

Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2020: Updates for Gas STAR and Methane Challenge Reductions

This memo documents the updates implemented in EPA's 2022 *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (GHGI) due to reassessing Natural Gas STAR ("Gas STAR") reductions and incorporating Methane Challenge reductions. Additional considerations for using reductions data in the GHGI were previously discussed in a memo released in September 2021 (*Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2020: Updates Under Consideration for Gas STAR and Methane Challenge Reductions*).¹

1 Background and Previous (1990-2019) GHGI Methodology

For a limited number of emission sources within Natural Gas Systems, EPA applies methane (CH₄) emission factors (EFs) from a 1996 Gas Research Institute (GRI) and EPA study (GRI/EPA study) across the entire 1990-2019 time series.² These EFs are representative of technologies and practices in the early 1990's, but not necessarily of more recent operations. Industry practices and technologies have evolved significantly in the 25 years since the release of the GRI/EPA study. For these emission sources, the methodology first estimated "potential" emissions with the GRI/EPA factors and then estimated "net" emissions by subtracting voluntary emissions reductions reported under EPA's Gas STAR program from the potential emissions.³ Throughout this memo, this is called a "potential methodology". Most other GHGI emission source calculation methodologies have been updated to use EFs developed from subpart W data or a recently published methane emissions study; throughout this memo, this is called a "net methodology".

Within the Gas STAR program, voluntary emission reductions are classified as either short- or long-term reductions. Short-term reductions are assumed to be 1-year reductions and in the GHGI are only applied to calculated potential emissions in the specific year of implementation. In contrast, long-term reductions are those reductions which extend beyond the specific year of implementation. Most of these long-term reductions are the result of capital investments in new equipment, controls, etc. For these sources, the Gas STAR program assigns a "sunset date", which is the length of time a technology or practice could be considered to generate emission reductions for the purposes of Gas STAR after implementation. For long-term reductions, the "sunset date" is either 7 or 10 years. For purposes of the GHGI, EPA assumes that all reported long-term reductions are permanent (i.e., Gas STAR "sunset dates" are ignored and the identified reductions are applied to the implementation year and all subsequent years). The net effect of this assumption is that the total annual quantity of long-term reductions gradually increases over time as more reductions are reported to Gas STAR.

In the previous GHGI (i.e., 1990-2019 GHGI), Gas STAR reductions were applied to the following sources:

- Production Segment
 - Gas engines
 - Compressor starts
 - Other (*for activities not assigned to a particular GHGI emission source*)
- Transmission and Storage Segment
 - Pipeline leaks
 - Dehydrator vents (Transmission)
 - Engines (Transmission)
 - Station venting (Transmission)

¹ https://www.epa.gov/system/files/documents/2021-09/2022-ghgi-update-gas-starmc_sept-2021.pdf

² GRI/EPA 1996. Methane Emissions from the Natural Gas Industry. EPA-600/R-96-080. June 1996.

³ In addition to adjustments for voluntary reductions, regulatory reductions are also applied for one source in the GHGI--production segment dehydrator vents, to reflect NESHAP reductions. Other sources covered by regulations (such as NSPS) are calculated with a net methodology.

The most recent Gas STAR reduction data that were incorporated into the GHGI were for 2013. These 2013 year reductions were then carried forward as proxy data for the 2014 through 2019 emission years without new reductions data being incorporated. Table 1 (Production Segment) and Table 2 (Transmission and Storage Segment) present the numerical Gas STAR reductions used and reported in the previous GHGI. Reductions are only presented for inventory years 1990, 2005, and 2015-2019 (i.e., the years shown in the main text of the previous GHGI report); Appendix A presents the numerical Gas STAR reductions for the entire 1990-2019 time series in the previous GHGI.

Table 1. Annual Production Segment Gas STAR Reductions for 1990, 2005, and 2015-2019 (mt CH₄) in the Previous (2021) GHGI.

Source	1990	2005	2015	2016	2017	2018	2019
Gas Engines	0	96,625	139,167	139,167	139,167	139,167	139,167
Compressor Starts	0	182	512	512	512	512	512
Other	0	100,762	104,624	104,624	104,624	104,624	104,624
Total	0	197,569	244,304	244,304	244,304	244,304	244,304

Table 2. Annual Transmission and Storage Segment Gas STAR Reductions for 1990, 2005, and 2015-2019 (mt CH₄) in the Previous (2021) GHGI.

