November 2023

Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2022: Updates Under Consideration for Completion and Workover Emissions

This memo discusses updates under consideration for the 2024 *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (GHGI) to estimate completion and workover emissions at the basin level. This includes potential updates to activity data (AD) sources and applying the current GHGI national-level methodology at the basin level.

EPA is considering updates to improve accuracy of activity data in certain categories:

- Hydraulically fractured (HF) gas well workovers
- Non-HF gas well completions
- Non-HF gas well workovers
- HF oil well workovers
- Non-HF oil well completions

EPA is considering updates to calculate emissions at the basin level for the following completion and workover emission sources:

- HF gas well completions
- HF gas well workovers
- Non-HF gas well completions
- Non-HF gas well workovers
- HF oil well completions
- HF oil well workovers
- Non-HF oil well completions

1 Current GHGI Methodology

The following sections summarize the methodology to determine event counts, control category counts, and emission factors. For additional details on the current GHGI methodology, please refer to the 2018 Year-Specific Emissions memo and the 2019 Other Updates memo.[1,2]

1.1 Event Counts

The current GHGI methodology for well completion and workover event counts involves a mix of Enverus data analyses, Greenhouse Gas Reporting Program (GHGRP) subpart W data analyses, and historical data. Table 1 lists the data sources and assumptions that are currently used to develop AD (event counts) for each completion and workover emission source.

Table 1. 2023 GHGI Well-Related Activity Data Summary

Activity Data Element	Data Source/Basis
HF gas well completions	Enverus data analysis (for 1990 – 2010) and Subpart W direct counts (for 2011 forward). For Enverus, counts represent newly spudded or newly producing gas wells located in unconventional formations and/or horizontally drilled
HF gas well workovers	1% of HF gas wells are worked-over annually (analysis for NSPS OOOO[a])
Non-HF gas well completions	400 completions for all gas wells in 1992 (1996 GRI/EPA[b]), scaled for other years
Non-HF gas well workovers	4.35% of non-HF gas wells are worked-over annually (1996 GRI/EPA)

[1] https://www.epa.gov/sites/default/files/2018-04/documents/ghgemissions_year_specific_2018.pdf
[2] https://www.epa.gov/sites/default/files/2019-04/documents/2019_ghgi_updates_-_other_updates_2019-04-10.pdf

Activity Data Element	Data Source/Basis
HF oil well completions	Enverus data analysis; count of newly spudded or newly producing oil wells located in unconventional formations and/or horizontally drilled
HF oil well workovers	1% of HF oil wells are worked-over annually (applied same rate as HF gas wells)
Non-HF oil well completions	Number of wells drilled (EIA[c]) minus the number of HF oil well completions (Enverus)

a. The assumption of a 1% workover rate for HF gas wells and HF oil wells comes from EPA's estimate of re-fracturing frequency of fractured gas wells in NSPS OOOO. 77 FR 49519 (Aug. 16, 2012). EPA applies this 1% assumption to counts of HF gas wells and HF oil wells from Enverus to determine counts of HF gas well workovers and HF oil well workovers.
b. 1996 GRI/EPA. Methane Emissions from the Natural Gas Industry. EPA-600/R-96-080a.
c. EIA Monthly Energy Review, 1995-2021 editions. Energy Information Administration, U.S. Department of Energy. Available online at: <http://www.eia.gov/totalenergy/data/monthly/index.cfm>.

1.2 Control Category Counts

Once the number of completion and workover events are determined over the time series, the events are split into control categories using activity factors (AFs). The control categories reflect whether the emissions were vented or flared (for both HF and non-HF events) and whether reduced emissions completion (REC) technologies were used or not (for HF events). To develop AFs for each control category, the current GHGI applies the control category assignments outlined below for early time series years, uses subpart W data for 2011 forward for gas wells and 2016 forward for oil wells, and applies linear interpolation for intermediate years. The control category assignments for HF wells and non-HF gas wells are:

HF oil wells:

- For years 1990-2007, all HF oil well completions and workovers are non-REC
- For years 1990-2007, 10% of HF oil well completions and workovers flare

HF gas wells:

- For years 1990-2000, all HF gas well completions and workovers are non-REC
- For years 1990-2010, 10% of HF gas well completions and workovers flare

Non-HF gas wells:

- For 1990 – 2010, 97% of completions are vented (based on subpart W RY2011 analyses)
- For 1990 – 1992, all non-HF workovers are vented

An assumption was made for the purpose of developing the national GHGI that RECs for HF oil wells started in 2008, based on the adoption of regulations in that year in Colorado and Wyoming that required RECs. Prior to the introduction of those state regulations, the GHGI methodology assumes that all HF oil well completions and workovers were non-REC. For HF gas well completions and workovers, the GHGI methodology assumes that RECs are introduced earlier, in year 2000. The GHGI methodology assumes that 10 percent of all HF gas well completions and workovers flare for 1990-2010 because 10 percent is the average of the percent of completions and workovers that were flared in RY2011 and RY2012 subpart W data. The same assumption of 10 percent of events flaring is applied to HF oil well completions and workovers for 1990-2007. For non-HF gas well completions, the current GHGI applies the subpart W RY2011 venting fraction (97%) to all prior years. For non-HF gas well workovers, the current GHGI assumes 100% of workovers are vented in 1990-1992, which is supported by the fact that more than 99% of non-HF workovers are vented in RY2011 subpart W data. For non-HF oil well completions, the current GHGI assumes all events of this type are vented for all years of the time series.

1.3 Emission factors

The current GHGI methodology for most well completion and workover emission factors (EFs) involves analyses of subpart W data at the national level to determine year-specific CH_4, CO_2, and N_2O EFs using reported emissions and completion and workover event counts. EPA calculates separate EFs for non-HF gas well completions and workovers, but combined completions and workovers EFs for HF wells (both oil and gas).

The non-HF oil well completion EF is based on data from the 1996 GRI/EPA study as information on non-HF oil well completions is not reported to subpart W.

2 Available Data

EPA assessed data available from subpart W of the GHGRP and Enverus for the completion and workover updates under consideration. 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. However, reporting requirements for HF oil well completions and workovers began in RY2016. Onshore production facilities in subpart W are defined as a unique combination of operator and basin of operation (i.e., all operator production sites within a basin). The GHGRP subpart W data used in the analyses discussed in this memo were reported to the EPA as of August 12, 2022.

EPA also assessed data available from Enverus for the updates under consideration. Enverus data includes well-level information such as completion dates, drilling orientation (e.g., vertical, horizontal), and location and formation type.

3 Analysis of Available Data

For the updates under consideration for the 2024 GHGI, EPA evaluated completion and workover activity data, activity factors for the fraction of completions or workovers in each control category, and emission factors, as discussed in the following subsections. The analyses focus on updating activity data sources, where it would improve accuracy, and developing basin-level approaches to estimate emissions.

3.1 Analysis of Data Sources for Completion and Workover Counts

3.1.1 Completions

The current GHGI uses Enverus data to determine the number of national HF oil well completion events and a combination of Enverus and subpart W data to determine the number of national HF gas well completion events in a given year. HF gas well completion counts reported under subpart W exceed Enverus-based event counts, so subpart W event counts are assumed to represent national coverage and are used directly as national total activity in the GHGI for 2011 forward, and Enverus HF gas well completion counts are used for 1990-2010. This combination of datasets provides the most complete data for HF gas and oil well completion events and EPA is not considering an updated dataset for these event counts.

EPA is considering an update to activity data to increase accuracy for estimates of emissions from non-HF gas well completions and non-HF oil well completions. The current GHGI non-HF gas well completion AD methodology is based on industry characteristics in the base year 1992 (from the 1996 GRI/EPA study). The counts for each year of the time series are developed by assuming there were 400 non-HF completions in 1992 (the year for which the estimate was developed). This assumption equates to an AF of 0.19% of all gas wells being completed using non-HF techniques (400 non-HF completions divided by 212,994 gas wells in 1992 equals 0.19%), which is then applied to all years in the time series. An updated data source could account for changing trends over time. As such, EPA used Enverus data to determine the total number of non-HF gas well completions

across the time series. Table 2 presents the number of non-HF gas well completions from the current GHGI compared to Enverus and subpart W counts for select years of the time series.

