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Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2022: Updates Under Consideration for Transmission Compressor Station Activity

This memo discusses updates under consideration for the 2024 *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (GHGI) to estimate the following activity data: number of transmission compressor stations, number of reciprocating compressors, and number of centrifugal compressors (total, dry seal, and wet seal).

The current methodology to estimate national transmission station and compressor counts is based on an application of a static scale up factor to annual Greenhouse Gas Reporting Program (GHGRP) subpart W data. As the fraction of the national population of transmission stations reporting to subpart W may change over time, we are considering an updated approach to improve national transmission activity data counts in the GHGI.

1 Current GHGI Methodology

Natural gas transmission involves transporting natural gas from production and processing areas to distribution systems or large volume customers such as power plants or chemical plants. Compressor station facilities, which contain reciprocating and centrifugal compressors, are used to move the natural gas throughout the U.S. transmission system. Transmission emissions result primarily from compressor stations (including compressors), pneumatic controllers, pipeline venting, and uncombusted engine exhaust.

This update under consideration impacts the calculated emissions for transmission compressor stations, reciprocating and centrifugal compressors, equipment leaks (including from compressors), flaring, dehydrator vents, pneumatic controllers, and station venting.

EPA is proposing to update components of the existing activity data (AD) methodology, which EPA has implemented since the "*Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2014: Revisions to Natural Gas Transmission and Storage Emissions*" memo (2016 memo).[1] A summary of EPA's current AD methodology (i.e., 1990-2021 GHGI) is described below.

The AD for transmission compressor stations for which EPA is considering updates consists of:

- Number of transmission compressor stations
- Number of reciprocating compressors
- Number of wet seal centrifugal compressors
- Number of dry seal centrifugal compressors

The current methodology to estimate national transmission station and compressor counts is based on Greenhouse Gas Reporting Program (GHGRP) subpart W data and results from the 2015 Zimmerle et al. study.[2] Zimmerle et al. used data from the Federal Energy Regulatory Commission (FERC) Form 2 for interstate gas transmission companies and pipeline mileage from the Energy Information Administration (EIA) to estimate the national transmission station count for 2012 (i.e., 1,587 stations). The study also analyzed GHGRP subpart W data for transmission stations and developed a scaling factor of 3.52 to develop national level counts from the GHGRP reported counts. In the current methodology, this scaling factor (3.52) is applied to subpart W annual station counts to estimate national transmission station counts for 2011 and 2013-2021. Station counts from the Zimmerle et al. study were directly used for 2012. The 1992 national transmission station counts (i.e., 1,730

[1] ERG/EPA Memo "Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2014: Revisions to Natural Gas Transmission and Storage Emissions". April 2016. Available online at: https://www.epa.gov/ghgemissions/natural-gas-and-petroleum-systems-ghg-inventory-additional-information-1990-2014-ghg.

[2] Zimmerle, D.J.; Williams L.L.; Vaughn, T.L.; Quinn, C.; Subramanian, R.; Duggan, G.P.; Willson, B.; Opsomer, J.D.; Marchese, A.J.; Martinez D.M.; Robinson, A.L. Methane Emissions from the Natural Gas Transmission and Storage System in the United States. *Environmental Science and Technology*, 49, 9374-9383. 2015

stations) are from the 1996 GRI/EPA study and are used as proxy for 1990 and 1991.[3] The national station counts for 1993-2010 are calculated using linear interpolation between 1992 and 2011 data.

The Zimmerle et al. study also estimated national-level transmission compressor counts for 2012. As is the case for transmission stations, reported transmission compressor counts are also available from subpart W data. The Zimmerle study assessed the subpart W-reported population of compressors and a broader data set collected in their study and determined that the number of compressors per station in the GHGRP was not representative of the number of compressors per station in the broader population. Therefore, instead of using the ratio of compressors per station in the subpart W data, the Zimmerle study developed a national level estimate of compressors in 2012 using a combination of subpart W data and study data.

EPA used the Zimmerle et al. study data to estimate national compressor counts for the GHGI. Using the study data, EPA calculated the number of compressors per stations by type of compressor (i.e., reciprocating compressors and centrifugal compressors) – 2.8 reciprocating compressors/station and 1.2 centrifugal compressors/station. These ratios are applied to the national transmission station counts to estimate national reciprocating compressor and centrifugal compressor counts for 2011 and 2013-2021. Compressor counts from the Zimmerle et al. study were directly used for 2012. The 1992 compressor counts are from the 1996 GRI/EPA study and are used as a proxy for 1990 and 1991. For the intermediate years (1993-2010), the current methodology uses linear interpolation between 1992 and 2011 data.