Source	1990	2005	2015	2016	2017	2018	2019
Pipeline Leaks	0	0	1,213	1,213	1,213	1,213	1,213
Dehydrator vents	0	2,718	2,819	2,819	2,819	2,819	2,819
Engines	0	83,207	126,910	126,910	126,910	126,910	126,910
Station Venting	0	126,310	136,856	136,856	136,856	136,856	136,856
Total	0	212,235	267,799	267,799	267,799	267,799	267,799

2 Update Implemented in the 2022 GHGI

2.1 Gas STAR

EPA replaced the Gas STAR data currently used in the GHGI with a revised dataset including reductions from 1990-2019⁴, adjusted to remove reductions for sources calculated with net methodologies. EPA continued to treat long-term Gas STAR reductions in the revised dataset in the same manner as the previous GHGI approach wherein those reductions are assumed to be permanent (see Section 1). Reduction data for 2019 were applied for 2020, as 2020 data were not yet available.

As part of the overall reassessment of the Gas STAR reductions, EPA examined every Gas STAR activity (i.e., the list of technologies and practices implemented by companies to mitigate emissions) in the Production, Transmission and Storage, and Distribution segments.⁵ First, EPA assigned each Gas STAR reduction activity in the Production segment and the Transmission and Storage segment to a GHGI emission source; in a few instances, a Gas STAR reduction activity was assigned to two GHGI emissions sources. EPA also assigned relevant Gas STAR reduction activities in the Distribution segment to specific Distribution segment emission sources: pressure relief valve releases, pipeline blowdowns, and mishaps (dig-ins). The Gas STAR reductions data assessed included a total of 102 Production segment reduction activities, 58 Transmission and Storage segment reduction activities, and 37 Distribution segment reduction activities.

⁴ <https://edap.epa.gov/public/extensions/NGS/Accomplishments.html>

⁵ EPA did not analyze the Gas STAR activities for the Processing segment as most Processing sources are quantified with net methodologies.

EPA then assessed which Gas STAR reduction activities were related to a GHGI emission source which still used the “potential methodology” (e.g., the GHGI emission source calculation methodology still relied on data from the 1996 GRI/EPA study) versus the “net methodology” (i.e., the GHGI emission source calculation methodology had been updated to use emissions data from subpart W or a recently published methane emissions study). EPA removed the reduction activities related to a GHGI emission source with a “net methodology” from further analysis. A total of 40 Production segment reduction activities, 23 Transmission and Storage segment reduction activities, and 12 Distribution segment reduction activities were determined to use the “potential methodology”. These activities are presented below in Table 3 (Production Segment), Table 4 (Transmission and Storage Segment), and Table 5 (Distribution Segment).

As indicated in the footnotes for Table 3 and Table 4, a few reduction activities were assigned to two GHGI emissions sources for which one source used the “net methodology” and the other source used the “potential methodology”. For these activities, the reductions were adjusted using a ratio of source-specific emissions versus overall emissions. For example, the reductions from the Production segment reduction activity (i.e., “Capture and use gas released from gas-operated pneumatic pumps”) were reduced by the ratio of Kimray pump emissions to the sum of Kimray pump and chemical injection pump emissions. Likewise, the reductions from the three Transmission and Storage segment reduction activities that were assigned to two GHGI emission sources (see the last three rows of Table 4) were reduced using similar ratios.

Table 3. Gas STAR Production Segment Reduction Activities Assigned to GHGI Emission Sources with a Potential Methodology

Gas STAR Reduction Activity	GHGI Emission Source
Reduce methane emissions from compressor rod packing systems	Compressors
Automate compressor systems operations to reduce venting	Compressors/Compressor Blowdowns
Lower compressor purge pressure for shutdown	Compressor Blowdowns
Redesign blowdown/alter ESD practices	Compressor Blowdowns
Reduce emissions when taking compressors offline	Compressor Blowdowns
Convert engine starting to nitrogen and/or CO ₂ rich gas	Compressor Starts
Convert to low pressure compressor starters	Compressor Starts
Install electric motor starters	Compressor Starts
Reduce gas venting with fewer compressor startups and improved ignition	Compressor Starts
Replace gas starters with air or nitrogen	Compressor Starts
Replace ignition/reduce false starts	Compressor Starts
Install condensers on glycol dehydrators	Dehydrator Vents/Kimray Pumps
Install flash tank separators on glycol dehydrators	Dehydrator Vents/Kimray Pumps
Reduce glycol circulation rates in dehydrators	Dehydrator Vents/Kimray Pumps
Replacing glycol dehydrators with desiccant dehydrators	Dehydrator Vents/Kimray Pumps
Reroute dehydrators/tank vents to flare or station suction	Dehydrator Vents/Kimray Pumps
Reroute glycol skimmer gas	Dehydrator Vents/Kimray Pumps
Shutdown glycol dehydrator stripping gas in winter	Dehydrator Vents/Kimray Pumps
Catalytic converter installation	Engines
Convert natural gas-fired generator to solar power	Engines
Install automated air/fuel ratio controls	Engines
Install electric compressors	Engines
Install electric motors	Engines
Install lean burn compressor	Engines