Table 2. Non-HF Gas Well Completion Event Counts

Dataset	Scope	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021
Current GHGI	National	365	421	503	659	821	823	811	807	801	790	770	748
Enverus	National	3,341	2,762	4,961	7,233	2,549	374	228	200	229	141	127	127
Subpart W	Total Reported	n/a	n/a	n/a	n/a	n/a	109	91	208	188	156	143	34

As shown in Table 2, the Enverus and subpart W data have fewer non-HF gas well completions in recent years while the Enverus data has more non-HF gas well completions in early years, compared to the current GHGI methodology. Using a static AF of 0.19% of gas wells over the time series to determine the number of non-HF gas well completions also does not reflect the advent of hydraulic fracturing. Of note, Enverus data may not provide a complete count for these events. For some years (i.e., 2017, 2019, 2020), counts reported under subpart W exceed Enverus-based estimates and may provide better coverage (see Table 2).

EPA is also considering an update to increase accuracy of AD for non-HF oil well completions. The current GHGI non-HF oil well completion activity data methodology uses information from EIA and Enverus. The number of non-HF oil well completions in a given year equals the number of oil wells drilled (from EIA) minus the number of HF oil well completions (from Enverus). However, the EIA dataset stopped reporting wells drilled counts in 2011 and the 2011 count is applied to all subsequent years. For the update under consideration, EPA evaluated using Enverus directly to determine the number of non-HF oil well completions in a year. Subpart W does not collect data on non-HF oil well completions. Table 3 compares the non-HF oil well completion counts from the current GHGI and Enverus for select years of the time series.

Table 3. Non-HF Oil Well Completion Event Counts

Dataset	Scope	1990	1995	2005	2010	2015	2016	2017	2018	2019	2020	2021
Current GHGI	National	8,916	5,082	5,228	6,363	1,401	8,239	5,294	2,682	3,007	9,323	9,323
Enverus	National	10,276	6,736	7,672	8,157	2,753	1,493	1,933	2,214	2,257	1,311	1,311

For recent years in Table 3 (2015 – 2021), there is volatility in the current GHGI dataset, where the number of non-HF oil well completions change dramatically from year to year. This is in part because these values rely on the number of oil wells drilled from 2011 and do not reflect year-specific data. The current GHGI and Enverus data both show a general decrease in completions from 1990 through 2015, but the trend continues for Enverus through 2021. A decrease in the number of non-HF oil well completions from 1990 through 2021, as indicated by Enverus data, corresponds with the related increase in HF oil well completions over this same time. Using Enverus instead of a combination of EIA and Enverus to determine the number of non-HF oil well completions creates consistency in the dataset and allows all counts to be determined using year-specific information.

3.1.2 Workovers

EPA investigated the use of subpart W data to update the current AD methodologies for the following workover emission sources:

- HF gas well workovers
- HF oil well workovers
- Non-HF gas well workovers

EPA is not considering an update of the AD for non-HF oil well workovers because subpart W and Enverus do not include data for non-HF oil well workovers.

Workover rates (which were developed from the 1996 GRI/EPA study for non-HF gas wells and in analyses supporting NSPS OOOO for HF wells) have not been updated in recent years. EPA analyzed subpart W data for potential updates. HF gas well and HF oil well counts are not available in the GHGRP subpart W data; therefore, EPA converted the current GHGI assumption (1% of active HF gas/oil wells) to a total gas/oil well basis for comparison. To do this, EPA divided the number of HF gas well (or oil well) completions by the total gas well (or oil well) population (e.g., 2,240 HF gas well completions in 2021 divided by 410,246 gas wells in 2021 equals 0.5%). Table 4 and Table 5 show the current GHGI and GHGRP data workover rates for HF gas wells and HF oil wells, respectively, at the national level.

Table 4. Percent of Total Gas Wells with HF Gas Well Workovers

Dataset	Scope	2015	2016	2017	2018	2019	2020	2021
Current GHGI	National	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
Subpart W	Total Reported	0.12%	0.04%	0.04%	0.05%	0.02%	0.04%	0.07%

Table 5. Percent of Total Oil Wells with HF Oil Well Workovers[a]

Dataset	Scope	2016	2017	2018	2019	2020	2021
Current GHGI	National	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%
Subpart W	Total Reported	0.12%	0.26%	0.33%	0.10%	0.05%	0.03%

a. Oil well data are available from GHGRP subpart W beginning in RY 2016.

As seen in Table 4 and Table 5, subpart W data analysis results in lower workover rates compared to the current GHGI methodology for HF gas and oil wells in recent years. In addition, using a static AF over the time series does not reflect the variable workover rates over time, as seen in subpart W data. The percentage of national gas and oil wells that are HF wells has consistently increased across the time series from 1990-2021. As of 2021, HF wells account for approximately 55% of gas wells (up from 27% in 1990) and approximately 45% of oil wells (up from 20% in 1990). While relying on a workover rate that uses total wells instead of only HF wells to calculate the number of HF workovers does not directly relate to the trend of increasing HF wells over time, applying the lower workover rates from subpart W to early years of the time series does lead to a lower estimate of the number of HF workovers than applying the 1% HF well workover rate to early years of the time series for the majority of the basins.

Non-HF gas well counts are similarly unavailable in the GHGRP subpart W data. EPA converted the current GHGI assumption (4.35% of non-HF gas wells are worked over) to the total gas well basis for comparison with GHGRP data, as shown in Table 6.

Table 6. Percent of Total Gas Wells with Non-HF Workovers

Dataset	Scope	2015	2016	2017	2018	2019	2020	2021
Current GHGI	National	2.08%	2.06%	2.05%	2.03%	2.00%	1.97%	1.97%
Subpart W	Total Reported	6.28%	5.08%	5.46%	5.31%	4.45%	7.45%	6.02%

As shown in Table 6, subpart W data analysis results in higher workover rates compared to the current GHGI methodology for non-HF gas wells in recent years. The subpart W percentages are approximately three times higher than the current GHGI.

3.1.3 Summary of Activity Data Updates Under Consideration

Based on the above analyses of available activity data, EPA is considering using Enverus to determine non-HF gas well completion and non-HF oil well completion event counts. EPA is also considering using well counts from Enverus paired with workover rates developed from subpart W data to determine HF gas well, HF oil well, and non-HF gas well workover event counts. These data sources are available at the basin level, which is discussed further in section 3.2.

3.2 Basin-Level

EPA is considering an update to calculate completion and workover emissions at the basin level and then sum those emissions to the national level. The approach would involve the development of basin-level completion and workover counts, control category fractions, and emission factors.

3.2.1 Completion and Workover Counts at the Basin Level

EPA is considering an update to develop completion and workover counts at the basin level. Consistent with AD updates discussed in sections 3.1.1 and 3.1.2 above, this update would use Enverus data to determine the total number of non-HF gas well completions and non-HF oil well completions across the time series and subpart W data to update counts for HF gas well workovers, HF oil well workovers, and non-HF gas well workovers. Table 9 through Table 13 present basin-level data and are available in Appendix A. The results in the tables show there is variability in the basin-level AFs when comparing between basins and over time.

