Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2021: Updates Under Consideration for Incorporating Additional Geographically Disaggregated Data

1 Introduction

This memo discusses updates under consideration for the 2023 *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (GHGI) to develop national emission estimates for certain emissions sources by quantifying emissions for those sources at the basin level and aggregating those estimates to develop the national emission estimates.

Currently in the GHGI, EPA estimates emissions from most of the emission sources in Natural Gas and Petroleum Systems at the national-level using emission factors (EFs) and activity data (AD) at the national-level. For example, for liquids unloading, EPA uses Greenhouse Gas Reporting Program (GHGRP) data to develop average national activity factors (e.g., fraction of wells conducting liquids unloading) and average national emission factors (e.g., annual emissions per well that conducts liquids unloading with a plunger lift). These average factors are then applied to the national well population to estimate national emissions.

Currently, EPA uses a basin-specific aggregation approach for two emission sources (i.e., associated gas venting and flaring and miscellaneous onshore production flaring).[1] For these emission sources, it was determined that national-level EFs and activity factors (AFs) would not reflect differences in associated gas venting and flaring among geographic regions and that over- or under-representation in GHGRP data by geographic regions where associated gas is vented or flared more or less frequently may disproportionately contribute to national-level factors. For associated gas venting and flaring (Petroleum Systems) and miscellaneous production flaring (both Petroleum and Natural Gas Systems), EPA calculates basin-specific activity and emission factors for basins that, in any year from 2011 forward, contributed at least 10 percent of total source emissions (on a CO_2 equivalents basis) in the GHGRP data. For associated gas venting and flaring, EPA calculates basin-specific factors for four basins: Williston, Permian, Gulf Coast, and Anadarko. For miscellaneous production flaring, EPA calculates basin-specific factors for three basins: Williston, Permian, and Gulf Coast. For these emission sources, data from all other basins are aggregated, and EPA calculates activity and emission factors for the other basins as a single group.

In recent years, EPA has developed additional GHG Inventory products that break out emissions from the national-level into gridded and state-level estimates.

- Gridded Inventory.[2] In an effort to improve the ability to compare the national-level Inventory with measurement results that may be at other spatial and temporal scales, a team at Harvard University along with EPA and other coauthors developed a gridded inventory of U.S. anthropogenic methane emissions with 0.1 degree x 0.1 degree spatial resolution, monthly temporal resolution, and detailed scale-dependent error characterization. The gridded methane inventory is designed to be consistent with the U.S. EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014* estimates for the year 2012, which presents national totals. An updated version of the gridded inventory is being developed and will improve efforts to compare results of the GHG Inventory with atmospheric studies.

[1] EPA 2018. Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2016: Revisions to CO_2 Emissions Estimation Methodologies. Available online at: <https://www.epa.gov/ghgemissions/natural-gas-and-petroleum-systems-ghg-inventory-additional-information-1990-2016-ghg>.

[2] U.S. EPA. Gridded 2012 Methane Emissions. https://www.epa.gov/ghgemissions/gridded-2012-methane-emissions

- State Inventory.[3] In 2022, EPA released its first annual publication of state greenhouse gas (GHG) data consistent with the GHGI, meaning state GHG totals when summed, will equal national totals in the GHGI. For Petroleum and Natural Gas Systems, the methods used to develop state-level estimates generally rely on relative differences in basic activity levels (e.g., petroleum production), and do not reflect differences between states due to differences in practices, technologies, or formation types.

Both the gridded and the state versions of the GHGI generally rely on national-level average activity and emission factors, along with location-specific information on activity drivers such as well counts or production. The update under consideration discussed in this memo seeks to improve the ability of the gridded and state inventories to reflect variation due to differences in formation types, technologies and practices, regulations, or voluntary initiatives, and not only the differences in key activity levels that are reflected in the current gridded and state inventories.

This memo discusses considerations for developing emissions estimates for the national GHGI using basin-specific data that are currently aggregated and averaged to develop national-level estimates. In this memo, EPA evaluates options to incorporate additional basin-level data from GHGRP subpart W in the GHGI. GHGRP subpart W data are used in the GHGI to calculate numerous EFs and AFs for emission sources across the industry segments in Natural Gas and Petroleum Systems.

The incorporation of these data would improve future versions of both the gridded and state-level inventories. This would allow EPA to use the gridded inventory for improved comparisons of the GHGI with various atmospheric observation studies (since regions will better reflect the local differences in emissions rates as reported to GHGRP) and would allow the state-level inventory to reflect differences in state-level programs, formation type mixes, and varying technologies and practices.

For many sources, an approach that develops estimates using geographically disaggregated data may not be possible or preferable to a national level approach based on the currently available data. For some emission sources in the GHGI, emission factor data come from research studies and are applied at the national level. For example, many of the emission factors used to quantify emissions in the GHGI for the gathering and boosting, transmission and storage, distribution, and post-meter segments are from research studies and do not have a level of detail or total population comparable to GHGRP. For petroleum refineries, because there is no reporting threshold for GHGRP subpart Y, facility-level data are generally available for all refineries in the U.S., and these site-specific data are already used to develop the gridded and state-level GHG estimates.[4] Even in cases where geographically disaggregated data are available, such an approach may not always be preferable. In cases with limited variation between areas, such an approach would have limited impact on emissions estimates regionally or nationally. In cases with limited data in certain areas, disaggregated approaches might substantially increase the uncertainty of estimates and basin-specific calculations would not be an improvement over use of a national average.

For this memo, EPA focused on the onshore oil and gas production segment, where data are available from the GHGRP that could be used to reflect distinctions in emissions levels by region, and which could impact (to varying extents) total emissions in the GHGI.

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[3] U.S. EPA. State GHG Emissions and Removals. https://www.epa.gov/ghgemissions/state-ghg-emissions-and-removals.

[4] Some refineries have ceased reporting under GHGRP. A GHGRP facility that has reported total non-biogenic GHG emissions below 15,000 metric tons of carbon dioxide equivalent (mt CO_2e) for three consecutive years or below 25,000 mt CO_2e for five consecutive years can discontinue reporting for all direct emitter subparts. In these cases, in the GHGI estimates for refineries, EPA has used previously reported data for a proxy for years without reports.

Key considerations for use of the GHGRP data for onshore production to develop subnational estimates are the variability of emissions and activity levels between basins and GHGRP coverage of total activity for each basin. EPA examined subpart W data at the basin-level to assess variability in the data and calculated the coverage of subpart W data for each basin.

An assessment of data variability between basins is used to identify if for a given emission source there is a potential impact when using basin-level activity or emissions data. To perform variability assessments, EPA identified relevant emissions or activity data to compare across basins. Examples of emission sources where emissions and activity differ greatly between basins are presented in this memo.