Gas STAR Reduction Activity	GHGI Emission Source
Install pilotless burner controls	Engines
Turbine fuel use optimization	Engines
DI&M at compressor stations	Equipment Leaks
DI&M at remote sites	Equipment Leaks
DI&M: leak detection using IR camera/optical imaging	Equipment Leaks
DI&M: leak detection using lower emission threshold	Equipment Leaks
DI&M: survey and repair leaks	Equipment Leaks
Install plugs on valves and open ended lines	Equipment Leaks
Test and repair pressure safety valves	Equipment Leaks
Capture and use gas released from gas-operated pneumatic pumps	Kimray Pumps/Chemical Injection Pumps ^a
Convert water tank blanket from natural gas to CO ₂	Produced Water
Install flash tank separator on water gathering system	Produced Water

^aKimray pumps use a potential methodology and chemical injection pumps use a net methodology.

Table 4. Gas STAR Transmission and Storage Segment Reduction Activities Assigned to GHGI Emission Sources with a Potential Methodology.

Gas STAR Reduction Activity	GHGI Emission Source
Install condensers on glycol dehydrators	Dehydrator Vents
Install flash tank separators/controls on transmission sector glycol dehydrators	Dehydrator Vents
Replace glycol dehydrator with separator and in-line heaters	Dehydrator Vents
Reroute dehydrators/tank vents to flare or station suction	Dehydrator Vents
Reroute glycol skimmer gas	Dehydrator Vents
Install automated air/fuel ratio controls	Engines
Install electric compressors	Engines
Install electric motor starters	Engines
Install electric motors	Engines
Install lean burn compressor	Engines
Replace gas starters with air or nitrogen	Engines
Replace ignition/reduce false starts	Engines
Use of turbines at compressor stations	Engines
DI&M: aerial leak detection using laser and/or infrared technology	Pipeline Leaks
Inspect/repair valves during pipeline replacement	Pipeline Leaks
Pipeline replacement and repair	Pipeline Leaks
Design isolation valves to minimize gas blowdown volumes	Station Venting
Lower compressor purge pressure for shutdown	Station Venting
Move in fire gates at compressors	Station Venting
Reduce emissions when taking compressors offline	Station Venting/Compressors ^a
Inject blowdown gas into low pressure mains or fuel gas system	Station Venting/Pipeline Venting ^a
Redesign blowdown/alter ESD practices	Station Venting/Pipeline Venting ^a

^aStation venting uses a potential methodology and pipeline venting and compressor emissions are estimated using net methodologies.

Table 5. Gas STAR Distribution Segment Reduction Activities Assigned to GHGI Emission Sources with a Potential Methodology.

Gas STAR Reduction Activity	GHGI Emission Source
Install excess flow valves	Mishaps (Dig-ins)
Reduced emissions through third-party damage prevention	Mishaps (Dig-ins)
Inject blowdown gas into low pressure mains or fuel gas system	Pipeline Blowdown
Install overpressure protection system	Pipeline Blowdown
Redesign blowdown/alter ESD practices	Pipeline Blowdown
Reduce/downgrade system pressure	Pipeline Blowdown
Reduce/downgrade system pressure (manual)	Pipeline Blowdown
Use automated systems to reduce pressure	Pipeline Blowdown
Use hot taps for in-service pipeline connections	Pipeline Blowdown
Use pipeline pump-down techniques to lower gas line pressure	Pipeline Blowdown
Test and repair pressure safety valves	Pressure Relief Valve Releases
Test gate station pressure relief valves with nitrogen	Pressure Relief Valve Releases

Tables 6, 7, and 8 present a summary of the year 2019 Gas STAR reductions by GHGI emission source (all Gas STAR reductions are summed together for a common GHGI emission source) for the Production segment, the Transmission and Storage segment, and the Distribution segment, respectively. Appendix B presents the complete time series of Gas STAR reductions of each emission source in Tables 6, 7, and 8.

Table 6. Year 2019 Production Segment Gas STAR Reductions by Emission Source (mt CH₄).

GHGI Emission Source	Gas STAR Reductions
Compressor Blowdowns	4,499
Compressor Starts	16,954
Compressors	48
Dehydrator Vents/Kimray Pumps	50,911
Engines	32,147
Equipment Leaks	85
Kimray Pumps	166
Produced Water	1,023
Total	105,833

Table 7. Year 2019 Transmission and Storage Segment Gas STAR Reductions by Emission Source (mt CH₄).