3.2.2 Completion and Workover Control Categories

EPA is considering an update to calculate AFs for all HF and non-HF well completion control categories at the basin level using subpart W data. This update would largely retain the current GHGI approach, but EPA would calculate AFs for each basin instead of a national average. The basin-level control category AFs would be applied to the Enverus completion counts at the basin level (see Section 3.2.1) and the AFs represent the percent of completions that fall within each control category (and thus sum to 100 percent). EPA calculated year-specific basin-level AFs using subpart W data for each of the following completion control categories:

- HF gas well completions – vented, non-REC
- HF gas well completions – vented, REC
- HF gas well completions – flared, non-REC
- HF gas well completions – flared, REC
- Non-HF gas well completions – vented
- Non-HF gas well completions – flared
- HF oil well completions – vented, non-REC
- HF oil well completions – vented, REC
- HF oil well completions – flared, non-REC
- HF oil well completions – flared, REC

Table 14 through Table 16, available in Appendix B, compare the current GHGI AFs to the AFs obtained using basin-level data for select basins, for the years 2015 through 2021. The selected basins represent the basins with the greatest number of completions reported for RY2021. The results in the tables show there is variability in the basin-level AFs, when comparing between basins and over time. However, there are general trends that hold in terms of the distribution between control categories. For example, gas well HF completions (Table 14) are predominantly RECs that are vented, gas well non-HF completions (Table 15) are predominantly vented, and oil well HF completions (Table 16) are RECs though split between vented and flared.

EPA is also considering a methodological update to calculate AFs for HF and non-HF well workover control categories at the basin level using subpart W data. This update would largely retain the current GHGI approach, but EPA would calculate AFs for each basin instead of a national average. The basin-level control category AFs

would be applied to the workover counts at the basin level (see Section 3.2.1) and the AFs represent the percent of workovers that fall within each control category (and thus sum to 100 percent). EPA calculated year-specific basin-level AFs using subpart W data for each of the following workover control categories:

- HF gas well workovers – vented, non-REC
- HF gas well workovers – vented, REC
- HF gas well workovers – flared, non-REC
- HF gas well workovers – flared, REC
- Non-HF gas well workovers – vented
- Non-HF gas well workovers – flared
- HF oil well workovers – vented, non-REC
- HF oil well workovers – vented, REC
- HF oil well workovers – flared, non-REC
- HF oil well workovers – flared, REC

Table 17 through Table 19, available in Appendix B, compare the current GHGI AFs to the AFs obtained using basin-level data for select basins, for the years 2015 through 2021. The selected basins represent the basins with the greatest number of workovers reported for RY2021. The results in the tables show there is variability in the basin-level AFs, when comparing between basins and over time. The AFs also show clear differences when compared to the national average AFs used in the current GHGI. Gas well HF workovers (
Table 17) commonly use RECs and vent emissions in most basins, but basin 220 employs these techniques more than basin 360. Gas well non-HF workover events (Table 18) are almost always vented for the basins, although basins 430 and 540 have years where flaring is more prevalent. Oil well HF workovers (Table 19) commonly use RECs and vent emissions in most basins, but for example, basin 395 is highly variable across the years.

3.2.3 Completion and Workover Emission Factors

EPA is considering a methodological update to calculate EFs for all completion and workover control categories at the basin level. This update would largely retain the current GHGI approach, but EPA would calculate EFs for each basin instead of a national average. EPA calculated year-specific basin-level CH_4, CO_2, and N_2O EFs (mt/event) using subpart W data for each of the following completion and workover control categories:

- HF gas well completions and workovers – vented, non-REC
- HF gas well completions and workovers – vented, REC
- HF gas well completions and workovers – flared, non-REC
- HF gas well completions and workovers – flared, REC
- Non-HF gas well completions – vented
- Non-HF gas well completions – flared
- Non-HF gas well workovers – vented
- Non-HF gas well workovers – flared
- HF oil well completions and workovers – vented, non-REC
- HF oil well completions and workovers – vented, REC
- HF oil well completions and workovers – flared, non-REC
- HF oil well completions and workovers – flared, REC

Table 20 through Table 31, available in Appendix C, compare the current GHGI EFs to the EFs obtained using basin-level data for select basins, for the years 2019 through 2021. The selected basins represent the basins with the greatest number of each completion and/or workover event type reported for RY2021. Most of the tables show notable variability in the basin-level EFs for the given category, when comparing between basins and over time. Most of the basin-level EFs also show clear differences when compared to the national average EFs used in the current GHGI. Additional observations of the basin-level EFs are discussed in Appendix C.

4 Time Series Considerations

GHGRP subpart W completion and workover data is available for gas wells for RY2011 forward and for oil wells for RY2016 forward.

EPA is considering using Enverus and subpart W data to determine counts of completions and workovers. To determine the number of events for HF oil well completions, non-HF gas well completions, and non-HF oil well completions, EPA is considering using Enverus across the time series. To determine the number of HF gas well completions, EPA is considering using Enverus for 1990 – 2010 and subpart W for 2011 forward. For workover counts, EPA is considering developing year-specific subpart W AFs for 2015 forward for gas well workovers and for 2016 forward for oil well workovers. EPA is then considering applying the earliest subpart W data (either 2015 or 2016) to all prior years.

For the fraction of completions or workovers in each control subcategory, EPA is considering applying year-specific AFs for 2011 forward for gas wells and 2016 forward for oil wells.

EPA is considering retaining the following control category assumptions from the current GHGI methodology (these values would also be applied at the basin level):

- For years 1990-2007, all HF oil well completions and workovers are non-REC
- For years 1990-2000, all HF gas well completions and workovers are non-REC
- For years 1990-2007, 10% of HF oil well completions and workovers are non-REC and flare

EPA is considering re-evaluating the following control category assumptions when using subpart W data to develop basin-specific assumptions:

- For years 1990-2010, 10% of HF gas well completions and workovers are non-REC and flare

The 10 percent values were derived from national-level subpart W data and retaining these percentages for all basins would not reflect the differences across basins.

Following the current GHGI methodology, for the first year in which subpart W data are available, EPA would determine the percent contribution of each control category directly from reported subpart W data. EPA would then use linear interpolation for intermediate years to determine the percent of gas wells with RECs (i.e., for 2001-2010) and the percent of oil wells with RECs and percent flaring for oil wells (i.e., for 2008-2015).

To apply EFs across the time series, EPA is considering applying year-specific EFs for GHGRP years, and EFs from the earliest GHGRP year (or an average of the first few GHGRP years) to all prior years.

5 Summary of Updates Under Consideration

Based on the information detailed in the above sections, the following is a summary of the updates EPA is considering to estimate completion and workover emissions for the 2024 GHGI:

- Use Enverus and subpart W data to determine completion and workover event counts at the basin level (see section 3.1 and section 3.2.1).
- Calculate control category AFs from subpart W data at the basin level (see section 3.2.2), coupled with assumptions for early years of the time series (see section 4).
- Calculate control category EFs from subpart W data at the basin level, using subpart W RY2011 EFs for gas wells and subpart W RY2016 EFs (or an average EF based on multiple years) for oil wells for early years of the time series (see section 3.2.3) and year specific information for the rest of the time series.

6 Preliminary National Emissions Estimates

EPA estimated preliminary national completion and workover emissions using the EFs, AFs, and AD described in Section 3, above. In addition, if Enverus data included a nonzero well or completion count for a specific basin and year, but subpart W did not have data for the same basin and year, EPA applied national average AFs and EFs developed from subpart W. Table 7 presents CH_4 emissions and Table 8 presents CO_2 emissions for completion and workover emission source.