GHGRP subpart W reporting coverage (assessed as activity that is included in GHGRP for a basin versus total activity for that basin) information is useful for assessing representativeness of reported data. Subpart W of the EPA's GHGRP collects annual activity and emissions data on numerous sources from Natural Gas and Petroleum Systems that meet a reporting threshold of 25,000 metric tons of CO_2 equivalent (CO_2e) emissions. Reporting requirements under subpart W began in reporting year (RY) 2011 for onshore production. Onshore production facilities in subpart W are defined as a unique combination of operator and basin of operation (i.e., all operator sites within a basin). Coverage of onshore production activities varies by basin. EPA is considering a variety of approaches to take coverage into consideration when evaluating and potentially implementing basin-specific calculations such as including basin-specific data for all basins regardless of coverage, selecting a coverage threshold and aggregating basin data from basins with lower coverage and developing a combined AF/EF for those basins, combining data from neighboring basins, retaining the national level approach, or developing another approach to rely on a larger (combined) dataset for emissions in those areas. In this memo, several examples are provided of an approach that would use 50 percent as a coverage threshold for basin-specific calculations. This coverage threshold was selected only for demonstration purposes. EPA is seeking stakeholder feedback on approaches for incorporating additional basin-level data including the use of a coverage threshold, and in case of its use, an appropriate coverage threshold level. Other approaches to address coverage could also be considered, such as a threshold based on the number of reported wells or number of reporters in each basin. Coverage data are also needed to determine how to scale emissions and/or activity from reported totals to basin totals.

For this memo, EPA examined the coverage of RY2020 subpart W data by estimating the percentage of each basin's oil and gas operations that subpart W data represents for each industry segment. The GHGRP subpart W data used in the analyses discussed in this memo are for RY2020 reported to the EPA as of August 7, 2021. In general, the coverage calculations equal subpart W RY2020 activity for a given basin divided by activity from a national dataset for the year 2020 for the given basin. In most cases, the national dataset is the same data source used in the GHGI.

GHGRP has proposed revisions to subpart W, some of which could impact sources discussed in this memo. The general analyses and approaches discussed in this memo would likely be applicable to both current and future GHGRP data.

The variability and coverage assessments conducted for onshore production are discussed in Section 2, with additional detail in Appendix A. Time series considerations are discussed in Section 3. Considerations for other segments are discussed in Section 4, with additional detail in Appendix B. Section 5 presents questions for stakeholder feedback.

2 Onshore Production

EPA assessed the three highest emitting sources within the onshore production segment for potential basin-level approaches. EPA analyzed subpart W basin-level data for pneumatic controllers (45 MMT CO_2e in the GHGI for 2020), associated gas flaring (15 MMT CO_2e in the GHGI in 2020), and well pad equipment (12 MMT CO_2e, including well pad equipment leaks and chemical injection pumps).

In addition, EPA assessed basin-level coverage of subpart W onshore production segment data relative to national data. Enverus data are currently used in the GHGI for national well counts and production volumes. Subpart W reports contain well counts and oil and gas production volumes for operators that meet the GHGRP reporting threshold, while Enverus contains well counts and oil and gas production volumes for all operators in the country. Coverage was determined at the basin level as the percentage of the national dataset included in subpart W data.

2.1 Variability

EPA reviewed pneumatic controller, associated gas flaring, and well pad equipment data to assess variability in subpart W data between basins.

2.1.1 Pneumatic Controllers—CH_4

In the current GHGI, EPA estimates pneumatic controller emissions using AFs and EFs developed from subpart W data at the national-level. The AFs are updated annually. Two types of AFs are calculated: (1) average controllers per well and (2) the fraction of controllers that are low-bleed, intermittent bleed, and high-bleed controllers. These AFs were calculated separately for gas wells and for oil wells. EFs were calculated for the different types of controllers using RY2014 data and combining oil and gas. To assess basin variability, EPA calculated the average controllers per well for each basin separately for gas wells and oil wells, using RY2020 subpart W data. Table 1 presents examples of AFs (i.e., pneumatic controllers per well) across select basins (i.e., basins with high well counts) listed in order of well population in Enverus and compares to the current GHGI estimate.

Table 1. Pneumatic Controllers Per Well for Select Basins (RY2020 Subpart W)

Basin Name	Basin Number	Controllers/Well (Gas)	Controllers/Well (Oil)
Current GHGI[a]		*1.9*	*1.37*
Permian	430	1.35	1.18
Appalachian (Eastern Overthrust)	160A	1.06	3.34
Appalachian	160	0.43	4.88
Anadarko	360	1.34	2.80
Gulf Coast	220	2.38	2.97
Williston	395	0.14	1.13

a. The current GHGI equals the average of all subpart W data for RY2020.

Compared to the current GHGI AF, most of the basins in Table 1 have a lower AF for gas well controllers and a higher AF for oil well controllers. Conversely, the Gulf Coast basin AF for gas well controllers is close to or more than double the AF for other basins while the oil well controller AFs for the two Appalachian basins are also higher than other basins.

EPA also calculated basin-level fractions of low-bleed, intermittent bleed, and high-bleed controllers for oil and gas wells separately. Table 2 presents examples of controller type fractions across select basins and compares to the current GHGI estimate.

Table 2. Pneumatic Controller Type Fractions for Select Basins (RY2020 Subpart W)

Basin Name	Basin Number	Bleed Type Fractions (Gas)			Bleed Type Fractions (Oil)		
		Low	Intermittent	High	Low	Intermittent	High
Current GHGI[a]		*0.26*	*0.73*	*0.01*	*0.29*	*0.70*	*0.01*
Permian	430	0.13	0.87	0.01	0.37	0.62	0.01
Appalachian (Eastern Overthrust)	160A	0.16	0.84	0	0.20	0.80	0
Appalachian	160	0.06	0.94	0	0.11	0.89	0
Anadarko	360	0.18	0.74	0.08	0.21	0.74	0.06
Gulf Coast	220	0.19	0.81	0	0.20	0.80	0
Williston	395	0.01	0.97	0.02	0.13	0.86	0.01

a. The current GHGI equals the average of all subpart W data for RY2020.
b. The bleed type fractions don't add up to 1, in some instances, due to rounding.

EPA applies separate pneumatic controller EFs in the current GHGI for low-bleed, intermittent-bleed, and high-bleed controllers calculated using subpart W RY2014 data. The same EFs are used for both gas wells and oil wells. As part of its analyses, EPA calculated EFs separately for controllers at gas wells and oil wells using RY2020 subpart W data. The EFs also show differences across basins and for controllers at gas wells versus oil wells. The complete set of AFs and EFs calculated for all basins are provided in Table A.4 of Appendix A.

EPA is considering several options for the GHGI approach for pneumatic controllers:

1. National-level approaches

   Option 1: Maintain current GHGI approach. Use RY2014 EFs, that combine data for controllers at oil wells and gas wells, with year-specific AFs.

   Option 2: Apply year-specific EFs, that combine data for controllers at oil wells and gas wells, at the national level with year-specific AFs.

2. Basin-level approaches

   Option 3: Apply year- and basin-specific AFs and EFs, developed separately for controllers at oil wells and gas wells, for all basins. Apply national-level average AFs and EFs, developed separately for controllers at oil wells and gas wells, for basins that have no GHGRP reporting.

   Option 4: Apply year- and basin-specific AFs and EFs, developed separately for controllers at oil wells and gas wells, for the 20 basins with more than 50 percent coverage (as an example threshold) of total wells and aggregate data from all other basins together. Aggregated AFs and EFs, calculated using data from those aggregated basins, were also used for basins that have no GHGRP reporting.

Table 3 shows the impact on the overall pneumatic controller emissions for 2020 for each option.