EPA estimated the year-specific distribution of dry seal and wet seal centrifugal compressors for 2011-2021 using subpart W data. The 1992 compressor distribution information is from the 1996 GRI/EPA study and used as proxy for 1990 and 1991. For intermediate years (i.e., 1993-2010), EPA linearly interpolated between 1992 and 2011 data. Refer to the 2016 memo for more details on AD methodology.

2 Available Data

EPA reviewed multiple data sources to identify relevant sources of AD (i.e., station and compressor counts). Each of the data sources are identified here, and a brief summary is provided:

- FERC – FERC requires major natural gas interstate transmission companies to report annual information on transmission pipeline miles, transmission compression station locations, and number of compressor units.[4] Information on the type of compressor (i.e., reciprocating, or centrifugal) is not available. Companies report this information annually using FERC Form 2. Annual Form 2 data are available from 1996-2022. For 1996-2020, annual data are compiled into single datasets that are available on FERC's website.[5] Starting with reporting year 2021, FERC stopped publishing annual datasets. Instead, individual company reports are available for download. More than 100 natural gas transmission companies reported Form 2 data for 2021 and 2022, each.
- Enverus Midstream Data – Transmission pipeline miles and number of transmission compressor stations are available from Enverus. Information on the number of compressor units is not available. These data are only available as a snapshot of current operations (and the current year). Historical data are currently not available from Enverus.
- Homeland Infrastructure Foundation-Level Data (HIFLD) – U.S. Department of Homeland Security's HIFLD contains information on transmission compressor stations and number of compressor units.[6]

[3] Methane Emissions from the Natural Gas Industry. Prepared by Harrison, M., T. Shires, J. Wessels, and R. Cowgill, eds., Radian International LLC for National Risk Management Research Laboratory, Air Pollution Prevention and Control Division, Research Triangle Park, NC. EPA-600/R-96-080a.

[4] Only "major" natural gas companies provide facility details in Form 2. "Major" companies are those whose combined gas transported or stored exceed 50 million dekatherms (1 dekatherm, Dth = 1 MMBtu) in each of the previous three years. "Non-major" companies complete Form 2A, which does not include detailed station information.

[5] FERC Form 2 Historical Data - https://ferc.gov/industries-data/natural-gas/industry-forms/form-2-2a-3-q-gas-historical-vfp-data.

[6] HIFLD Open Data - https://hifld-geoplatform.opendata.arcgis.com/.

Similar to Enverus midstream data, these data are only available for current operations. Information on the type of compressor is not available. One of the data sources used in developing the HIFLD transmission compressor station data is FERC Form 2 annual reports.

- Other Sources – Year-specific subpart W data, including transmission station counts and compressor counts (by type), and annual onshore transmission segment mileage from the Pipeline and Hazardous Materials Safety Administration (PHMSA).

3 Analysis of Available Data

EPA reviewed and analyzed data from FERC Form 2 that could be used to update national transmission station and compressor counts used in the GHGI. The FERC Form 2 annual reporting data that were evaluated consisted of transmission miles, number of transmission compressor stations, and number of transmission compressors. Every year, applicable interstate natural gas transmission companies are required to report this information to FERC. This information is available for public use on FERC's website. For this analysis, EPA compiled annual data from FERC for several years – 1996, 2000, 2006, 2011, 2012, 2016, and 2020. EPA reviewed the annual FERC data and performed a series of data cleaning steps. Refer to Appendix A for a summary of the FERC data cleaning process employed by EPA. After the data cleaning steps were completed, EPA calculated total transmission pipeline mileage, compressor station count, and number of compressors from FERC annual data.

PHMSA data contains national level pipeline miles from transmission and gathering segments for the entire time series (i.e., 1990-present). The transmission pipeline miles are categorized by offshore and onshore transmission pipelines. PHMSA data does not include information on compressor stations or compressor units.

GHGRP's subpart W data for the transmission segment contains annual reported information from transmission compression and pipeline facilities. These data include information on transmission pipeline miles, compressor stations, and compressor units (by type) for 2011-2022. The subpart W data only includes data for facilities that have operations above the reporting threshold established by the GHGRP.

EPA also reviewed Enverus midstream data and HIFLD data. Neither of these data sources provide a time series and both present only snapshots of current operations. Table 1 presents a summary of pipeline miles, station counts, and compressor unit counts (as available) from FERC, Enverus, HIFLD, PHMSA data, and the reported subpart W data.