GHGI Emission Source	Gas STAR Reductions
Dehydrator Vents	4,089
Engines	132,410
Pipeline Leaks	590
Station Venting	21,418
Total	158,507

Table 8. Year 2019 Distribution Segment Gas STAR Reductions by Emission Source (mt CH₄).

GHGI Emission Source	Gas STAR Reductions
Pressure Relief Valve Releases	0 ^a
Pipeline Blowdowns	2,202
Mishaps (Dig-ins)	1,383
Total	3,586

^a Gas STAR reductions were not reported for pressure relief valve releases in year 2019; however, reductions were reported for other years in the time series.

In order to correspond with GHGI emission sources, EPA disaggregated Gas STAR reductions for production segment “dehydrator vents/Kimray pumps” and “equipment leaks” to the individual GHGI emission sources. EPA applied the average source-specific distribution of emissions over the entire time series to estimate the reductions for each emission source (e.g., production segment separator emissions account for 48 percent of equipment leak emissions over the 1990-2020 time series and EPA assigned 48 percent of the equipment leak Gas STAR reductions to separators):

- Dehydrator vents/Kimray pumps
 - Dehydrator vents – 24 percent
 - Kimray pumps – 76 percent
- Equipment leaks
 - Heaters – 9 percent
 - Separators – 48 percent
 - Dehydrators – 6 percent
 - Meters/piping – 37 percent

2.2 Methane Challenge

EPA’s Methane Challenge Program has collected reductions data starting with reductions reported for 2016. EPA incorporated these data into the GHGI.

Methane Challenge data are available for two commitment options (Best Management Practice Commitment Option (BMP) and the ONE Future Emissions Intensity Commitment Option [ONE Future]) and reductions for both commitment options are considered. BMP partners make a commitment to implement mitigation activities for specific emission sources and the list of emission sources varies by industry segment. ONE Future partners make a commitment to achieve a ONE Future-defined target segment intensity rate by 2025 for all their operations in the segment and may implement mitigation activities for any of their emission sources to achieve that rate. For both options, partners report the emissions reductions achieved in a given year as a result of implementing specific mitigation activities to achieve their commitment. BMP emissions reductions are available for years 2016-2019 and ONE Future emissions reductions are available for years 2017-2019.⁶ Table 9 presents the Methane Challenge reductions by industry segment and emission source for 2016-2019. Table 9 also shows the Methane Challenge emission sources that are related to GHGI emission sources with a potential methodology.

⁶ <https://www.epa.gov/natural-gas-star-program/methane-challenge-program-accomplishments>

Table 9. Methane Challenge CH₄ Emission Reductions by Emission Source (mt CH₄) and Identification of Sources That Use a Potential Methodology.

Methane Challenge Emission Source	2016	2017	2018	2019	GHGI Emission Source Uses a Potential Methodology?
Transmission Segment					
Transmission Pipeline Blowdowns	4,787	58,113	98,147	74,971	No
Equipment Leaks [transmission station leaks]	0	3,411	8,314	15,118	No
Reciprocating Compressors	0	621	583	911	No
Pneumatic Controllers	0	6	184	215	No
Distribution Segment					
Distribution Mains	2,449	8,974	8,709	9,652	No
Distribution Services	1,014	3,126	2,528	2,682	No
Distribution Pipeline Blowdowns	0	4	802	192	Yes
Pressure Relief Valves	0	789	52	47	Yes
Onshore Production					
Storage Tanks	0	0	0	14	No
Gathering and Boosting					
Reciprocating Compressors	0	0	0	196	No

Only two sources with Methane Challenge reductions use a potential methodology in the GHGI and both are in the distribution segment. For 2016-2019 in the 2022 GHGI, distribution pipeline blowdown emissions average 4,400 mt CH₄ and pressure relief valve releases average 1,300 mt CH₄.

3 Time Series Considerations

Gas STAR reductions are available over the entire time series. Methane Challenge data are available for year 2016 forward. With the exception of the long-term GasSTAR reductions discussed in Section 2.1, EPA applied the reductions data only to the years reported and did not make adjustments to other years of the time series.

Upon comparing the reductions data to the potential emissions over the time series for each emission source, there were a number of instances where the reductions exceeded the potential emissions resulting in “negative emissions”. The sources with calculated negative net emissions (and years of negative emissions) include:

- Production Segment
 - Compressor blowdowns (2001-2020)
 - Compressor starts (1994-2020)
 - Dehydrator vents (2010-2011)
- Transmission segment
 - Dehydrator vents (1997-2020)
 - Pipeline leaks (1998-1999, 2007-2012, 2014, 2017-2018)
- Distribution segment
 - Pipeline blowdowns (1997, 2005-2006)
 - PRV releases (2002)

EPA removed Gas STAR reductions entirely for sources with more than 10 years of negative calculated emissions (i.e., production segment compressor blowdowns and compressor starts, and transmission segment dehydrator vents and pipeline leaks).