Table 7. Preliminary National CH_4 Estimates (metric tons) for the Basin-Level Updates Under Consideration Compared to the Current GHGI

Emission Source / Control Category	2015	2016	2017	2018	2019	2020	2021
HF Gas Well Completions							
Basin-Level GHGI	26,926	18,138	47,252	32,175	20,187	5,437	3,244
Current GHGI	26,288	18,416	46,827	32,147	20,001	5,219	6,111
Non-HF Gas Well Completions							
Basin-Level GHGI	6,577	1,890	421	132	159	561	202
Current GHGI	14,232	8,302	1,439	513	796	2,659	267
HF Gas Well Workovers							
Basin-Level GHGI	1,846	1,431	1,986	2,022	177	238	4,688
Current GHGI	12,580	14,516	28,474	19,593	13,612	6,772	8,144
Non-HF Gas Well Workovers							
Basin-Level GHGI	4,420	2,977	5,869	1,154	881	961	1,145
Current GHGI	658	641	733	414	436	259	396
HF Oil Well Completions							
Basin-Level GHGI	74,432	22,752	15,201	16,670	14,160	10,850	4,524
Current GHGI	89,673	18,508	15,329	18,089	14,864	10,569	4,429
HF Oil Well Workovers							
Basin-Level GHGI	4,367	2,261	1,510	1,699	1,764	174	66
Current GHGI	15,949	7,298	2,508	2,670	3,679	3,873	2,152
Total for Gas and Oil Completion and Workover Categories included in Update							
Basin-Level GHGI	118,570	49,449	72,239	53,852	37,327	18,221	13,868
Current GHGI	*159,380*	*67,681*	*95,310*	*73,426*	*53,388*	*29,351*	*21,499*

Table 8. Preliminary National CO_2 Estimates (Metric Tons) for the Basin-Level Updates Under Consideration Compared to the Current GHGI

Emission Source / Control Category	2015	2016	2017	2018	2019	2020	2021
HF Gas Well Completions							
Basin-Level GHGI	265,849	177,355	439,410	292,732	215,659	96,188	14,825
Current GHGI	266,985	176,576	436,503	289,655	214,303	95,815	15,337
Non-HF Gas Well Completions							
Basin-Level GHGI	3,485	3,352	2,091	8,605	19	58	5,562
Current GHGI	6,310	13,167	7,454	29,834	81	364	222
HF Gas Well Workovers							
Basin-Level GHGI	17,322	2,982	26,783	4,010	904	243	642
Current GHGI	49,429	52,772	362,399	98,964	85,744	7,929	1,180

Emission Source / Control Category	2015	2016	2017	2018	2019	2020	2021
Non-HF Gas Well Workovers							
Basin-Level GHGI	10,939	6,322	699	334	711	2,186	10,479
Current GHGI	3,825	3,285	309	185	293	476	4,539
HF Oil Well Completions							
Basin-Level GHGI	2,298,447	1,323,982	1,558,656	2,421,657	1,907,828	748,983	449,078
Current GHGI	2,311,832	1,333,242	1,815,930	3,174,461	2,430,900	836,134	465,742
HF Oil Well Workovers							
Basin-Level GHGI	35,856	35,517	80,765	53,921	20,900	8,123	5,409
Current GHGI	210,591	224,830	220,239	89,049	97,516	97,767	205,160
Total for Gas and Oil Completion and Workover Categories included in Update							
Basin-Level GHGI	2,631,898	1,549,511	2,108,402	2,781,258	2,146,021	855,782	485,995
Current GHGI	*2,848,972*	*1,803,872*	*2,842,834*	*3,682,148*	*2,828,837*	*1,038,485*	*692,180*

7 Requests for Stakeholder Feedback

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

1. Are there additional data sources that EPA should review and consider using to update completion and workover event counts used in the GHGI to reflect ongoing trends?
2. When comparing HF and non-HF gas well completion counts between subpart W and Enverus, there are instances when subpart W exceed Enverus. EPA seeks stakeholder feedback on these discrepancies and when it is appropriate to use counts from subpart W versus Enverus to represent total event counts for a basin (e.g., select the dataset with the highest number of events for a given basin and year, always use one dataset for all basins and years):
    a. For a few years, subpart W reports higher counts of non-HF gas well completions than total national counts in Enverus. Similarly, in certain basins, subpart W reports higher reported counts than total counts in Enverus for non-HF gas well completions for most years.
    b. When the national-level methodology was developed for HF gas well completions, EPA observed that subpart W counts exceeded Enverus counts in all subpart W years (i.e., RY2011 forward). As such, EPA chose to use subpart W HF gas well completion counts to represent the national total. This same discrepancy exists at the basin level, though there are instances where Enverus exceeds subpart W counts for some basins.
3. EPA requests stakeholder feedback on the use of subpart W data to develop workover rates for early years of the time series, versus retaining previous data sources. EPA seeks stakeholder feedback on other available data sources.
4. EPA requests stakeholder feedback on assumptions applied in early years of the time series such as for fraction of RECs and fraction with flaring.
5. EPA requests stakeholder feedback on the potential benefits and potential disadvantages of updating the GHGI to use an approach that incorporates additional basin-level calculations.
6. EPA requests stakeholder feedback on approaches for basins that have subpart W data reported in certain years (e.g., RY2015-RY2017, RY2019, RY2021), but not all GHGRP years (e.g., no data in RY2018, RY2020). For example, using a basin's data from surrounding years, applying average data (based on multiple basins) to those years, or assume the activity did not occur in that year.

Appendix A: Basin-Level Completion and Workover Counts

Table 9 through Table 12 present basin-level completions and workovers data for select basins.

- Table 9 presents the number of non-HF gas well completions from the current GHGI compared to Enverus and subpart W counts for select basins for 2015 through 2021. EPA analyzed Enverus and subpart W data to calculate the percentage of gas wells with non-HF completions in a given year for select basins (e.g., the number of non-HF completions in a basin divided by the number of gas wells in a basin) to compare against the current GHGI activity assumption, as summarized in Table 10 for 2015 through 2021. The percentage of gas wells with non-HF completions is highly variable across basins, with basins 160A and 220 having low percentages compared to basins 300 and 820.
- Table 11 shows the current GHGI workover rates for HF gas wells and the subpart W workover rates for HF gas wells for select basins. The selected basins represent the basins with the greatest number of each workover event type reported over RY2015 through RY2021. The workover rates for each of the select basins are much lower than the current GHGI rates, with the exception of basin 455 which does have higher workover rates for 2020 and 2021.
- Table 12 shows the current GHGI workover rates for HF oil wells and the subpart W workover rates for HF oil wells for select basins. The selected basins represent the basins with the greatest number of each workover event type reported over RY2015 through RY2021. Similar to HF gas well workovers, the HF oil well workover rates for each of the select basins are generally lower than the current GHGI rates, though there are exceptions. Basins 360, 395, 430, and 575 have at least one year where the subpart W workover rate is higher than the current GHGI rate.
- Table 13 shows the current GHGI workover rates for non-HF gas wells and the subpart W workover rates for non-HF gas wells for select basins. The selected basins represent the basins with the greatest number of each workover event type reported over RY2015 through RY2021. The workover rates for each of the basins are higher than the current GHGI rates in all instances, and in some cases the basin-level data are several orders of magnitude higher (e.g., basins 430, 540, 580)

Table 9. Non-HF Gas Well Completion Event Counts

Dataset	Basin	2015	2016	2017	2018	2019	2020	2021
Current GHGI	National	823	811	807	801	790	770	748
Enverus	160A – Appalachian (Eastern Overthrust Area)	130	122	78	102	62	72	72
	220 – Gulf Coast (LA, TX)	41	17	33	23	19	9	9
	300 – Cincinnati Arch	2	1	0	2	3	3	3
	375 – Sedgwick	60	6	6	10	5	1	1
	385 – Central Kansas Uplift	6	0	3	3	4	0	0
	730 – Sacramento	0	6	3	3	2	1	1
	820 – AK Cook Inlet	5	1	5	0	3	10	10
Subpart W Basin-Level Analysis	160A – Appalachian (Eastern Overthrust Area)	2	53	113	99	59	11	5
	220 – Gulf Coast (LA, TX)	5	14	9	26	8	71	8
	300 – Cincinnati Arch	0	0	0	0	0	0	0
	375 – Sedgwick	0	0	0	0	0	0	0
	385 – Central Kansas Uplift	0	0	0	0	0	0	0
	730 – Sacramento	0	0	0	0	0	0	0
	820 – AK Cook Inlet	0	0	8	0	3	11	4