Table 1. Comparison of FERC, Enverus, HIFLD, and PHMSA Data.

Source	Year of Data in this Table	Transmission Miles	Transmission Stations	Transmission Compressor Units	Current Available Years of Data	Scope of Data
FERC[a]	2020	184,774	1,163	4,692	1996-2022	"Major" companies
Enverus	2022[b]	325,215	1,930	ND	Snapshot of current operations	National total
DHS/HIFLD	2023[c]	ND	1,874	6,603	Snapshot of current operations	National total
PHMSA	2020	298,835	ND	ND	1990-2022	National total
Subpart W	2020	190,691	644	3,344	2011-2022	Reported total from facilities

[a] Transmission miles, stations, and compressors listed here are unscaled counts from annual FERC data for 2020.
[b] Enverus midstream data used in this analysis represent transmission segment operations as of June 2022.
[c] DHS/HIFLD data used in this analysis represent transmission segment operations as of July 2023.
ND – No Data.

Compressor counts are not available from Enverus or PHMSA data and transmission pipeline miles are not available from the DHS/HIFLD data. The DHS/HIFLD data are primarily from FERC (form 2 annual data) and supplemented with data from subpart W and state agencies (e.g., Oklahoma Department of Environmental Quality and Kansas Department of Health and Environment).

Table 2 presents a summary of annual activity factors of transmission miles per station and compressors per station calculated from FERC data, and Enverus (miles/station), and DHS/HIFLD (compressors/station) and compares them to the current GHGI data.

Table 2. Activity Factor Comparison.

Source	1996	2000	2006	2011	2012	2016	2020[a]
Transmission pipeline miles/station							
FERC	167.7	167.7	179.1	163.7	165.8	172.2	158.9
Enverus							168.5
Current GHGI	169.7	183.9	194.1	205.9	191.2	160.1	133.1
Subpart W	N/A	N/A	N/A	N/A	N/A	286.8	296.1
Compressors/station							
FERC	4.80	4.69	4.57	4.13	4.15	4.14	4.03
DHS/HIFLD[a]							3.53
Current GHGI	4.41	4.40	4.38	4.36	4.03	4.03	4.03
Subpart W	N/A	N/A	N/A	7.82	7.49	5.95	5.30

[a] For Enverus and DHS/HIFLD, the values in this column are snapshots of current operations obtained in 2022 and 2023, respectively.

The FERC and Enverus data show more transmission pipeline miles between stations than in the current GHGI, which would suggest fewer transmission stations than in the GHGI. The subpart W data show much higher values for transmission pipeline miles between stations; however, in subpart W transmission pipelines and transmission stations are included under separate reporting categories with different coverage, so the populations are not directly comparable.

The FERC data show the same value for compressors per station as in the current GHGI for 2020, but different results over the time series. Subpart W shows a much higher count of compressors per station than the GHGI, likely due to the subpart W reporting population for transmission stations consisting of larger compressors stations than the national average.

Update Under Consideration

EPA is considering updating the GHGI using a combination of data from FERC and PHMSA. The Enverus and DHS/HIFLD do not provide a time series of data but do provide data that can be used to compare with the values developed in our approach using FERC and PHMSA data.

As noted previously, not all transmission companies report annual data to FERC. In the updated approach under consideration, national level station counts would be developed by dividing the PHMSA total national transmission pipeline miles by the value for miles per station (table 2). Total national compressor counts would then be developed by multiplying the annual ratio of compressors per station from FERC data by the calculated total national station counts. This approach considers that the FERC “major companies” data is the most complete dataset available for the U.S. and the best option to represent national activity.

To estimate the national reciprocating and centrifugal compressor counts (wet seal and dry seal), EPA would use subpart W data. Subpart W data are currently used to calculate the proportions of wet and dry seal centrifugal compressors. National transmission station and compressor counts (AD) developed using the proposed update

and from the current GHGI are presented in Table 3. In this memo, AD refers to transmission station counts and compressor counts, by type of compressor.

Table 3. AD Comparison.