For the remaining sources with negative emissions (i.e., production segment dehydrator vents and distribution segment pipeline blowdowns and PRV releases), calculated negative emissions occur for a maximum of three years in the time series. EPA replaced the negative net emissions value with zero for the years of negative net emissions for these sources.

4 National Emissions Estimates

Tables 10, 11, and 12 present the impact of Gas STAR and Methane Challenge voluntary reductions, along with regulatory reductions, for the Production, Transmission and Storage, and Distribution segments in the GHGI. Appendix C presents the complete time series of reductions used for each emission source in the 2022 GHGI. The reductions in Tables 10 – 12 and Appendix C reflect the adjustments presented in Section 2 (to disaggregate emissions) and Section 3 (to exclude certain reductions that resulted in negative net emissions values).

Table 10. Year 2019 Production Segment Potential and Net Emissions with Reductions (mt CH₄).

Parameter	Emissions/Reductions Previous (2021) GHGI	Emissions/Reductions Current (2022) GHGI
Potential Emissions	3,992,187	3,801,962
Gas STAR Reductions	236,934	84,380
Regulatory Reductions ^a	7,370	7,370
Net Emissions	3,747,883	3,710,212

a. Regulatory reductions include the impacts of EPA National Emission Standards for Hazardous Air Pollutants (NESHAP) regulations for dehydrator vents.

Table 11. Year 2019 Transmission and Storage Segment Potential and Net Emissions with Reductions (mt CH₄).

Parameter	Emissions/Reductions Previous (2021) GHGI	Emissions/Reductions Current (2022) GHGI
Potential Emissions	1,746,133	1,736,643
Gas STAR Reductions	267,799	153,828
Net Emissions	1,478,334	1,582,815

Table 12. Year 2019 Distribution Segment Potential and Net Emissions with Reductions (mt CH₄).

Parameter	Emissions/Reductions Previous (2021) GHGI	Emissions/Reductions Current (2022) GHGI
Potential Emissions	559,880	559,199
Gas STAR Reductions	0	3,586
Methane Challenge Reductions	0	239
Net Emissions	559,880	555,375

5 Requests for Stakeholder Feedback

EPA sought stakeholder feedback on the approaches under consideration through two 2021 webinars, in the September 2021 memo, and in the public review draft of the GHGI. EPA received stakeholder comments on

April 2022

the September 2021 version of the memo and through the public review draft of the Inventory. Stakeholder feedback is summarized here.

Stakeholders agreed with using updated Gas STAR reductions and with the incorporation of Methane Challenge reductions. One stakeholder supported the approach of treating long-term reductions as permanent reductions instead of applying long-term reductions that incorporate sunset dates.

The requests for stakeholder feedback below were not updated for this memorandum and are copied from the September 2021 memorandum:

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

1. Are the Gas STAR reduction activity assignments to GHGI emission sources in Tables 3 - 5 appropriate?
2. Are there any Gas STAR activities identified in Tables 3 - 5 as having a potential methodology that should be considered to have a net methodology?
3. Are there other data sources available to quantify emissions or reductions for the identified sources?

Appendix A. Previous (2021) GHGI Gas STAR Reductions

A-1. Previous (2021) GHGI Annual Production Segment Gas STAR Reductions for 1990-2019 (mt CH₄).

GHGI Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Gas Engines	0	0	0	3,217	6,845	12,456	20,855	28,958	34,950	43,414
Compressor Starts	0	0	0	0	0	3	5	6	117	117
Other	0	0	0	5,562	20,524	29,361	59,362	60,621	75,855	81,560
Total	0	0	0	8,778	27,369	41,820	80,222	89,586	110,922	125,091

GHGI Source	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Gas Engines	51,862	60,473	69,101	74,801	87,824	96,625	103,170	110,329	115,060	121,762
Compressor Starts	117	179	179	179	182	182	182	189	197	395
Other	76,656	83,116	77,643	95,796	99,957	100,762	93,875	98,577	107,160	102,361
Total	128,635	143,768	146,923	170,777	187,962	197,569	197,226	209,096	222,417	224,517

GHGI Source	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Gas Engines	132,021	135,866	138,672	139,167	139,167	139,167	139,167	139,167	139,167	139,167
Compressor Starts	512	512	512	512	512	512	512	512	512	512
Other	104,184	99,639	99,772	104,624	104,624	104,624	104,624	104,624	104,624	104,624
Total	236,718	236,017	238,956	244,304	244,304	244,304	244,304	244,304	244,304	244,304

A-2. Previous (2021) GHGI Annual Transmission and Storage Segment Gas STAR Reductions for 1990-2019 (mt CH₄).