Table 10. Percent of Gas Wells with Non-HF Completions

Dataset	Basin	2015	2016	2017	2018	2019	2020	2021
Current GHGI	National	0.19%	0.19%	0.19%	0.19%	0.19%	0.19%	0.18%
Enverus	160A – Appalachian (Eastern Overthrust Area)	0.12%	0.11%	0.07%	0.09%	0.06%	0.07%	0.07%
	220 – Gulf Coast (LA, TX)	0.26%	0.11%	0.22%	0.16%	0.13%	0.06%	0.06%
	300 – Cincinnati Arch	1.16%	1.43%	0.00%	0.95%	1.68%	1.72%	1.72%
	375 – Sedgwick	1.66%	0.18%	0.18%	0.31%	0.16%	0.03%	0.03%
	385 – Central Kansas Uplift	1.00%	0.00%	0.57%	0.57%	0.82%	0.00%	0.00%
	730 – Sacramento	0.00%	0.65%	0.34%	0.35%	0.24%	0.13%	0.13%
	820 – AK Cook Inlet	3.25%	0.71%	3.38%	0.00%	2.42%	7.35%	7.35%

Table 11. Percent of Gas Wells with HF Gas Well Workovers

Dataset	Basin	2015	2016	2017	2018	2019	2020	2021
Current GHGI	National	1.1%	1.1%	1.1%	1.1%	1.2%	1.2%	1.2%
Subpart W Basin-Level Analysis	220 – Gulf Coast (LA, TX)	0.06%	0.03%	0.08%	0.12%	0.04%	0.08%	0.02%
	260 – East Texas	0.45%	0.27%	0.14%	0.15%	0.10%	0.07%	0.01%
	360 – Anadarko	0.41%	0.05%	0.05%	0.00%	0.02%	0.00%	0.00%
	420 – Fort Worth Syncline	0.07%	0.00%	0.16%	0.45%	0.03%	0.10%	1.78%
	455 – Las Vegas-Raton	0.00%	0.00%	0.00%	0.00%	0.00%	1.38%	2.37%

Table 12. Percent of Oil Wells with HF Oil Well Workovers[a]

Dataset	Basin	2016	2017	2018	2019	2020	2021
Current GHGI	National	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%
Subpart W Basin-Level Analysis	220 – Gulf Coast (LA, TX)	0.09%	0.15%	0.13%	0.19%	0.32%	0.03%
	360 – Anadarko	0.03%	0.92%	0.73%	0.12%	0.01%	0.00%
	395 – Williston	0.48%	0.66%	0.58%	0.09%	0.04%	0.05%
	430 – Permian	0.12%	0.29%	0.49%	0.14%	0.02%	0.01%
	575 – Uinta	1.21%	1.45%	0.02%	0.00%	0.00%	0.48%

a. Oil well data are available from GHGRP subpart W beginning in RY 2016.

Table 13. Percent of Total Gas Wells with Non-HF Workovers

Dataset	Basin	2015	2016	2017	2018	2019	2020	2021
Current GHGI	National	2.08%	2.06%	2.05%	2.03%	2.00%	1.97%	1.97%
Subpart W Basin-Level Analysis	220 – Gulf Coast (LA, TX)	7.23%	7.33%	6.10%	8.27%	8.22%	6.18%	6.59%
	360 – Anadarko	6.29%	7.88%	7.72%	8.27%	7.85%	5.57%	10.16%
	430 – Permian	4.18%	5.35%	8.18%	4.56%	7.13%	84.74%	25.53%
	540 – Denver	11.42%	7.04%	6.58%	11.41%	8.73%	7.37%	14.11%
	580 – San Juan	13.47%	13.73%	16.06%	13.18%	8.10%	10.64%	11.15%

Appendix B: Basin-Level Control Category AFs

Table 14 through Table 16 compare the current GHGI AFs for completions to the AFs obtained using subpart W basin-level data for select basins, for the years 2015 through 2021.
Table 17 through Table 19 compare the current GHGI AFs for workovers to the AFs obtained using subpart W basin-level data for select basins, for the years 2015 through 2021. The selected basins represent the basins with the greatest number of workovers reported for RY2021.

Table 14. Gas Well HF Completion AFs – Percentage of Completions Within Each Control Category

Dataset	Basin	2015	2016	2017	2018	2019	2020	2021
Vented and non-REC								
Current GHGI	National	2%	5%	3%	3%	3%	1%	6%
Subpart W Basin-Level Analysis	160A – Appalachian (Eastern Overthrust Area)	0%	7%	5%	2%	0%	0%	0%
	220 – Gulf Coast (LA, TX)	0%	10%	0%	1%	3%	4%	2%
	230 – Arkla	4%	7%	3%	0%	2%	0%	1%
	430 – Permian	2%	0%	1%	0%	1%	0%	0%
	540 – Denver	0%	0%	0%	0%	0%	0%	34%
Vented and REC								
Current GHGI	National	59%	64%	74%	67%	67%	73%	63%
Subpart W Basin-Level Analysis	160A – Appalachian (Eastern Overthrust Area)	71%	81%	80%	83%	88%	85%	90%
	220 – Gulf Coast (LA, TX)	54%	51%	58%	62%	64%	68%	73%
	230 – Arkla	90%	91%	94%	100%	97%	96%	88%
	430 – Permian	47%	16%	17%	18%	21%	68%	57%
	540 – Denver	13%	46%	97%	72%	58%	58%	6%
Flared and non-REC								
Current GHGI	National	6%	4%	4%	3%	4%	2%	8%
Subpart W Basin-Level Analysis	160A – Appalachian (Eastern Overthrust Area)	1%	4%	1%	0%	1%	0%	1%
	220 – Gulf Coast (LA, TX)	12%	6%	15%	10%	17%	16%	3%
	230 – Arkla	1%	0%	0%	0%	0%	0%	0%
	430 – Permian	10%	24%	21%	15%	6%	2%	8%
	540 – Denver	19%	0%	1%	0%	0%	0%	34%
Flared and REC								
Current GHGI	National	33%	27%	19%	27%	25%	24%	23%
Subpart W Basin-Level Analysis	160A – Appalachian (Eastern Overthrust Area)	28%	7%	14%	15%	12%	15%	8%
	220 – Gulf Coast (LA, TX)	34%	34%	26%	28%	16%	13%	21%
	230 – Arkla	5%	2%	4%	0%	1%	4%	11%
	430 – Permian	40%	59%	60%	67%	72%	29%	35%
	540 – Denver	67%	54%	2%	28%	42%	42%	26%

Table 15. Gas Well Non-HF Completion AFs – Percentage of Completions Within Each Control Category

Dataset	Basin	2015	2016	2017	2018	2019	2020	2021
Vented								
Current GHGI	National	76%	35%	60%	72%	99%	100%	97%

Subpart W Basin-Level Analysis	160A – Appalachian (Eastern Overthrust Area)	100%	0%	51%	78%	100%	100%	100%
	220 – Gulf Coast (LA, TX)	40%	71%	78%	8%	88%	100%	88%
	230 – Arkla	100%	100%	0%	100%	100%	100%	100%
	430 – Permian	33%	0%	100%	50%	0%	100%	100%
	540 – Denver	0%	0%	0%	0%	0%	0%	0%
Flared								
Current GHGI	National	24%	65%	40%	28%	1%	0%	3%
Subpart W Basin-Level Analysis	160A – Appalachian (Eastern Overthrust Area)	0%	100%	49%	22%	0%	0%	0%
	220 – Gulf Coast (LA TX)	60%	29%	22%	92%	13%	0%	13%
	230 – Arkla	0%	0%	0%	0%	0%	0%	0%
	430 – Permian	67%	0%	0%	50%	0%	0%	0%
	540 – Denver	0%	0%	0%	0%	0%	0%	0%

Table 16. Oil Well HF Completion AFs – Percentage of Completions Within Each Control Category