AD – Update Under Consideration							
Data Element	**1996**	**2000**	**2006**	**2011**	**2012**	**2016**	**2020**
National station counts	1,657	1,752	1,640	1,831	1,801	1,725	1,881
National compressor counts[a]	7,946	8,213	7,494	7,561	7,482	7,144	7,589
Reciprocating compressors	6,948	6,899	5,908	5,636	5,557	5,204	5,106
Centrifugal compressors[b]	998	1,314	1,586	1,925	1,925	1,940	2,483
Dry seal centrifugal compressors	130	343	724	1,192	1,157	1,233	1,707
Wet seal centrifugal compressors	868	971	862	733	768	707	776
AD – Current Methodology (1990-2021 GHGI)							
Data Element	**1996**	**2000**	**2006**	**2011**	**2012**	**2016**	**2020**
National station counts	1,678	1,626	1,547	1,482	1,587	1,876	2,267
National compressor counts	7,403	7,152	6,775	6,461	6,398	7,564	9,139
Reciprocating compressors	6,469	5,981	5,249	4,640	4,518	5,341	6,454
Centrifugal compressors	934	1,171	1,525	1,821	1,880	2,223	2,685
Dry seal centrifugal compressors	238	475	832	1,129	1,129	1,413	1,846
Wet seal centrifugal compressors	697	695	694	692	751	809	839

[a] National compressor counts = reciprocating compressors + centrifugal compressors

[b] Centrifugal compressors = dry seal centrifugal compressors + wet seal centrifugal compressors

4 Time Series Considerations

FERC and PHMSA annual data are publicly available from 1996 onwards. Therefore, national station counts developed using FERC data scaled up by PHMSA mileage can be developed for 1996-onwards. EPA proposes to retain existing AD (national station counts) for 1990-1992 and develop national station counts for intermediate time series years (i.e., 1993-1995) using linear interpolation between 1992 and 1996 station counts.

Annual ratios of compressors per station can be developed using FERC annual data for 1996-onwards. These ratios would then be applied to the national station counts to estimate the total number of compressors for 1996-onwards. EPA proposes to retain existing AD (national compressor counts) for 1990-1992 and develop compressor counts for 1993-1995 using linear interpolation between 1992 and 1996 compressor counts.

EPA would use subpart W data to determine the distribution of reciprocating compressors, wet seal centrifugal compressors, and dry seal centrifugal compressors within the total compressor counts. Subpart W data are available for 2011 and recent years (i.e., 2011-2022). EPA proposes to retain the existing activity factors (distribution of reciprocating and centrifugal compressors within total compressor counts) from the 1996 GRI/EPA study for 1990-1992 and develop data for 1993-2010 using linear interpolation between 1992 and 2011 data.

5 Preliminary National Emissions Estimates

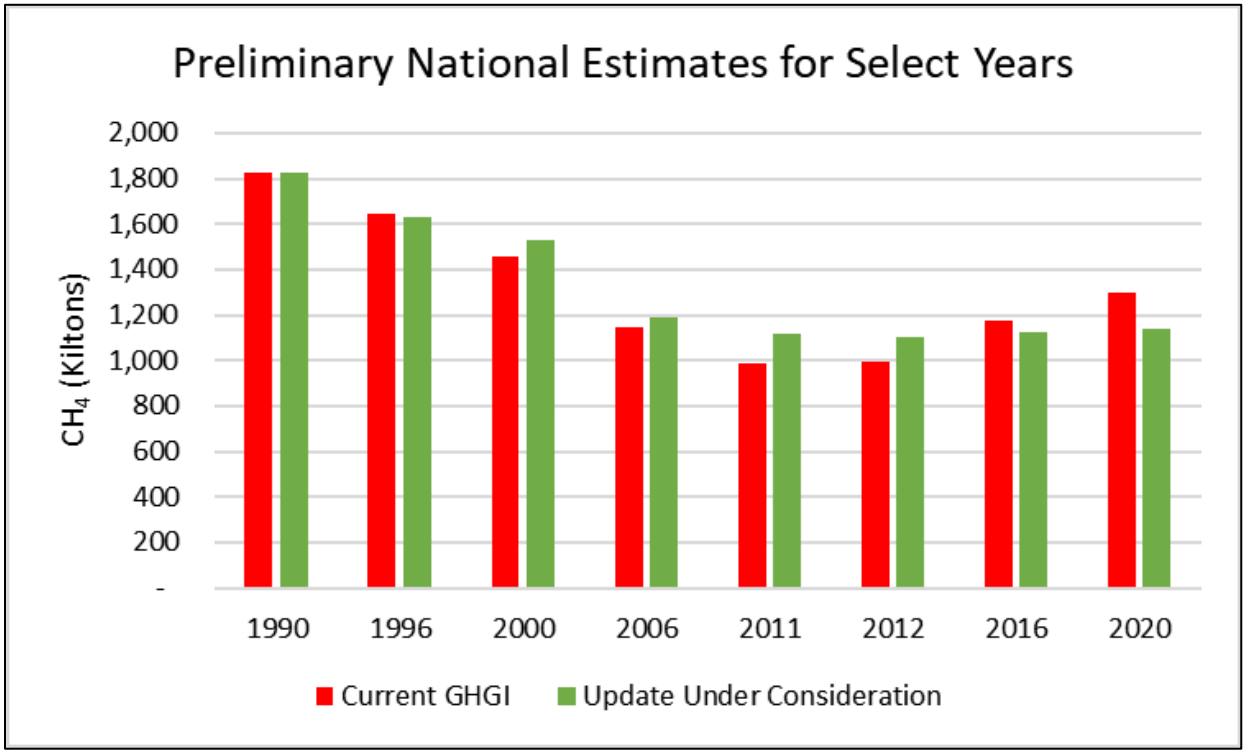
EPA estimated preliminary national transmission station fugitive emissions using existing GHGI EFs and proposed AD described in sections 3 and 4, above. Table 4 and Figure 1 present the resulting CH_4 emissions for select years.