GHGI Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Pipeline Leaks	0	0	0	0	0	33	0	0	0	0
Dehydrator vents (Transmission)	0	0	0	0	0	0	755	3,249	3,225	3,182
Engines (Transmission)	0	0	0	2,803	7,725	12,547	15,909	19,339	40,719	45,526
Station Venting (Transmission)	0	0	0	2,740	1,416	5,161	7,239	23,627	42,847	58,878
Total	0	0	0	5,543	9,141	17,742	23,904	46,215	86,790	107,586

GHGI Source	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Pipeline Leaks	0	0	0	0	0	0	0	0	0	1,136
Dehydrator vents (Transmission)	2,718	2,718	2,718	2,718	2,718	2,718	2,840	2,819	2,819	2,819
Engines (Transmission)	49,291	54,241	68,381	72,424	77,975	83,207	87,797	94,454	103,082	116,170
Station Venting (Transmission)	77,530	106,355	119,998	125,039	127,850	126,310	146,461	129,026	161,055	136,592
Total	129,539	163,313	191,098	200,181	208,543	212,235	237,097	226,299	266,956	256,718

GHGI Source	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Pipeline Leaks	0	2,773	4,199	1,213	1,213	1,213	1,213	1,213	1,213	1,213
Dehydrator vents (Transmission)	2,819	2,819	2,819	2,819	2,819	2,819	2,819	2,819	2,819	2,819
Engines (Transmission)	119,382	121,688	124,050	126,910	126,910	126,910	126,910	126,910	126,910	126,910
Station Venting (Transmission)	135,250	134,419	135,824	136,856	136,856	136,856	136,856	136,856	136,856	136,856
Total	257,451	261,700	266,891	267,799	267,799	267,799	267,799	267,799	267,799	267,799

Appendix B. Updated Gas STAR Reductions

Appendix B reflects the updated Gas STAR reductions data that was assessed for the 2022 GHGI, and does not include adjustments other than treating long-term reductions as permanent reductions (i.e., these data do not reflect the adjustments presented in Section 2 (to disaggregate emissions) and Section 3 (to exclude certain reductions that resulted in negative net emissions values)).

B-1. Annual Production Segment Gas STAR Reductions, by GHGI Emission Source, for 1990-2019 (mt CH₄).

GHGI Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Compressors	0	0	0	0	0	0	0	0	0	0
Compressor Blowdowns	0	0	0	46	61	94	94	95	95	103
Compressor Starts	0	0	0	391	6,891	6,893	9,939	12,705	12,893	12,816
Dehydrator Vents/Kimray Pumps	0	0	0	3,766	5,051	6,862	12,391	20,007	22,873	22,769
Engines	0	0	0	3,037	3,847	5,831	8,618	8,323	6,259	9,123
Equipment Leaks	0	0	0	0	9	250	594	790	9,678	14,378
Kimray Pumps	0	0	0	0	0	0	0	0	65	0
Produced Water	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	7,240	15,858	19,931	31,636	41,920	51,864	59,189

GHGI Source	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Compressors	0	0	0	0	0	2,790	957	451	984	981
Compressor Blowdowns	125	3,828	4,132	9,103	4,450	4,450	5,407	5,908	6,244	6,161
Compressor Starts	12,833	13,030	13,116	13,118	13,707	14,269	14,344	14,379	17,705	15,416
Dehydrator Vents/Kimray Pumps	24,369	28,742	26,836	30,737	32,510	35,434	43,333	52,245	63,917	70,806
Engines	9,498	9,790	10,472	7,928	15,928	12,250	13,399	18,650	17,646	20,610
Equipment Leaks	8,117	9,082	9,097	22,792	24,792	20,118	29,246	23,927	42,160	39,416
Kimray Pumps	0	0	0	0	0	0	42	822	2,530	424
Produced Water	628	628	628	628	628	628	686	1,023	1,023	1,023
Total	55,570	65,099	64,282	84,306	92,015	89,939	107,414	117,405	152,208	154,836