Table 3. Pneumatic Controller Emissions for Different Options, Year 2020

Option	Gas Well Controller CH_4 Emissions (mt)	Oil Well Controller CH_4 Emissions (mt)	Total Well Controller CH_4 Emissions (mt)
Option 1: Current GHGI	*950,718*	*853,546*	*1,804,264*
Option 2: Updated National-Level Factors	836,441	705,393	*1,541,834*
Option 3: Basin-Specific Factors for All Basins	765,884	1,096,239	*1,862,123*
Option 4: Basin-Specific Factors for Basins with >50% Coverage	731,994	968,184	*1,700,178*

Option 2, using RY2020 data to calculate separate national-level AFs and EFs for oil and gas well pneumatic controllers, results in lower calculated national emissions for 2020 compared to the current GHGI estimate (Option 1) calculated using RY2014 EFs. In both approaches that utilize basin-level data (i.e., Option 3 and Option 4), gas well pneumatic controller emissions decrease and oil well pneumatic controller emissions increase, compared to both national-level approaches (i.e., Option 1 and Option 2). The basin-specific approaches lead to a decrease in gas well controller emissions because the AFs for certain basins with high activity generally have lower AFs than the national AFs, and the aggregated AFs are lower than the national AFs. For example, the Permian basins and the two Appalachian basins have much lower emissions using a basin-specific approach compared to using national average data. In addition, the Appalachian Eastern Overthrust basin (160A) does not meet the total wells coverage example threshold of 50%, but accounts for the majority of the aggregated data because there is much more subpart W data reported for this basin compared to other basins that are below the threshold. Conversely, the basin-specific approaches lead to an increase in oil well controller emissions because the AFs for certain basins with high activity generally have higher AFs than the national AFs, and the aggregated AFs are higher than the national AFs. For example, the Gulf Coast, Anadarko, and the two Appalachian basins have significantly higher emissions from oil well controllers using the basin-specific approach compared to using national average data.

The difference in emissions between the two basin-specific approaches (i.e., Option 3 and Option 4) is largely due to the two Appalachian basins, which have oil well AFs (controllers per well) that are higher than other basins. Neither Appalachian basin meets the total wells coverage example threshold of 50% and thus basin-specific calculations for the Appalachian basins are only in Option 3. When Appalachian AFs and EFs from subpart W are applied to all oil wells in the Appalachian basins, it has a large impact on total calculated national emissions from oil wells (i.e., emissions increase). The Appalachian basins have a relatively large population of oil wells owned by facilities that do not report under subpart W. The Appalachian Eastern Overthrust basin (basin 160A) data reported to subpart W for 2020 includes information from 1,129 oil wells. In the Appalachian basin (basin 160), data reported to subpart W for 2020 includes information from 26 wells. For comparison, national level activity and emission factors for pneumatic controllers currently used in the GHGI draw on subpart W data from around 500,000 wells.

2.1.2 Associated Gas Flaring—CO_2

EPA assessed CO_2 emission factor variability between basins for associated gas flaring. The current GHGI uses basin-specific calculations for four basins (i.e., 220 Gulf Coast, 360 Anadarko, 395 Williston, and 430 Permian) and applies an aggregated approach to the remaining basins. These four basins represent nearly 98 percent of total oil produced in 2020. For this memo, EPA calculated EFs and AFs for all 16 basins with associated gas emissions data reported to subpart W in RY2020. Of the 16 basins, ten basins have more than 50 percent

coverage (example threshold) for oil production. Table 4 presents the flaring CO_2 EFs, percent of gas flared, and percent of liquids production with associated gas for these ten basins (listed in ascending order by basin number, with the four basins used in the current GHGI included first and shown in *italics*).

Table 4. Associated Gas Flaring CO_2 EFs and AFs (RY2020 Subpart W)

Basin Name	Basin Number	CO_2 EF (scf/bbl)	Percent of Associated Gas that is Flared	Percent of Liquids Production with Associated Gas
Gulf Coast[a]	*220*	*430*	*98%*	*7%*
Anadarko	*360*	*159*	*64%*	*1%*
Williston	*395*	*584*	*100%*	*58%*
Permian	*430*	*203*	*98%*	*21%*
Michigan	305	1,155	87%	25%
Powder River	515	438	100%	19%
Green River	535	1,432	100%	1%
Denver	540	2,521	100%	0.5%
Uinta	575	986	99%	5%
San Juan	580	22	99%	11%
All Others		1,508	21%	1%
Current GHGI All Others		*737*	*75%*	*3%*
National Average in GHGRP	All reporting	397	98%	20%

a. The current GHGI relies on basin-specific calculations for the Anadarko, Gulf Coast, Permian, and Williston Basins and aggregates data from all other basins. *Italicized rows show the input values currently used in the GHGI.*

As seen in Table 4, there is considerable variability between the basins in terms of the EF and the AF for the percent of liquids production with associated gas. The CO_2 EFs vary from 22 to 2,521 scf per barrel of liquids production, while the percent of liquids production with associated gas ranges from 0.5 percent to 58 percent across the basins.

Next, EPA examined the impact of including additional basin-specific information on national emissions. EPA calculated associated gas flaring CO_2 emissions using the following three options:

1. Applying a basin-level approach for all 16 basins with associated gas emissions data reported to subpart W. For basins with no GHGRP reporting, aggregated EFs and AFs developed for all other basins were used.

2. Applying a basin level approach for the 10 basins with more than 50 percent of oil production coverage (example threshold) and that have associated gas emissions data reported to subpart W, and using aggregated data from all other basins. For basins with no GHGRP reporting, aggregated EF and AF developed for all other basins were used.

3. Applying a national-level approach.

Table 5 compares associated gas flaring emissions from the current GHGI to the two basin-level approaches and the national-level approach.

Table 5. Associated Gas Flaring CO_2 Emissions for Different Options, Year 2020

Option	Associated Gas Flaring CO_2 Emissions (mt)
Current GHGI	*13,041,364*
Option 1: Basin-Specific Factors for All Basins	13,201,231
Option 2: Basin-Specific Factors for Basins with >50% Coverage (example threshold)	13,013,920
Option 3: National-Level Factors	14,613,229

After calculating and comparing the emissions for each method of basin selection, the national emissions estimates exhibited only a small change between the different basin-level options. Furthermore, estimating basin-specific emissions for basins with lower oil production coverage did not lead to dramatically higher or lower emissions at the national level. The associated gas venting and flaring emission source is unique in that a few basins dominate the emissions. As such, it is not unexpected that adjusting the approaches for the other basins does not significantly change the national emissions because the EPA already accounts for basin-specific calculations for the basins that account for the majority of the emissions. As discussed in more detail in EPA 2018[5], use of a national-level approach for associated gas (Option 3) results in higher calculated emissions.

2.1.3 Other Well Pad Equipment

The current GHGI uses subpart W data to calculate AFs (e.g., average number of separators per gas well) for several emission sources in onshore production. EPA calculates the current GHGI AFs separately for equipment on gas wells versus oil wells using RY2014 data. For gas wells, EPA calculates AFs for separators, heaters, dehydrators, meters/piping, compressors, and chemical injection pumps. For oil wells, EPA calculates AFs for separators, heater-treaters, headers, and chemical injection pumps.

For this memo, EPA calculated AFs for each emission source at the basin-level, using RY2020 subpart W data. Table A.5 in Appendix A presents the results for all basins and sources. Table 6 presents the results for separators and chemical injection pumps for select basins.