Dataset	Basin	2015	2016	2017	2018	2019	2020	2021
Vented and non-REC								
Current GHGI	National	12%	3%	2%	0%	1%	1%	1%
Subpart W Basin-Level Analysis	160A – Appalachian (Eastern Overthrust Area)	NR	0%	0%	0%	0%	0%	0%
	220 – Gulf Coast (LA, TX)	NR	0%	0%	0%	0%	1%	2%
	230 – Arkla	NR	75%	0%	0%	100%	0%	0%
	430 – Permian	NR	5%	1%	0%	1%	1%	0%
	540 – Denver	NR	0%	0%	0%	0%	0%	0%
Vented and REC								
Current GHGI	National	30%	34%	42%	38%	46%	54%	54%
Subpart W Basin-Level Analysis	160A – Appalachian (Eastern Overthrust Area)	NR	100%	100%	100%	0%	0%	0%
	220 – Gulf Coast (LA, TX)	NR	28%	50%	42%	44%	46%	24%
	230 – Arkla	NR	25%	0%	0%	0%	100%	100%
	430 – Permian	NR	32%	40%	40%	55%	64%	68%
	540 – Denver	NR	10%	32%	19%	24%	50%	54%
Flared and non-REC								
Current GHGI	National	12%	13%	13%	15%	13%	10%	6%
Subpart W Basin-Level Analysis	160A – Appalachian (Eastern Overthrust Area)	NR	0%	0%	0%	0%	0%	0%
	220 – Gulf Coast (LA, TX)	NR	3%	7%	11%	10%	7%	13%
	230 – Arkla	NR	0%	0%	0%	0%	0%	0%
	430 – Permian	NR	4%	7%	7%	5%	6%	1%
	540 – Denver	NR	49%	37%	27%	22%	1%	5%
Flared and REC								
Current GHGI	National	26%	50%	44%	46%	41%	35%	39%
Subpart W Basin-Level Analysis	160A – Appalachian (Eastern Overthrust Area)	NR	0%	0%	0%	0%	0%	0%
	220 – Gulf Coast (LA, TX)	NR	69%	43%	47%	46%	46%	62%
	230 – Arkla	NR	0%	0%	0%	0%	0%	0%
	430 – Permian	NR	58%	52%	53%	39%	29%	32%

Dataset	Basin	2015	2016	2017	2018	2019	2020	2021
	540 – Denver	NR	41%	31%	55%	54%	49%	41%

Table 17. Gas Well HF Workover AFs – Percentage of Workovers Within Each Control Category

Dataset	Basin	2015	2016	2017	2018	2019	2020	2021
Vented and non-REC								
Current GHGI	National	8%	43%	12%	7%	29%	5%	4%
Subpart W Basin-Level Analysis	220 – Gulf Coast (LA, TX)	0%	0%	0%	0%	0%	0%	0%
	260 – East Texas	0%	66%	61%	17%	67%	60%	0%
	360 – Anadarko	1%	7%	0%	100%	0%	0%	100%
	420 – Fort Worth Syncline	0%	0%	0%	0%	0%	0%	0%
	455 – Las Vegas-Raton	0%	0%	0%	0%	0%	0%	0%
Vented and REC								
Current GHGI	National	75%	42%	52%	80%	56%	93%	94%
Subpart W Basin-Level Analysis	220 – Gulf Coast (LA, TX)	100%	100%	67%	78%	75%	100%	100%
	260 – East Texas	99%	24%	17%	83%	33%	30%	0%
	360 – Anadarko	93%	43%	38%	0%	100%	0%	0%
	420 – Fort Worth Syncline	80%	0%	0%	100%	100%	100%	100%
	455 – Las Vegas-Raton	0%	0%	0%	0%	0%	100%	100%
Flared and non-REC								
Current GHGI	National	3%	5%	7%	11%	11%	1%	0%
Subpart W Basin-Level Analysis	220 – Gulf Coast (LA, TX)	0%	0%	0%	22%	0%	0%	0%
	260 – East Texas	0%	6%	22%	0%	0%	0%	0%
	360 – Anadarko	4%	21%	19%	0%	0%	0%	0%
	420 – Fort Worth Syncline	0%	0%	0%	0%	0%	0%	0%
	455 – Las Vegas-Raton	0%	0%	0%	0%	0%	0%	0%
Flared and REC								
Current GHGI	National	14%	9%	28%	1%	4%	1%	1%
Subpart W Basin-Level Analysis	220 – Gulf Coast (LA, TX)	0%	0%	33%	0%	25%	0%	0%
	260 – East Texas	1%	4%	0%	0%	0%	10%	100%
	360 – Anadarko	2%	29%	44%	0%	0%	0%	0%
	420 – Fort Worth Syncline	20%	0%	100%	0%	0%	0%	0%
	455 – Las Vegas-Raton	0%	0%	0%	0%	0%	0%	0%

Table 18. Gas Well Non-HF Workover AFs – Percentage of Workovers Within Each Control Category

Dataset	Basin	2015	2016	2017	2018	2019	2020	2021
Vented								
Current GHGI	National	96%	96%	97%	93%	98%	99%	98%
Subpart W Basin-Level Analysis	220 – Gulf Coast (LA, TX)	81%	91%	89%	84%	100%	97%	93%
	360 – Anadarko	99%	99%	99%	99%	100%	100%	93%
	430 – Permian	58%	74%	79%	76%	98%	100%	100%
	540 – Denver	100%	100%	100%	73%	81%	87%	94%
	580 – San Juan	100%	100%	100%	100%	100%	100%	100%

Dataset	Basin	2015	2016	2017	2018	2019	2020	2021
Flared								
Current GHGI	National	4%	4%	3%	7%	2%	1%	2%
Subpart W Basin-Level Analysis	220 – Gulf Coast (LA, TX)	19%	9%	11%	16%	0%	3%	7%
	360 – Anadarko	1%	1%	1%	1%	0%	0%	7%
	430 – Permian	42%	26%	21%	24%	2%	0%	0%
	540 – Denver	0%	0%	0%	27%	19%	13%	6%
	580 – San Juan	0%	0%	0%	0%	0%	0%	0%

Table 19. Oil Well HF Workover AFs – Percentage of Workovers Within Each Control Category

Dataset	Basin	2015	2016	2017	2018	2019	2020	2021
Vented and non-REC								
Current GHGI	National	14%	5%	0%	5%	6%	1%	4%
Subpart W Basin-Level Analysis	220 – Gulf Coast (LA, TX)	NR	0%	0%	0%	0%	0%	0%
	360 – Anadarko	NR	100%	0%	0%	0%	0%	0%
	395 – Williston	NR	1%	0%	0%	0%	0%	0%
	430 – Permian	NR	0%	0%	6%	0%	0%	20%
	575 – Uinta	NR	0%	0%	0%	0%	0%	0%
Vented and REC								
Current GHGI	National	54%	60%	69%	85%	81%	80%	27%
Subpart W Basin-Level Analysis	220 – Gulf Coast (LA, TX)	NR	94%	100%	93%	100%	74%	57%
	360 – Anadarko	NR	0%	99%	100%	40%	100%	0%
	395 – Williston	NR	94%	63%	88%	27%	100%	11%
	430 – Permian	NR	70%	69%	82%	94%	100%	80%
	575 – Uinta	NR	0%	0%	100%	0%	0%	0%
Flared and non-REC								
Current GHGI	National	6%	6%	3%	1%	1%	1%	4%
Subpart W Basin-Level Analysis	220 – Gulf Coast (LA, TX)	NR	0%	0%	7%	0%	1%	29%
	360 – Anadarko	NR	0%	1%	0%	0%	0%	0%
	395 – Williston	NR	1%	14%	2%	7%	0%	0%
	430 – Permian	NR	4%	0%	0%	0%	0%	0%
	575 – Uinta	NR	0%	0%	0%	0%	0%	0%
Flared and REC								
Current GHGI	National	26%	29%	29%	9%	12%	18%	65%
Subpart W Basin-Level Analysis	220 – Gulf Coast (LA, TX)	NR	6%	0%	0%	0%	24%	14%
	360 – Anadarko	NR	0%	0%	0%	60%	0%	0%
	395 – Williston	NR	3%	24%	10%	67%	0%	89%
	430 – Permian	NR	26%	30%	11%	6%	0%	0%
	575 – Uinta	NR	100%	100%	0%	0%	0%	100%

NR – Not reported, subpart W did not begin collecting data for oil well completions until RY2016.