GHGI Source	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Compressors	333	1,769	48	48	48	51	51	48	48	48
Compressor Blowdowns	19,802	4,510	4,500	5,211	5,224	5,566	4,633	4,499	4,499	4,499
Compressor Starts	16,126	15,240	15,238	15,927	15,932	15,909	15,909	15,909	15,909	16,954
Dehydrator Vents/Kimray Pumps	76,552	82,728	48,177	49,987	49,987	50,043	50,125	51,798	50,125	50,911
Engines	29,069	29,208	29,074	28,817	30,100	32,255	30,938	44,629	31,396	32,147
Equipment Leaks	50,043	48,832	13,191	12,261	5,102	4,049	6,477	2,700	23	85
Kimray Pumps	278	166	166	166	167	166	166	166	166	166
Produced Water	1,023	1,023	1,023	1,023	1,023	1,023	1,023	1,023	1,023	1,023
Total	193,226	183,476	111,417	113,441	107,583	109,063	109,322	120,772	103,190	105,833

B-2. Annual Transmission and Storage Segment Gas STAR Reductions, by GHGI Emission Source, for 1990-2019 (mt CH₄).

GHGI Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Dehydrator Vents	0	0	0	61	74	77	849	3,374	3,371	3,341
Engines	0	0	0	2,803	6,007	9,108	11,438	13,495	35,790	37,132
Pipeline Leaks	0	0	0	136	0	33	465	0	21,251	3,382
Station Venting	0	0	0	1,071	429	1,164	1,650	916	1,239	1,113
Total	0	0	0	4,071	6,510	10,381	14,402	17,784	61,652	44,969

GHGI Source	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Dehydrator Vents	3,219	3,415	3,367	3,318	3,229	3,135	2,860	2,759	2,759	2,759
Engines	38,732	44,477	56,309	57,719	65,869	70,824	73,845	80,627	86,944	98,272
Pipeline Leaks	0	0	0	0	0	2	0	6,929	3,659	4,098
Station Venting	2,246	3,766	2,590	6,563	5,069	2,032	9,255	1,664	6,140	3,350
Total	44,197	51,658	62,266	67,600	74,167	75,993	85,960	91,978	99,502	108,479

GHGI Source	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Dehydrator Vents	2,759	2,759	2,759	2,759	2,759	2,759	2,759	2,759	2,759	4,089
Engines	86,793	87,773	91,931	91,575	95,736	97,156	97,258	97,084	115,091	132,410
Pipeline Leaks	5,066	6,972	6,972	1,919	4,179	1,194	2,534	4,085	4,083	590
Station Venting	3,475	2,541	3,258	3,556	3,243	3,639	18,151	25,998	28,402	21,418
Total	98,093	100,044	104,919	99,809	105,918	104,748	120,701	129,926	150,335	158,507

B-3. Annual Distribution Segment Gas STAR Reductions, by GHGI Emission Source, for 1990-2019 (mt CH₄).

GHGI Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Pressure Relief Valve Releases	0	0	0	0	0	0	0	0	193	0
Pipeline Blowdowns	0	0	0	963	1,813	1,258	1,555	4,270	1,468	1,550
Mishaps (Dig-ins)	0	0	0	0	0	13	18	39	38	61
Total	0	0	0	963	1,813	1,272	1,573	4,308	1,699	1,611

GHGI Source	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Pressure Relief Valve Releases	0	0	1,490	0	0	1	10	0	143	0
Pipeline Blowdowns	1,502	1,607	3,111	2,645	3,609	5,986	8,804	3,024	3,034	2,652
Mishaps (Dig-ins)	13	42	51	100	343	618	816	2,382	1,101	1,495
Total	1,516	1,650	4,652	2,744	3,952	6,605	9,630	5,406	4,278	4,147

GHGI Source	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Pressure Relief Valve Releases	0	0	0	0	0	0	0	0	0	0
Pipeline Blowdowns	3,021	2,200	1,988	2,170	1,871	2,282	2,022	2,334	2,801	2,202
Mishaps (Dig-ins)	1,593	5,441	1,415	1,891	2,054	1,978	2,188	1,420	1,331	1,383
Total	4,614	7,642	3,403	4,062	3,925	4,260	4,209	3,754	4,133	3,586

Appendix C. Adjusted Gas STAR Reductions Applied for the 2022 GHGI Update

Appendix C reflects the Gas STAR reductions data as applied for the 2022 GHGI, and includes the adjustments presented in Section 2 (to disaggregate emissions) and Section 3 (to exclude certain reductions that resulted in negative net emissions values)).

C-1. Annual Production Segment Adjusted Gas STAR Reductions, by GHGI Emission Source, for 1990-2020 (mt CH₄).

