pneumatic controllers per well)

Region	2014 GHG Inventory Gas Wells	2014 GHG Inventory Oil Wells	Allen et al. Survey: Wells with Venting Pneumatics	Allen et al. Field Survey: All Wells[1]
Northeast-Appalachian	0.5	-	2.3	1.3
Mid Continent	1.6		1.9	1.1
Southwest	1.3			
Rocky Mountain	1.5		3.6	2.0
West Coast	1.0			
Gulf Coast	0.7		3.3	1.9
National Average	**1.0**	**0.8**	**2.7**	**1.5**

Table 4 footnotes:
[1] As described above, Allen et al. only visited wells with venting pneumatic controllers (while not all wells use pneumatic controllers, and not all controllers actively vent) and found that these wells had, on average, 2.7 controllers per well. Allen et al. provided a rough estimate that 75% of 75% of the observed per-well controller count to estimate the controller count for the entire national well population. Column 5 presents regional activity data based on this estimate.

Potential Impact of Allen et al. 2014 on GHG Inventory Estimates

Table 5 below, based on data from the Allen et al. study, presents several approaches for estimating national emissions from pneumatic devices at natural gas production sites using the Allen et al. study data for year 2012. The first scenario in the table uses the activity data from in the 2014 GHG Inventory and applies the average factor from Allen et al. The second scenario in the table uses the rough estimate from Allen et al. that 75% of wells have 2.7 pneumatic controllers per well (the count per well observed in the Allen et al. study). The third scenario is based on the Allen et al. study conclusion that a national emission estimate would need to account for the fraction of controllers that were not pneumatic and/or not actively venting. They suggested that possibly 75% of all controllers were pneumatic-style controllers, of which 75% would be actively venting methane. This assumption results in an estimated average of 1.5 venting pneumatic controllers per well, which is then multiplied by the Allen et al. emission factor of 4.9 scf/h and the GHG Inventory well count of 470,913 wells. The fourth scenario is based on the public review draft of the 2015 GHG Inventory which uses the same basic approach as used in the 2014 Inventory (first scenario) but with a minor adjustment to the number of devices and the reallocation of some Gas STAR reductions from the natural gas production sector to the oil production sector.

Table 5. 2012 National Methane Emission Estimates for Natural Gas Production Sites, Various Scenarios

Activity Factor	Emission Factor	National Methane Emission Estimate
Number of controllers in EPA 2014 GHG Inventory, 477,606 controllers	Average emission rate for all controllers measured in this work, 4.9 scf methane/h	394 kt/y 20.5 bcf/y
Number of wells in EPA 2014 GHG Inventory, 470,913 wells, with 75% of the wells assumed to have 2.7 pneumatic controllers per well, as observed in this work	Average emission rate for all controllers measured in this work, 4.9 scf methane/h	786 kt/y 40.9 bcf/y

Number of wells in EPA 2014 GHG Inventory, 470,913 wells, with 75% of the wells assumed to have 2.7 pneumatic controllers per well, and assuming only 75% of the pneumatic controllers vent methane as suggested by some study participants.	Average emission rate for all controllers measured in this work, 4.9 scf methane/h	600 kt/y 31.2 bcf/y
Number of controllers in EPA 2015 (draft) GHG Inventory, 468,303 controllers	Average emission rate for natural gas controllers in the Inventory, 8.2 scf methane/h	653 kt/y 34.0 bcf/y

Oklahoma Independent Petroleum Association

Oklahoma Independent Petroleum Association (OIPA)[2] recently conducted a study quantifying methane emissions from 680 pneumatic controllers across Oklahoma. The study collected data for each controller and calculated emissions using an engineering equation.

The calculation approach determined controller emissions as the sum of the controller, tubing, and actuator emissions as a result of actuation plus any continuous bleed and seepage emissions. The calculation did not include any unintended leaks.

OIPA observed an average of 3.6 pneumatic controllers per well, including 15 wells that did not have controllers. See Figure 1, below.

The study grouped controllers based on age (new (first production in 2000 or later) or old (first production 1999 or earlier)) and production (oil or gas), and observed an average controller count per site 2.2 times higher for new sites than for old sites, which OIPA noted was due to the increased number of process units at newer sites.

The study observed that a small fraction of sources (3.5%) were responsible for a large fraction of emissions (73%).

[2] Oklahoma Independent Petroleum Association, *Pneumatic Controller Emissions from a Sample of 172 Production Facilities,* November 2014. Available online: http://www.oipa.com/page_images/1418911081.pdf

SITES

172 sites (205 wells) visited for data collection
162 sites (190 wells) had natural gas pneumatic controllers
10 sites (15 wells) did not have natural gas pneumatic controllers

CONTROLLERS

680 natural gas pneumatic controllers
77 controller models
659 intermittent vent controllers
21 continuous bleed controllers

AVERAGE CONTROLLER COUNTS

4.0 pneumatic controllers per site
5.0 pneumatic controllers per new gas site
3.1 pneumatic controllers per old gas site
3.6 pneumatic controllers per well
5.3 pneumatic controllers per new oil site
2.7pneumatic controllers per old oil site

ACTUATION FREQUENCIES

538 controllers (79%) had no actuations detected during the observation period and were assigned the default rate
126 controllers (19%) had actuation rates less frequent than the once per 15 minute default rate
16 controllers (2%) had actuation rates more frequent than or equal to the default rate

Figure 1. Key Observational Results from OIPA Study

Prasino Group Study

The Prasino Group conducted a survey of high bleed devices used in the Fort St. John area of British Columbia, Canada to determine the average bleed rates from high bleed pneumatic controllers and pumps[3] in field conditions. The study sampled bleed rates using a positive displacement bellows meter at upstream oil and gas facilities across a variety of producing fields in the area.