Appendix C: Basin-Level Emission Factors

Table 20 through Table 31 compare the current GHGI EFs to the EFs obtained using basin-level data for select basins, for the years 2019 through 2021. The selected basins represent the basins with the greatest number of each completion and/or workover event type reported for RY2021.

The following are observations on the EF data.

- Table 20 for non-REC vented HF gas well completions and workovers shows the greatest variability between basins in the 2021 CH_4 EFs due to the relatively large quantity of emissions reported to subpart W for the Green River Basin that year (45 MT CH_4) despite a small number of reported events (2 events).
- Table 21 for REC vented HF gas well completions and workovers shows the greatest variability between basins in the 2021 CH_4 EFs due to the relatively large quantity of emissions reported to subpart W for the Fort Worth Syncline that year (3,435 MT CH_4) despite a relatively small number of reported events (142 events).

- Table 22 for non-REC flared HF gas well completions and workovers shows the greatest variability between basins in the 2020 CO_2 EFs due to the relatively small number of events reported to subpart W for the Permian Basin that year (4 events) despite average emission levels relative to other years (13,168 MT CO_2).
- Table 23 for REC flared HF gas well completions and workovers shows the greatest variability between basins in the 2020 CO_2 EFs due to the relatively small number of events reported to subpart W for the Permian Basin that year (50 events) despite average emission levels relative to other years (66,553 MT CO_2).
- Table 24 for vented non-HF gas well completions shows the greatest variability between basins in the 2020 CH_4 EFs due to the relatively large quantity of emissions reported to subpart W for the Arkla Basin that year (368 MT CH_4) despite a lower than average number of reported events for the basin (3 events).
- Table 25 for flared non-HF gas well completions shows there is no difference when comparing basin-level EFs to the national average EFs used in the current GHGI. This is because the Gulf Coast Basin was the only basin with flared non-HF gas well completion events reported for 2019 through 2021, so the national-level EFs for this time period are based on this basin alone.
- Table 26 shows there is minimal variability in the basin-level EFs for vented non-HF gas well workovers, when comparing between basins and over time. There are also minimal differences when compared to the national average EFs used in the current GHGI.
- Table 27 for flared non-HF gas well workovers shows the greatest variability between basins in the 2021 CO_2 EFs due to the relatively large quantity of emissions reported to subpart W for the Arkla Basin that year (2,065 MT CH4) despite an average number of reported events for the basin relative to other years (19 events).
- Table 28 for non-REC vented HF oil well completions and workovers shows the greatest variability between basins in the 2020 CH_4 EFs due to the relatively small number of events reported to subpart W for the Anadarko Basin that year (5 events) despite average emission levels relative to other years (200 MT CH_4).
- Table 29 for REC vented HF oil well completions and workovers shows the greatest variability between basins in the 2020 CH_4 EFs due to the relatively large quantity of emissions reported to subpart W for the Permian Basin that year (4,052 MT CH_4) despite an average number of reported events for the basin relative to other years (1,592 events).
- Table 30 for non-REC flared HF oil well completions and workovers shows the greatest variability between basins in the 2021 CO_2 EFs due to the relatively small number of events reported to subpart W for the Permian Basin that year (22 events) despite average emission levels relative to other years (51,042 MT CH_4).
- Table 31 for REC flared HF oil well completions and workovers shows the greatest variability between basins in the 2019 CO_2 EFs due to the relatively large quantity of emissions reported to subpart W for the Williston Basin that year (526,941 MT CO_2) despite an average number of reported events for the basin relative to other years (629 events).

Table 20. Emission Factors for Non-REC Vented HF Gas Well Completions and Workovers (mt/event)

Dataset	Basin	CH_4			CO_2		
		2019	2020	2021	2019	2020	2021
Current GHGI	National	5.9	3.5	1.2	0.2	0.0	0.1

Dataset	Basin	CH_4			CO_2		
		2019	2020	2021	2019	2020	2021
Subpart W Basin-Level Analysis	220 – Gulf Coast (LA, TX)	0.0	0.0	7.0	0.0	0.0	0.3
	230 – Arkla	2.8	-	1.2	0.2	-	0.1
	260 – East Texas	6.9	0.3	0.4	0.3	0.0	0.0
	360 – Anadarko	-	2.7	1.2	-	0.0	0.0
	535 – Green River	-	-	22.7	-	-	1.5
	540 – Denver	-	-	0.2	-	-	0.0

a. A hyphen indicates instances where no events of this type were reported to subpart W for this year and basin.

Table 21. Emission Factors for REC Vented HF Gas Well Completions and Workovers (mt/event)

Dataset	Basin	CH_4			CO_2		
		2019	2020	2021	2019	2020	2021
Current GHGI	National	7.1	3.0	3.8	0.1	0.1	0.2
Subpart W Basin-Level Analysis	160A – Appalachian (Eastern Overthrust Area)	13.0	5.0	2.4	0.0	0.0	0.0
	220 – Gulf Coast (LA, TX)	5.0	1.2	2.3	0.2	0.1	0.1
	230 – Arkla	3.4	2.3	0.5	0.3	0.3	0.1
	260 – East Texas	2.9	2.5	0.7	0.2	0.2	0.1
	420 – Fort Worth Syncline	1.0	1.8	24.2	0.3	0.4	1.4
	430 – Permian	0.1	0.1	0.7	0.0	0.0	0.0

Table 22. Emission Factors for Non-REC Flared HF Gas Well Completions and Workovers (mt/event)

Dataset	Basin	CH_4			CO_2			N_2O		
		2019	2020	2021	2019	2020	2021	2019	2020	2021
Current GHGI	National	2.4	3.8	0.1	266.0	247.9	11.9	0.0006	0.0004	0.0000
Subpart W Basin-Level Analysis	160A – Appalachian (Eastern Overthrust Area)	0.3	-	0.1	44.3	-	8.7	0.0001	-	0.0000
	220 – Gulf Coast (LA, TX)	2.8	4.1	0.7	325.2	132.4	92.8	0.0008	0.0003	0.0001
	260 – East Texas	1.2	0.1	0.0	141.1	9.6	6.9	0.0003	0	0.0000
	430 – Permian	7.6	5.4	0.0	665.2	1,380.7	2.5	0.0011	0.0023	0.0000
	540 – Denver	-	-	0.1	-	-	9.3	-	-	0.0000
	580 – San Juan	0.4	-	0.0	77.8	-	5.6	0.0002	-	0.0000

a. A hyphen indicates instances where no events of this type were reported to subpart W for this year and basin, while a zero indicates no emissions, but at least one event, were reported to subpart W.

Table 23. Emission Factors for REC Flared HF Gas Well Completions and Workovers (mt/event)

Dataset	Basin	CH_4			CO_2			N_2O		
		2019	2020	2021	2019	2020	2021	2019	2020	2021
Current GHGI	National	1.1	1.3	0.2	181.7	175.6	22.7	0.0003	0.0003	0.0000
Subpart W Basin-Level Analysis	160A – Appalachian (Eastern Overthrust Area)	1.1	1.2	0.1	48.3	12.9	8.2	0.0001	0.0000	0.0000
	220 – Gulf Coast (LA, TX)	2.2	1.5	1.1	236.1	23.2	56.6	0.0005	0.0000	0.0001
	260 – East Texas	3.7	0.7	0.0	83.4	121.0	0.1	0.0002	0.0002	0.0000
	430 – Permian	2.5	6.1	0.2	551.1	1,331.1	33.5	0.0008	0.0023	0.0000
	540 – Denver	0.0	0.1	0.0	12.9	9.6	0.1	0.0002	0.0000	0
	595 – Piceance	0.0	0.0	0.2	2.0	1.0	11.1	0.0000	0.0000	0

a. A zero indicates instances where no emissions, but at least one event, were reported to subpart W.