Table 6. Well Pad Equipment Leak AFs for Select Basins (RY2020 Subpart W)

Basin Name	Basin Number	Separator Activity Factors		Chemical Injection Pump Activity Factors	
		Separators/ Gas Well	Separators/ Oil Well	Pumps/ Gas Well	Pumps/ Oil Well
Current GHGI (RY 2014 AFs)		*0.71*	*0.36*	*0.18*	*0.07*
Combined RY2020 AFs		0.76	0.45	0.06	0.22
Permian	430	0.90	0.43	0.09	0.01
Appalachian (Eastern Overthrust)	160A	0.50	0.46	0.03	0.03
Appalachian	160	0.27	0.73	0.00	0.04

[5] EPA 2018. Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2016: Revisions to CO2 Emissions Estimation Methodologies. https://www.epa.gov/sites/default/files/2018-04/documents/ghgemissions_co2_2018.pdf

Basin Name	Basin Number	Separator Activity Factors		Chemical Injection Pump Activity Factors	
		Separators/ Gas Well	Separators/ Oil Well	Pumps/ Gas Well	Pumps/ Oil Well
Anadarko	360	0.57	1.17	0.13	0.40
Gulf Coast	220	0.87	0.87	0.22	0.36
Williston	395	1.08	0.59	0.00	0.03

There is variability between basins for the AFs for separators and chemical injection pumps, with values above and below the current GHGI. For example, separators vary from 0.27 to 1.08 separators per gas well and 0.43 to 1.17 separators per oil well.

2.2 Coverage

For the pneumatic controller and other well equipment examples, EPA assessed basin-level coverage of wells in GHGRP. Well coverage was considered in three different ways: for all well types, for oil wells only, and for gas wells only. The GHGI uses the gas-to-oil ratio (GOR) to determine whether a well in Enverus is an "oil well" or a "gas well." Wells with a GOR less than or equal to 100 are classified as oil wells, while wells with a GOR greater than 100 are classified as gas wells. EPA uses the formation type to classify subpart W wells as either oil wells or gas wells. Specifically, subpart W wells reported under the "oil" formation type are classified as oil wells and wells reported under all other formation types are classified as gas wells. Both datasets reflect wells that produced at some time within a year; for subpart W data that equals the number of producing wells at the end of the calendar year plus wells permanently taken out of production.

Throughout the memo, an example threshold of 50 percent overage is applied. Of the 65 basins with oil or gas production, 20 have more than 50 percent coverage of the national dataset in subpart W for all wells. Eleven of the 65 basins have at least 50 percent coverage in subpart W for oil wells and 24 basins have at least 50 percent coverage in subpart W for gas wells.

For the 13 basins with well counts exceeding 20,000 (collectively accounting for 76 percent of all wells in 2020); eight basins have more than 50 percent coverage of the national dataset in subpart W for all wells, four basins have more than 50 percent coverage of oil wells in subpart W, and ten basins have more than 50 percent coverage of gas wells in subpart W.

Appendix A contains detailed tables comparing the basin-level populations of subpart W wells versus the national dataset for total wells, oil wells, and gas wells. The well counts tables in Appendix A are organized in descending order of national well counts.

2.3 Considerations for Production Emission Sources

EPA reviewed the onshore production segment emissions data and calculation methodologies to identify update considerations for individual emission sources. A majority of the sources with the largest emissions for Natural Gas and Petroleum Systems rely on subpart W data for emission factors and/or activity factors. Table 7 presents emissions by source, for the ten highest emitting sources, and information on how subpart W data are used, where applicable, in the calculation methodology. For emission sources that use subpart W data, EPA is considering updating the calculation methodology to use basin-level data.

Table 7. Current GHGI Onshore Exploration and Production Emission Source Emissions and Methodology Information

Emission Source	Natural Gas Systems		Petroleum Systems	
	Subpart W Used in GHGI?	Specific Year vs. Range in GHGI	Subpart W Used in GHGI?	Specific Year vs. Range in GHGI
Pneumatic Controllers	Yes (AF and EF)	AF updated annually, EF static value from 2014	Yes (AF and EF)	AF updated annually, EF static value from 2014
Associated Gas Venting / Flaring	N/A	N/A	Yes (AF and EF)	updated annually, 2015 - 2020
Well Pad Equipment Leaks[a]	Yes (AF)	2015	Yes (AF)	2015
Tanks	Yes (AF and EF)	updated annually, 2015 - 2020	Yes (AF and EF)	updated annually, 2015 - 2020
Gas Engines	No	N/A	No	N/A
Miscellaneous Onshore Production Flaring	Yes (AF and EF)	updated annually, 2015 - 2020	Yes (AF and EF)	updated annually, 2015 - 2020
Produced Water	No	N/A	No	N/A
Chemical Injection Pumps	Yes (AF and EF)	N/A	Yes (AF and EF)	N/A
Liquids Unloading	Yes (AF and EF)	updated annually, 2011 - 2020	N/A	N/A
Dehydrator Vents	No	N/A	N/A	N/A

a. For NG systems, GHGRP data are used for AFs for heaters, separators, dehydrators, compressors, and meters/piping. For Petroleum systems, GHGRP data are used for Afs for separators, compressors, headers, and heater/treaters. Leak emissions from wellheads are not calculated using GHGRP data.

3 Time Series Considerations

For most sources, reporting under GHGRP for onshore production began with emissions data for the year 2011. Basin-specific emissions information is unavailable for previous years. EPA is considering several approaches for developing the 1990-2021 times series for the 2023 GHGI. For example, EPA could generally apply at the basin-level the approaches currently used across the time series at the national level. For pneumatic controllers for example, in each basin, EPA could apply the 1992 (earliest year with available data) national average AF values for 1990-1992, use year-specific data for 2011-2021, and interpolate AD between 1992 and 2011. A similar approach could be taken for "other well pad equipment." Values for years prior to GHGRP are not available for associated gas venting and flaring. In addition, GHGRP-reported production data used to calculate associated gas venting and flaring data were first reported in RY2015. To be consistent with the current GHGI, a time series approach for this source would likely apply the basin-level EFs developed for 2015 to all previous years of the time series.

4 Considerations for Other Industry Segments

Considerations for implementing basin or state-level approaches vary by industry segment due to the extent to which GHG Inventory approaches already reflect variation and available data for basin or state-level approaches.

- Exploration. The current gridded GHGI and state GHGI reflect region-specific completion and drilling counts; however, the EFs applied are national averages (developed from GHGRP data). EPA could consider use of basin-specific information (AD and EFs) on completion type (e.g., with and without RECs) from GHGRP. This would likely have a small impact on total basin-level oil and gas emissions, since this

is a relatively small source. Basin-specific EFs for drilling are unavailable. See Appendix B for additional information.

- Gathering and Boosting. Spatial allocation for gathering and boosting in the gridded GHGI and state GHGI is largely based on production data. For this sector, the GHGI uses national EFs and GHGRP AD. The GHGI scales up emissions using an assumption of 93 percent subpart W coverage for gathering and boosting stations and 100 percent subpart W coverage for gathering pipelines. Because of these coverage assumptions and current lack of other data to assess coverage, incorporating basin-level variation in the GHGI would not impact national emissions. See Appendix B for additional information.
- Processing. The current GHGI uses GHGRP data for AFs and EFs and *Oil and Gas Journal* data to scale up to the national level. An initial assessment of variation between states found limited variation in CH_4 emissions, but larger variation in CO_2 emissions. See Appendix B for additional information.
- Transmission and Storage. The current GHGI uses GHGRP data for AFs and largely relies on a national-level research study for EFs. Transmission and storage segments have lower GHGRP coverage than other segments, which would mean that state-level EFs would rely on a small data set in many states. See Appendix B for additional information.
- Distribution. Both the gridded GHGI and state GHGI reflect location-specific pipeline materials. Regional EFs are unavailable in the GHGI data set for other distribution sources.
- Post-meter. The EFs used in the GHGI do not include region-specific information.
- Refineries. The gridded GHGI and state GHGI use GHGRP data directly and therefore already reflect facility and state differences.