Table 4. Preliminary National CH_4 Estimates (Kilotons)

Emission Source	1990	1996	2000	2006	2011	2012	2016	2020
Station Total Emissions	1,097	941	879	660	586	582	551	580
Station + Compressor Fugitive Emissions					117	115	110	120
Reciprocating Compressor					366	361	338	332
Centrifugal Compressor (wet seals)					50	52	48	53
Centrifugal Compressor (dry seals)					52	51	54	75
Dehydrator vents (Transmission)	2	2	2	2	2	2	2	2
Flaring (Transmission)	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.5
Pneumatic Devices Transmission	213	168	128	74	37	24	24	30
High Bleed					24	11	9	9
Intermittent Bleed					12	12	14	20
Low Bleed					1	1	1	1
Station Venting Transmission	145	137	145	128	151	148	127	137
Other Transmission Sources	368	385	374	324	340	345	423	388
Total Transmission Emissions - Update Under Consideration	**1,825**	**1,634**	**1,527**	**1,189**	**1,116**	**1,099**	**1,127**	**1,138**
Total Transmission Emissions - Current GHGI	***1,827***	***1,647***	***1,454***	***1,149***	***987***	***994***	***1,175***	***1,300***

Note: The EFs used in the GHGI are available at equipment-level for 2011 forward. The EFs used for 1990-2010 are not available at equipment-level and therefore, station-level EFs are used in the GHGI for 1990-2010. Refer to the 2016 memo for more details on the EFs used in the GHGI.

Figure 1. Preliminary National Estimates.



6 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 transmission station and compressor counts used in the GHGI to reflect ongoing trends?
2. Are there data sources that contain information on state-level or regional (e.g., basin-level) station and compressor counts that can be used in the GHGI?
3. Are there alternative data sources or methods that EPA should consider applying to scale up station and compressor counts to generate national estimates?

Appendix A – FERC Data Cleaning Steps

The data downloaded from FERC's website are not in a readily usable format and need significant data cleaning and processing before they can be used for GHGI purposes. The relevant FERC data are available in two tables – Compressor Stations and Transmission Lines. Below is a summary of data cleaning and processing steps employed by EPA in developing annual station and compressor counts from FERC data:

- Respondents reported subtotals and totals for pipeline miles and compressor stations. These records were excluded to avoid double-counting.
- Some respondents reported multiple compressor stations in a single record and indicated the number of stations that are being reported. These records were processed such that the number of stations grouped together were properly accounted in the results.
- Transmission pipeline miles and compressor station data were reported as "operated and owned by respondent", "operated but not owned by respondent", "operated and jointly owned by respondent", or "owned but not operated by respondent". Records that were indicated as not being operated by respondent (regardless of ownership) were excluded to avoid double-counting in case these data were reported by another respondent.
- In some instances, respondents reported compressor stations that were retired or otherwise inactive (labelled as "retired" or "not operating"). These records were excluded from the results.
- Pipeline records that were labelled as gathering system miles or offshore miles were excluded from the transmission pipeline totals. Only onshore transmission miles were included in this analysis.
- Compressor station records that were labelled as gathering, production, field, or other compressor stations were excluded. Only onshore transmission compressor stations were included in this analysis.
- Compressor stations and units with zero annual operational hours were also excluded from final counts.