Table 24. Emission Factors for Vented Non-HF Gas Well Completions (mt/event)

Dataset	Basin	CH_4			CO_2		
		2019	2020	2021	2019	2020	2021
Current GHGI	National	1.0	3.5	0.4	0.1	0.5	0.1
Subpart W Basin-Level Analysis	160A – Appalachian (Eastern Overthrust Area)	1.2	1.0	2.2	0.0	0.0	0
	220 – Gulf Coast (LA, TX)	2.2	0.2	0	0.0	0.1	0
	230 – Arkla	0.5	122.7	0	0.0	20.6	0
	430 – Permian	1.0	0	0.1	0.1	0	0.0
	580 – San Juan	8.4	3.5	0.0	2.1	0.5	2.2
	820 – AK Cook Inlet	0	0	0	0	0	0

a. A hyphen indicates instances where no events of this type were reported to subpart W for this year and basin, while a zero indicates no emissions, but at least one event, were reported to subpart W.

Table 25. Emission Factors for Flared Non-HF Gas Well Completions (mt/event)

Dataset	Basin	CH_4			CO_2			N_2O		
		2019	2020	2021	2019	2020	2021	2019	2020	2021
Current GHGI	National	0.0	0.0	16.0	5.2	0.0	2,688.7	0.0000	0.0000	0.0057
Subpart W Basin-Level Analysis	220 – Gulf Coast (LA, TX)	0.0	-	16.0	5.2	-	2,688.7	0	-	0.0057

a. A hyphen indicates instances where no events of this type were reported to subpart W for this year and basin, while a zero indicates no emissions, but at least one event, were reported to subpart W.
b. Basin 220 was the only basin with Flared Non-HF Gas Well Completion events reported for 2019 through 2021.

Table 26. Emission Factors for Vented Non-HF Gas Well Workovers (mt/event)

Dataset	Basin	CH_4			CO_2		
		2019	2020	2021	2019	2020	2021
Current GHGI	National	0.1	0.0	0.0	0.0	0.1	0.0
Subpart W Basin-Level Analysis	160A – Appalachian (Eastern Overthrust Area)	0.1	0.1	0.1	0.0	0.0	0.0
	360 – Anadarko	0.1	0.0	0.0	0.0	0.0	0.0
	420 – Fort Worth Syncline	0.0	0.0	0.0	0.0	0.0	0.0
	430 – Permian	0.0	0.0	0.0	0.0	0.1	0.0
	540 – Denver	0.0	0.0	0.0	0.0	0.0	0.0
	580 – San Juan	0.1	0.1	0.1	0.0	0.0	0.0

Table 27. Emission Factors for Flared Non-HF Gas Well Workovers (mt/event)

Dataset	Basin	CH_4			CO_2			N_2O		
		2019	2020	2021	2019	2020	2021	2019	2020	2021
Current GHGI	National	0.0	0.0	0.1	1.5	0.2	23.0	0.0000	0.0000	0.0000
Subpart W Basin-Level Analysis	160A – Appalachian (Eastern Overthrust Area)	0.6	-	0.0	87.9	-	1.8	0.0002	-	0.0000
	220 – Gulf Coast (LA, TX)	-	0	0.3	-	0.2	85.7	-	0	0.0001
	230 – Arkla	-	-	0.7	-	-	108.7	-	-	0.0002
	305 – Michigan	-	-	0	-	-	0	-	-	0
	360 – Anadarko	0.0	-	0.0	0.0	-	2.0	0	-	0.0000
	540 – Denver	0.0	0.0	0.0	0.2	0.2	0.2	0.0000	0.0000	0.0000

a. A hyphen indicates instances where no events of this type were reported to subpart W for this year and basin, while a zero indicates no emissions, but at least one event, were reported to subpart W.

Table 28. Emission Factors for Non-REC Vented HF Oil Well Completions and Workovers (mt/event)

Dataset	Basin	CH_4			CO_2		
		2019	2020	2021	2019	2020	2021
Current GHGI	National	11.6	11.5	2.0	0.5	0.4	0.1
Subpart W Basin-Level Analysis	220 – Gulf Coast (LA, TX)	0.2	23.4	1.2	0.0	1.8	0.2
	360 – Anadarko	-	39.9	3.8	-	0.8	0.1
	395 – Williston	0	-	0	0	-	0
	430 – Permian	5.4	5.2	0.0	0.1	0.1	0.0
	515 – Powder River	-	-	0	-	-	0

Dataset	Basin	CH_4			CO_2		
		2019	2020	2021	2019	2020	2021
	575 – Uinta	-	-	0	-	-	0

a. A hyphen indicates instances where no events of this type were reported to subpart W for this year and basin, while a zero indicates no emissions, but at least one event, were reported to subpart W.

Table 29. Emission Factors for REC Vented HF Oil Well Completions and Workovers (mt/event)

Dataset	Basin	CH_4			CO_2		
		2019	2020	2021	2019	2020	2021
Current GHGI	National	0.9	1.7	0.2	0.035	0.042	0.008
Subpart W Basin-Level Analysis	220 – Gulf Coast (LA, TX)	0.3	0.2	0.3	0.02	0.02	0.02
	360 – Anadarko	0.7	0.1	0.2	0.01	0.00	0.00
	395 – Williston	0.1	0.0	0.0	0.00	0.00	0.00
	430 – Permian	1.2	2.5	0.2	0.05	0.06	0.01
	540 – Denver	0.3	0	0	0.02	0	0
	575 – Uinta	0	0	0	0	0	0

a. A zero indicates instances where no emissions, but at least one event, were reported to subpart W.

Table 30. Emission Factors for Non-REC Flared HF Oil Well Completions and Workovers (mt/event)

Dataset	Basin	CH_4			CO_2			N_2O		
		2019	2020	2021	2019	2020	2021	2019	2020	2021
Current GHGI	National	1.9	3.2	2.3	565.8	611.7	528.9	0.0009	0.0010	0.0009
Subpart W Basin-Level Analysis	220 – Gulf Coast (LA, TX)	1.0	4.7	4.4	213.9	819.0	498.9	0.0003	0.0020	0.0012
	395 – Williston	1.6	1.4	0.9	682.3	562.7	399.5	0.0011	0.0008	0.0006
	430 – Permian	4.0	5.8	9.2	645.9	625.8	2,320.1	0.0010	0.0011	0.0041
	515 – Powder River	1.6	0.2	0.3	497.2	155.4	227.9	0.0009	0.0003	0.0004
	540 – Denver	0.7	0.1	0.1	173.3	21.5	17.8	0.0003	0.0000	0.0000
	580 – San Juan	-	-	5.2	-	-	1,739.5	-	-	0.0031

a. A hyphen indicates instances where no events of this type were reported to subpart W for this year and basin.

Table 31. Emission Factors for REC Flared HF Oil Well Completions and Workovers (mt/event)

Dataset	Basin	CH_4			CO_2			N_2O		
		2019	2020	2021	2019	2020	2021	2019	2020	2021
Current GHGI	National	1.2	0.9	1.1	291.1	200.5	102.3	0.0004	0.0003	0.0002
Subpart W Basin-Level Analysis	220 – Gulf Coast (LA, TX)	0.5	0.2	0.2	49.1	120.9	31.8	0.0001	0.0001	0.0001
	360 – Anadarko	0.9	3.6	0.7	113.6	121.0	39.3	0.0002	0.0002	0.0001
	395 – Williston	2.0	1.5	0.4	837.7	619.0	133.2	0.0007	0.0007	0.0002
	430 – Permian	1.2	0.7	1.9	213.5	148.1	143.4	0.0004	0.0004	0.0003
	515 – Powder River	1.0	0.2	0.7	123.0	67.0	40.5	0.0002	0.0001	0.0001
	540 – Denver	0.3	0.1	0.1	41.9	15.3	20.5	0.0001	0.0000	0.0000