5 Requests for Stakeholder Feedback

EPA seeks stakeholder feedback on the update under consideration discussed in this memo and the questions below.

1. The potential benefits and potential disadvantages of updating the GHGI to use an approach that incorporates additional basin-level calculations.
2. Approaches for quantifying emissions for the full time series.
3. Considerations for prioritizing sources for application of a more disaggregated approach.
4. Prioritization for the production segment examples given.
5. Use of basin-specific data for all basins, or application of a coverage threshold for use of basin-specific data for a basin versus a national or other average value.
6. Type and level of coverage threshold (e.g., percentage total activity covered by subpart W, a certain number of wells included in the data set), and the rationale for a threshold.
7. If a coverage threshold were to be applied, approaches for basins with coverage below a threshold (e.g., combining data for basins below the threshold to develop EFs/AFs for all basins below the threshold or using data from all basins to apply to basins below the threshold).
8. Data sources in addition to GHGRP that EPA should consider for disaggregating emissions data to a basin-level.

9. Additional industry segments for which EPA should consider basin-/state-level approaches.
10. Underlying reasons for examples of variation noted in this memo (e.g., differences form national averages for Gulf Coast and Appalachia for pneumatic controllers). For example, are production conditions in certain basins likely to result in the use of more or fewer controllers per well?

Appendix A – Onshore Production Segment Assessment Tables

All appendix A tables (A.1 – A.5) are ordered in descending order of well counts in the national dataset. Subpart W and national well counts reflect wells that produced at some time within a year; for subpart W data that equals the number of producing wells at the end of the calendar year plus wells permanently taken out of production.

Table A.1. Total Well Population Coverage for Year 2020 – Subpart W Versus National Dataset (Enverus), for Basins with Reported Wells in Either Dataset

Basin Name	Basin Number	Subpart W Wells	Total Wells	% Coverage
Permian	430	104,650	156,740	67%
Appalachian (Eastern Overthrust Area)	160A	63,403	139,955	45%
Anadarko	360	38,397	69,759	55%
Appalachian	160	31,058	68,432	45%
Gulf Coast	220	39,843	62,993	63%
San Joaquin	745	41,346	39,020	106%
Arkla	230	9,075	29,554	31%
East Texas	260	15,494	29,060	53%
Illinois	315	0	29,017	0%
San Juan	580	21,317	23,479	91%
Williston	395	19,928	22,541	88%
Denver	540	18,027	21,090	85%
Chautauqua Platform	355	501	20,968	2%
Arkoma	345	9,555	17,654	54%
Cherokee	365	0	16,826	0%
Piceance	595	13,304	14,701	90%
Fort Worth Syncline	420	7,123	14,667	49%
Central Kansas Uplift	385	0	13,895	0%
Bend Arch	425	0	13,877	0%
South Oklahoma Folded Belt	350	1,668	13,156	13%
Michigan	305	8,841	12,491	71%
Green River	535	11,290	12,484	90%
Forest City	335	0	11,001	0%
Uinta	575	9,821	10,728	92%
Powder River	515	1,932	10,571	18%
Strawn	415	8,068	7,211	112%
Sedgwick	375	189	7,167	3%
Palo Duro	435	281	6,224	5%
Black Warrior	200	0	4,460	0%
Ouachita Folded Belt	400	167	3,811	4%
Sweetgrass Arch	500	0	3,553	0%
Las Vegas-Raton	455	2,455	3,522	70%
Mid-Gulf Coast	210	1,103	3,231	34%
Los Angeles	760	446	3,160	14%
Wind River	530	567	2,801	20%

Basin Name	Basin Number	Subpart W Wells	Total Wells	% Coverage
Big Horn	520	0	2,516	0%
Nemaha Anticline	370	0	2,212	0%
Arctic Coastal Plains Province	890	2,927	1,883	155%
Central Western Overthrust	507	1,482	1,723	86%
Las Animas Arch	450	278	1,711	16%
Ventura	755	0	1,328	0%
Cincinnati Arch	300	0	1,283	0%
Paradox	585	424	1,214	35%
Chadron Arch	390	0	977	0%
Coastal	740	201	894	22%
Central Montana Uplift	510	0	893	0%
Santa Maria	750	741	844	88%
Sacramento	730	683	799	85%
Sierra Grande Uplift	445	0	681	0%
Salina	380	0	297	0%
AK Cook Inlet	820	287	170	169%
North Park	545	18	133	14%
Llano Uplift	410	0	65	0%
Great Basin Province	625	0	65	0%
Overthrust & Wasatch Uplift	630	0	33	0%
Eel River	720	0	26	0%
Mojave	640	0	24	0%
Upper Mississippi Embayment	250	0	19	0%
Black Mesa	590	0	17	0%
Northern Coast Range Prov	725	0	17	0%
Florida Platform	140	0	16	0%
Western Columbia	710	0	10	0%
Kerr	405	0	3	0%
Santa Cruz	735	0	2	0%
Sierra Nevada Province	650	0	1	0%

Table A.2. Oil Well Population Coverage for Year 2020 – Subpart W Versus National Dataset (Enverus), for Basins with Reported Wells in Either Dataset

Basin Name	Basin Number	Subpart W Oil Wells	Total Oil Wells	% Coverage
Permian	430	91,547	132,457	69%
Gulf Coast	220	22,671	48,770	46%
San Joaquin	745	41,346	38,228	108%
Appalachian (Eastern Overthrust Area)	160A	1,127	32,587	3%
Anadarko	360	11,468	32,143	36%
Illinois	315	0	27,513	0%
Williston	395	17,261	19,644	88%
Appalachian	160	26	18,790	0%
Chautauqua Platform	355	143	16,312	1%
Denver	540	8,018	14,313	56%
Arkla	230	845	14,282	6%
Central Kansas Uplift	385	0	13,456	0%
Cherokee	365	0	12,719	0%
East Texas	260	810	11,957	7%
South Oklahoma Folded Belt	350	783	11,114	7%
Forest City	335	0	10,961	0%
Bend Arch	425	0	10,430	0%
Palo Duro	435	5	5,696	0%
Powder River	515	1,751	5,578	31%
Uinta	575	4,662	5,374	87%
Fort Worth Syncline	420	491	5,119	10%
Sedgwick	375	188	4,237	4%
Michigan	305	1,847	3,551	52%
Ouachita Folded Belt	400	0	3,293	0%
Los Angeles	760	446	3,102	14%
Green River	535	192	3,068	6%
San Juan	580	898	2,247	40%
Big Horn	520	0	2,182	0%
Nemaha Anticline	370	0	2,130	0%
Mid-Gulf Coast	210	612	2,108	29%
Wind River	530	10	2,032	0%
Sweetgrass Arch	500	0	1,749	0%
Arctic Coastal Plains Province	890	2,926	1,745	168%
Piceance	595	24	1,299	2%
Ventura	755	0	1,258	0%
Arkoma	345	0	1,143	0%
Cincinnati Arch	300	0	1,109	0%
Chadron Arch	390	0	977	0%
Coastal	740	201	894	22%
Las Animas Arch	450	0	856	0%
Santa Maria	750	741	768	96%