The study found that whole gas emissions from high bleed controllers averaged 9.2 scf/h and from high bleed intermediate controllers averaged 8.7 scf/h. The average of these two type of high bleed devices was 9.0 scf/h.

The Prasino study did not collect activity data on the population of pneumatic controllers per well.

Summary of Recent Studies

Table 6 summarizes the findings of the above three studies.

Table 6. Summary of Results of Studies Discussed in this Memo

Data Element	Allen et al.	Prasino	OIPA
Pneumatic Controllers per well	Observed an average of 2.7 controllers per well measured. Authors suggest the national average may be between 1.5 to 2.7 controllers per well.	N/A	Average of 3.6 controllers per well, with variations between new and old sites and oil and gas
Bleed type fraction	N/A	N/A	97% intermittent vent; 3% continuous bleed
Emission factors	Ranging from 0.7 to 10.6 (dependent on region); averaging 4.9	9.2 scf/h high bleed; 8.7 scf/h intermediate controllers averaged 8.7 scf/h. The average of these	Average 1.05 scf whole gas/hour; 0.40 scf/h intermittent vent, 21.54 scf/h continuous bleed

[3] The Prasino Group, *Final Report- For Determining Bleed Rates for Pneumatic Devices in British Columbia,* December 18, 2013. Available online: http://www2.gov.bc.ca/gov/DownloadAsset?assetId=1F074ABD990D4EFB8AE555AEB3B8D771&filename=prasino_pneumatic_ghg_ef_final_report.pdf

		two type of high bleed devices was 9.0 scf/h	
Observations on distribution	19% of controllers responsible for 95% of emissions	N/A	3.5% of controllers responsible for 73% of emissions

Greenhouse Gas Reporting Program

EPA's Greenhouse Gas Reporting Program (GHGRP) has collected 3 years of emissions data for pneumatic controllers at oil and gas production sites. The GHGRP data currently available include total emissions from controllers by type for each facility. Starting in 2015, data will also be reported to the GHGRP on the number of controllers, by type, and total number of wells for each facility. This data could be used to allow EPA to update its assumption on the types and numbers of controllers in use for the 2016 GHG Inventory.

Table 7. Comparison of GHGRP and GHG Inventory Production Segment Pneumatic Controller CH_4 (kt)

Year	GHGRP	GHG Inventory (2015 PR draft)
2011	839	1,064
2012	879	1,072
2013	974	1,046

Request for Stakeholder Feedback

- EPA seeks feedback on activity data sources that may be used to estimate the number of pneumatic controllers per gas well and per oil well, across the Inventory time series (1990 through 2013). EPA seeks feedback on whether certain sub-populations of wells (e.g., stripper oil wells) warrant sub-population-specific assumptions.
- EPA seeks feedback on Allen et al. assumptions used to calculate national activity data for pneumatic controllers and their applicability for the GHG Inventory.
- EPA seeks feedback on an appropriate emission factor structure that may be used in the GHG Inventory to better account for the high emission rate observed for a very limited number of emission sources. Are activity data available to support this option?
- EPA seeks feedback on industry dynamics that should be reflected over the time series—i.e., how have emissions or activity data significantly changed over time; and how can EPA apply updated data across the time series that would reflect such changes?
- EPA seeks feedback on whether the same or different emission factors and activity factors should be applied for pneumatic controllers in natural gas and petroleum systems.
- There is a very high degree of regional variation in the Allen et al. study emission factors (a factor of 10, as seen in Table 3 above) which is different than the findings of the 1996 EPA-GRI study. EPA seeks comment on potential application of region-specific EFs versus national EFs in the GHG Inventory.
- EPA seeks comment on whether it is appropriate to develop activity data on a regional versus national basis for the GHG Inventory.
- The Allen et al. study noted a large number of devices with malfunctions. EPA seeks feedback on how this can be accounted for within the GHG Inventory, across all years of the time series (1990-2013).
- EPA seeks feedback on an approach to use GHGRP data in the GHG Inventory, across all years of the time series (1990-2013). One comment on the expert review draft inventory suggested

estimating the controller counts in GHGRP and increasing them by 15% to estimate national controllers. The comment also suggested applying the Allen et al. average emission values to the population of high and intermittent bleed controllers in GHGRP, and using a value of 6 scf/h to calculate low bleed emissions.

- NSPS OOOO regulates new pneumatic controllers. EPA seeks stakeholder feedback on methods that will allow the GHG Inventory to reflect changes in emissions due to the impacts of this regulation.
- EPA seeks comment on the allocation of Gas STAR reductions between the natural gas and petroleum systems categories. The 2015 public review draft of the Inventory allocates the reductions based on the potential emissions calculated for each category. Other options could include a split based on well counts. Future revisions to this category will likely include use a net calculation approach and will not rely on Gas STAR data.
- OIPA study noted differences in the number of pneumatic controllers on site for new versus old well sites. EPA seeks stakeholder feedback on approaches for applying data on new versus old sites in the GHG Inventory.