Basin Name	Basin Number	Subpart W Oil Wells	Total Oil Wells	% Coverage
Paradox	585	343	652	53%
Central Western Overthrust	507	26	406	6%
Salina	380	0	297	0%
Central Montana Uplift	510	0	231	0%
Black Warrior	200	0	138	0%
North Park	545	0	131	0%
Strawn	415	139	86	162%
Great Basin Province	625	0	65	0%
Llano Uplift	410	0	65	0%
AK Cook Inlet	820	56	34	165%
Overthrust & Wasatch Uplift	630	0	33	0%
Mojave	640	0	24	0%
Northern Coast Range Prov	725	0	17	0%
Florida Platform	140	0	16	0%
Black Mesa	590	0	9	0%
Sacramento	730	0	9	0%
Kerr	405	0	3	0%
Santa Cruz	735	0	2	0%

Table A.3. Gas Well Population Coverage for Year 2020 – Subpart W Versus National Dataset (Enverus) for Basins with Wells Reported in Either Dataset

Basin Name	Basin Number	Subpart W Gas Wells	Total Gas Wells	% Coverage
Appalachian (Eastern Overthrust Area)	160A	62,276	107,368	58%
Appalachian	160	31,032	49,642	63%
Anadarko	360	26,929	37,616	72%
Permian	430	13,103	24,283	54%
San Juan	580	20,419	21,232	96%
East Texas	260	14,684	17,103	86%
Arkoma	345	9,555	16,511	58%
Arkla	230	8,230	15,272	54%
Gulf Coast	220	17,172	14,223	121%
Piceance	595	13,280	13,402	99%
Fort Worth Syncline	420	6,632	9,548	69%
Green River	535	11,098	9,416	118%
Michigan	305	6,994	8,940	78%
Strawn	415	7,929	7,125	111%
Denver	540	10,009	6,777	148%
Uinta	575	5,159	5,354	96%
Powder River	515	181	4,993	4%
Chautauqua Platform	355	358	4,656	8%
Black Warrior	200	0	4,322	0%
Cherokee	365	0	4,107	0%
Las Vegas-Raton	455	2,455	3,522	70%
Bend Arch	425	0	3,447	0%
Sedgwick	375	1	2,930	0%
Williston	395	2,667	2,897	92%
South Oklahoma Folded Belt	350	885	2,042	43%
Sweetgrass Arch	500	0	1,804	0%
Illinois	315	0	1,504	0%
Central Western Overthrust	507	1,456	1,317	111%
Mid-Gulf Coast	210	491	1,123	44%
Las Animas Arch	450	278	855	33%
San Joaquin	745	0	792	0%
Sacramento	730	683	790	86%
Wind River	530	557	769	72%
Sierra Grande Uplift	445	0	681	0%
Central Montana Uplift	510	0	662	0%
Paradox	585	81	562	14%
Palo Duro	435	276	528	52%
Ouachita Folded Belt	400	167	518	32%
Central Kansas Uplift	385	0	439	0%
Big Horn	520	0	334	0%
Cincinnati Arch	300	0	174	0%
Arctic Coastal Plains Province	890	1	138	1%

Basin Name	Basin Number	Subpart W Gas Wells	Total Gas Wells	% Coverage
AK Cook Inlet	820	231	136	170%
Nemaha Anticline	370	0	82	0%
Santa Maria	750	0	76	0%
Ventura	755	0	70	0%
Los Angeles	760	0	58	0%
Forest City	335	0	40	0%
Eel River	720	0	26	0%
Upper Mississippi Embayment	250	0	19	0%
Western Columbia	710	0	10	0%
Black Mesa	590	0	8	0%
North Park	545	18	2	900%
Sierra Nevada Province	650	0	1	0%

Table A.4. RY2020 Subpart W Basin-Level Pneumatic Controllers AFs and EFs (for Basins Reporting Pneumatic Controllers in 2020)

Basin Name	Basin Number	Controllers/Well AF		Fraction Low-Bleed		Low-Bleed EF (scfd/device)		Fraction Intermittent-Bleed		Intermittent Bleed EF (scfd/device)		Fraction High-Bleed		High Bleed EF (scfd/device)	
		Gas	Oil	Gas	Oil	Gas	Oil	Gas	Oil	Gas	Oil	Gas	Oil	Gas	Oil
Permian	430	1.3	1.2	0.1	0.4	21.0	22.2	0.9	0.6	89.8	153.0	0.01	0.01	488.7	545.3
Appalachian (Eastern)	160A	1.1	3.3	0.2	0.2	28.5	25.8	0.8	0.8	196.1	223.4	0.002	-	599.7	-
Anadarko	360	1.3	2.8	0.2	0.2	25.4	23.1	0.7	0.7	214.8	223.8	0.08	0.06	620.5	716.7
Appalachian	160	0.4	4.9	0.1	0.1	25.7	27.7	0.9	0.9	229.8	261.8	-	-	-	-
Gulf Coast	220	2.4	3.0	0.2	0.2	21.3	21.9	0.8	0.8	169.7	206.2	0.005	0.002	670.7	629.9
San Joaquin	745	-	0.0	-	-	-	-	-	1.0	-	220.7	-	-	-	-
Arkla	230	2.1	1.2	0.1	0.0	29.9	23.4	0.8	0.9	256.7	229.6	0.01	0.12	682.9	593.0
East Texas	260	1.5	1.2	0.2	0.1	31.9	28.1	0.7	0.9	261.1	254.7	0.03	0.01	795.7	545.9
San Juan	580	5.1	2.4	0.5	0.7	23.2	21.5	0.5	0.3	238.9	279.4	0.004	0.01	751.5	781.2
Williston	395	0.1	1.1	0.0	0.1	12.8	11.9	1.0	0.9	306.7	156.9	0.02	0.01	868.2	466.3
Denver	540	3.2	2.7	0.1	0.1	13.7	14.1	0.9	0.9	138.4	125.3	-	-	-	-
Chautauqua Platform	355	1.0	0.5	0.1	1.0	23.6	17.8	0.9	-	247.4	-	-	-	-	-
Arkoma	345	1.7	-	0.0	-	30.1	-	0.9	-	86.6	-	0.07	-	793.7	-
Piceance	595	3.4	2.7	0.2	-	28.4	-	0.8	1.0	163.5	272.1	-	-	-	-
Fort Worth Syncline	420	1.5	0.7	0.5	0.3	27.7	18.5	0.5	0.7	232.1	236.0	0.01	0.01	739.5	686.5
South Oklahoma Folded Belt	350	1.9	2.1	0.2	0.1	21.9	21.7	0.8	0.9	213.0	209.2	-	-	-	-
Michigan	305	0.5	0.6	0.1	0.2	25.7	24.9	0.9	0.7	236.3	230.2	0.01	0.08	663.6	666.9
Green River	535	4.2	3.2	0.2	0.6	27.2	20.5	0.7	0.4	127.9	196.7	0.001	0.002	704.4	996.6
Uinta	575	3.5	6.0	0.6	0.5	27.9	19.2	0.4	0.5	174.5	162.2	0.0001	-	809.4	-
Powder River	515	0.7	1.4	0.9	0.2	16.4	18.5	0.1	0.8	198.2	195.3	-	0.0004	-	358.1
Strawn	415	2.6	1.4	0.1	0.8	28.8	30.5	0.9	0.2	241.4	296.9	0.01	-	771.1	-
Sedgwick	375	4.0	2.6	-	-	-	-	1.0	1.0	264.3	264.5	-	-	-	-
Palo Duro	435	0.9	0.8	-	-	-	-	-	-	-	-	1.00	1.00	688.7	739.2
Ouachita Folded Belt	400	4.1	-	-	-	-	-	0.7	-	243.6	-	0.25	-	664.9	-
Las Vegas-Raton	455	0.1	-	-	-	-	-	1.0	-	319.9	-	-	-	-	-
Mid-Gulf Coast	210	1.0	0.9	0.0	0.5	32.3	3.2	1.0	0.5	299.7	267.5	0.01	0.02	793.9	895.8
Wind River	530	4.2	3.6	0.6	0.5	26.6	27.6	0.3	0.2	249.2	306.0	0.12	0.31	787.9	812.8
Central Western Overthrust	507	5.4	4.7	0.3	0.5	23.7	15.5	0.7	0.5	194.8	151.7	0.01	0.01	711.9	490.9
Las Animas Arch	450	0.4	-	-	-	-	-	1.0	-	215.3	-	-	-	-	-

Basin Name	Basin Number	Controllers/Well AF		Fraction Low-Bleed		Low-Bleed EF (scfd/device)		Fraction Intermittent-Bleed		Intermittent Bleed EF (scfd/device)		Fraction High-Bleed		High Bleed EF (scfd/device)	
		Gas	Oil	Gas	Oil	Gas	Oil	Gas	Oil	Gas	Oil	Gas	Oil	Gas	Oil
Paradox	585	3.1	0.0	-	-	-	-	1.0	1.0	257.2	265.6	-	-	-	-
Santa Maria	750	-	0.0	-	-	-	-	-	1.0	-	292.3	-	-	-	-
Sacramento	730	0.0	-	-	-	-	-	1.0	-	316.3	-	-	-	-	-
AK Cook Inlet	820	1.0	0.8	0.1	0.0	28.9	36.8	0.9	0.9	268.6	265.2	0.02	0.02	487.6	476.8
North Park	545	1.3	1.3	-	-	-	-	1.0	1.0	231.8	232.7	-	-	-	-

- Indicates no subpart W data were reported for this basin.

Table A.5. RY2020 Subpart W Basin-Level Well Pad Equipment AFs (for Basins Reporting Well Pad Equipment in 2020)

Basin Name	Basin Number	Separators/ Well		Chemical Injection Pump/ Well		Heaters/ Well	Dehydrators/ Well	Meters/Piping / Well	Compressors/ Well	Heater-Treaters/ Well	Headers/ Well
		Gas	Oil	Gas	Oil	Gas	Gas	Gas	Gas	Oil	Oil
Permian	430	0.90	0.43	0.09	0.01	0.04	0.00	1.40	0.20	0.19	0.18
Appalachian (Eastern)	160A	0.50	0.46	0.03	0.03	0.10	0.00	0.96	0.01	0.01	0.01
Anadarko	360	0.57	1.17	0.13	0.40	0.11	0.01	1.01	0.13	0.71	0.22
Appalachian	160	0.27	0.73	0.00	0.04	0.01	-	0.92	0.00	-	-
Gulf Coast	220	0.87	0.87	0.22	0.36	0.05	0.02	1.27	0.08	0.28	0.37
San Joaquin	745	-	0.02	-	-	-	-	-	-	0.00	0.07
Arkla	230	1.02	-	0.28	-	0.02	0.03	0.92	0.03	-	-
East Texas	260	0.63	1.06	0.29	0.55	0.06	0.01	1.04	0.04	0.17	-
San Juan	580	0.97	1.04	0.02	0.01	0.97	0.00	1.06	0.20	0.00	0.21
Williston	395	1.08	0.59	0.00	0.03	0.04	0.00	1.71	0.00	0.83	-
Denver	540	0.56	0.54	0.02	0.03	0.22	0.00	0.69	0.09	0.12	0.17
Chautauqua Platform	355	0.95	1.05	0.27	-	0.01	0.00	0.52	0.08	0.96	-
Arkoma	345	0.91	-	0.15	-	0.00	0.01	1.18	0.07	-	-
Piceance	595	0.54	1.00	0.07	-	0.16	0.00	0.39	0.00	-	1.00
Fort Worth Syncline	420	1.04	1.16	0.31	0.02	0.00	0.00	0.97	0.16	0.03	0.29
South Oklahoma Folded Belt	350	1.49	0.70	0.28	0.39	0.05	-	0.82	0.21	0.23	0.33
Michigan	305	0.04	0.26	0.02	0.01	0.00	0.02	0.88	0.06	0.30	0.10
Green River	535	0.81	-	1.26	0.96	0.22	0.22	0.77	0.02	0.47	0.01
Forest City	335	-	-	-	-	-	-	-	-	-	0.08
Uinta	575	0.99	0.57	2.27	0.06	0.52	0.02	0.82	0.00	0.39	0.70
Powder River	515	1.33	0.96	19.00	0.15	1.67	-	40.33	-	1.13	0.40
Strawn	415	1.05	0.88	1.49	0.94	-	0.00	0.96	0.24	-	0.34
Sedgwick	375	-	1.02	-	-	-	-	-	-	0.67	0.29
Palo Duro	435	0.21	0.20	-	-	-	-	1.00	0.11	-	0.20
Ouachita Folded Belt	400	1.07	-	1.80	-	-	-	1.00	0.25	-	-

Basin Name	Basin Number	Separators/ Well		Chemical Injection Pump/ Well		Heaters/ Well	Dehydrators/ Well	Meters/Piping / Well	Compressors/ Well	Heater-Treaters/ Well	Headers/ Well
		Gas	Oil	Gas	Oil	Gas	Gas	Gas	Gas	Oil	Oil
Las Vegas-Raton	455	1.00	-	-	-	-	-	1.00	0.22	-	-
Mid-Gulf Coast	210	0.95	-	0.30	-	0.12	0.03	0.78	0.04	-	-
Wind River	530	1.05	-	0.98	-	0.77	0.02	0.89	0.05	-	-
Arctic Coastal Plains Province	890	0.03	0.05	-	-	-	0.03	0.21	0.08	0.00	0.08
Central Western Overthrust	507	0.97	-	0.84	0.93	0.75	0.62	1.01	0.01	-	-
Las Animas Arch	450	0.01	-	-	-	-	-	1.00	-	-	-
Paradox	585	1.40	0.25	0.15	-	0.14	0.02	3.68	0.20	0.05	0.10
Coastal	740	-	0.01	-	-	-	-	-	-	0.01	0.34
Salina	380	-	-	-	-	-	-	-	-	-	0.52
AK Cook Inlet	820	0.53	0.59	0.22	0.07	0.53	0.23	0.44	0.21	-	0.91
North Park	545	0.20	0.26	-	-	-	-	1.00	-	-	1.00
Upper Mississippi Embayment	250	-	-	-	-	-	-	-	-	-	0.28

- Indicates no subpart W data were reported for this basin.

Appendix B – Preliminary Example Analyses and Considerations for Other Industry Segments

B.1 Exploration

EPA assessed hydraulically fractured (HF) completion CO_2 emissions for RY2019. HF completions are the largest emission source within exploration (on a CO_2 equivalent basis). RY2019 data were evaluated because the number of HF completion events in RY2020 was almost half of the number of events in RY2019. EPA calculated the average HF completion CO_2 emissions per completion event, separately for oil well and gas well completions, for each basin that reported HF completion data to subpart W. Table B.1 shows the average emissions per event for the nine basins with the highest number of completions (collectively accounting for 92 percent of HF completions and 96 percent of HF completion CO_2 emissions). The basins listed in the table below are in descending order of total HF completion events for RY2019.

Table B.1. Well Completion CO_2 Emissions Per Completion Event, by Basin (Subpart W RY2019)

Basin	Oil Well Completion CO_2 Emissions (mt/event)	Gas Well Completion CO_2 Emissions (mt/event)
Permian	117	434
Gulf Coast	43	97
Williston	670	N/A
Appalachian (Eastern Overthrust Area)	N/A	6
Anadarko	33	3
Denver	61	5
Arkla	N/A	1
Green River	N/A	10
Piceance	N/A	1
All Other Basins	111	23

There is significant variability in HF completion CO_2 emissions across the basins, as seen in Table B.1. This variability reflects differences in completion practices such as reduced emission completions. EPA is considering calculating basin-level activity factors for exploration sources such as HF completions and well testing.

B.2 Gathering and Boosting

To quantify national level emission from gathering and boosting (G&B) stations in the current GHGI, EPA uses national emissions factors and GHGRP activity data. EPA scales up GHGRP activity data using a factor calculated by the Zimmerle et al. 2020 study (i.e., subpart W accounts for 93 percent of total G&B stations).[6] For G&B pipeline emissions, EPA assumes GHGRP covers 100 percent of pipelines.

[6] Zimmerle et al. 2020. Methane Emissions from Gathering Compressor Stations in the U.S. *Environ. Sci. Technol*. 2020, 54, 12, 7552–7561. Available at: https://doi.org/10.1021/acs.est.0c00516

EPA assessed AD within the G&B segment to determine potential sources of variability. Three of the largest G&B sources that utilize subpart W data are compressors, tanks, and pneumatic controllers, with intermittent bleed controllers representing the bulk of pneumatic controller emissions. Table shows information on intermittent bleed pneumatic controllers, tanks, and compressors in the 10 basins with the largest amount of pipeline mileage, totaling 83 percent of the national mileage total. To show variability for compressors and tanks, each is normalized against gathering pipeline miles in a basin.

Table B.2. Percent Intermittent Bleed Controllers and Compressors and Tanks per Mile of G&B Pipeline (RY2020 Subpart W)

Basin Name	Basin Number	Percent of All Pneumatic Controllers that are Intermittent Bleed	Compressors per Mile	Tanks per Mile
Appalachian	160	94%	0.02	0.02
Appalachian- Eastern Overthrust	160A	82%	0.07	0.03
Gulf Coast	220	66%	0.06	0.15
East Texas	260	81%	0.01	0.06
Arkoma	345	82%	0.07	0.01
Anadarko	360	56%	0.03	0.03
Williston	395	87%	0.03	0.31
Fort Worth Syncline	420	86%	0.03	0.01
Permian	430	61%	0.05	0.17
San Juan	580	45%	0.04	0.03

Examining the activity factors for intermittent bleed pneumatic controllers, compressors, and tanks indicates that the basins do have variability in their G&B operations. For example, the Gulf Coast basin, which in addition to having the highest count of equipment for the three emission sources evaluated, has higher activity factors than most other basins.

All G&B station emission sources in the current GHGI rely on subpart W data for national activity estimates. However, based on the current GHGI approach where a single national scaling factor is used, basin-level calculations would not result in any differences to the national GHGI emissions (assuming each basin has the same scaling applied). Emission factor data are not available to develop regional disaggregation.

The current GHGI G&B station scaling factor of 93 percent could be applied at the basin-level; this approach would not account for potentially different coverages of subpart W data among basins nor would it account for variability across basins. However, the basin-level data could be more directly incorporated in the approach used to develop the state-level GHGI without impacting the national GHGI.

B.3 Processing

In the current GHGI, the AFs and EFs for natural gas processing plants are from GHGRP and the values are scaled to the national level using plant counts from the *Oil & Gas Journal* (*O&GJ*). Year 2015 processing plant counts are the most recent and are applied for each year from 2015 forward.

EPA calculated average emissions per processing plant for each state by summing the total reported subpart W emissions from all emission sources in a state and dividing by the number of plants in that state. Table 2 shows CH_4 and CO_2 emissions per processing plant for select states.

Table B.3. Natural Gas Processing Emissions per Plant by State (RY2020 Subpart W)

State	Total Number of Plants	Average CH_4 Emissions per Plant (mt)	Average CO_2 Emissions per Plant (mt)
Colorado	24	236	70,209
Louisiana	50	209	38,428
New Mexico	25	341	76,800
North Dakota	18	210	13,305
Oklahoma	50	290	7,907
Texas	214	194	35,904
West Virginia	10	220	7,300
Wyoming	20	225	114,301
All Others	51	206	28,159
Subpart W	462	220	38,182

The average CH_4 emissions per plant have minimal differences amongst the states. As shown in Table B.3, the average CH_4 emissions per plant range from 194 mt/plant to 341 mt/plant. With the exception of a few states, most states have average plant CH_4 emissions that are similar to the subpart W average of 220 mt CH_4 per plant (considering all data together). Conversely, average CO_2 emissions per state vary widely, from 7,300 mt/plant to 114,301 mt/plant. These differences in average CO_2 emissions per plant indicate there is significant variability in flaring practices and in acid gas removal emissions (the key contributors to CO_2 emissions) between the states.

The current GHGI relies on subpart W to calculate EFs and AFs for a majority of natural gas processing emission sources. Therefore, based on the observed variability in emissions shown above, updating the GHGI methodology for CO_2 from processing plants to use state-level EFs and AFs calculated from subpart W could improve state-level estimates. Preliminary assessment of coverage at the state-level with *Oil and Gas Journal* data indicates that many states have coverage lower than 50 percent on a processing plant count basis.

B.4 Transmission

For this memo, EPA used subpart W data on average compressors per station, by state, for a preliminary assessment of the variability of subpart W transmission segment data across states. These results are shown in Table B.4 for the states that collectively represent 70 percent of the total number of transmission stations in subpart W. As seen in the table below, Kentucky has the highest number of compressors per station at 9 compressors followed by Kansas, Michigan, and Mississippi with 7 compressors per station for each state. All the other states (12 out of 16 states) have compressors per station close to the subpart W average of 5 compressors per station (i.e., between 4 and 6 compressors per transmission station).

Table B.4. Compressors Per Station by State (RY2020 Subpart W)

State	Compressors per Station
Alabama	6
Arizona	4
Florida	5
Illinois	6

State	Compressors per Station
Kansas	7
Kentucky	9
Louisiana	6
Michigan	7
Mississippi	7
New Mexico	4
New York	4
Ohio	5
Oklahoma	4
Pennsylvania	5
Texas	5
West Virginia	5
Subpart W Average	5

The variability analysis for compressor station shows some variability across states. However, most states have similar compressors per station as the subpart W average. The current GHGI approach to develop national level activity data involves applying a single national scale up factor. Preliminary assessment of coverage at the state-level with Pipeline and Hazardous Materials Safety Administration (PHMSA) data indicates that many states have coverage lower than 50 percent for transmission.