GHGI Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Compressors	0	0	0	0	0	0	0	0	0	0
Compressor Blowdowns ^a	0	0	0	0	0	0	0	0	0	0
Compressor Starts ^a	0	0	0	0	0	0	0	0	0	0
Dehydrator Vents/Kimray Pumps	0	0	0	3,766	5,051	6,862	12,391	20,007	22,873	22,769
<i>Dehy Vents</i>	0	0	0	904	1,212	1,647	2,974	4,802	5,490	5,464
<i>Kimray Pumps</i>	0	0	0	2,862	3,839	5,215	9,417	15,205	17,384	17,304
Engines	0	0	0	3,037	3,847	5,831	8,618	8,323	6,259	9,123
Equipment Leaks	0	0	0	0	9	250	594	790	9,678	14,378
<i>Heaters</i>	0	0	0	0	1	21	51	67	823	1,222
<i>Separators</i>	0	0	0	0	4	120	286	380	4,655	6,916
<i>Dehydrators</i>	0	0	0	0	1	16	38	51	619	920
<i>Meters/Piping</i>	0	0	0	0	3	93	220	292	3,581	5,320
Kimray Pumps	0	0	0	0	0	0	0	0	65	0
Produced Water	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	6,803	8,907	12,944	21,604	29,119	38,875	46,270

GHGI Source	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Compressors	0	0	0	0	0	2,790	957	451	984	981
Compressor Blowdowns ^a	0	0	0	0	0	0	0	0	0	0
Compressor Starts ^a	0	0	0	0	0	0	0	0	0	0
Dehydrator Vents/Kimray Pumps	24,369	28,742	26,836	30,737	32,510	35,434	43,333	52,245	63,917	70,806
<i>Dehy Vents</i>	5,849	6,898	6,441	7,377	7,802	8,504	10,400	12,539	15,340	16,994
<i>Kimray Pumps</i>	18,521	21,844	20,396	23,360	24,708	26,930	32,933	39,706	48,577	53,813
Engines	9,498	9,790	10,472	7,928	15,928	12,250	13,399	18,650	17,646	20,610
Equipment Leaks	8,117	9,082	9,097	22,792	24,792	20,118	29,246	23,927	42,160	39,416
<i>Heaters</i>	690	772	773	1,937	2,107	1,710	2,486	2,034	3,584	3,350
<i>Separators</i>	3,904	4,369	4,376	10,963	11,925	9,677	14,068	11,509	20,279	18,959
<i>Dehydrators</i>	519	581	582	1,459	1,587	1,288	1,872	1,531	2,698	2,523
<i>Meters/Piping</i>	3,003	3,360	3,366	8,433	9,173	7,444	10,821	8,853	15,599	14,584
Kimray Pumps	0	0	0	0	0	0	42	822	2,530	424
Produced Water	628	628	628	628	628	628	686	1,023	1,023	1,023
Total	42,612	48,242	47,034	62,085	73,858	71,220	87,663	97,119	128,258	133,260

GHGI Source	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Compressors	333	1,769	48	48	48	51	51	48	48	48	48
Compressor Blowdowns ^a	0	0	0	0	0	0	0	0	0	0	0
Compressor Starts ^a	0	0	0	0	0	0	0	0	0	0	0
Dehydrator Vents/Kimray Pumps	75,140 ^b	79,345 ^b	48,177	49,987	49,987	50,043	50,125	51,798	50,125	50,911	50,911
<i>Dehy Vents</i>	<i>18,372</i>	<i>19,855</i>	<i>11,562</i>	<i>11,997</i>	<i>11,997</i>	<i>12,010</i>	<i>12,030</i>	<i>12,431</i>	<i>12,030</i>	<i>12,219</i>	<i>12,219</i>
<i>Kimray Pumps</i>	<i>58,179</i>	<i>62,874</i>	<i>36,614</i>	<i>37,990</i>	<i>37,990</i>	<i>38,033</i>	<i>38,095</i>	<i>39,366</i>	<i>38,095</i>	<i>38,692</i>	<i>38,692</i>
Engines	29,069	29,208	29,074	28,817	30,100	32,255	30,938	44,629	31,396	32,147	32,147
Equipment Leaks	50,043	48,832	13,191	12,261	5,102	4,049	6,477	2,700	23	85	85
<i>Heaters</i>	<i>4,254</i>	<i>4,151</i>	<i>1,121</i>	<i>1,042</i>	<i>434</i>	<i>344</i>	<i>551</i>	<i>229</i>	<i>2</i>	<i>7</i>	<i>7</i>
<i>Separators</i>	<i>24,071</i>	<i>23,488</i>	<i>6,345</i>	<i>5,898</i>	<i>2,454</i>	<i>1,947</i>	<i>3,115</i>	<i>1,299</i>	<i>11</i>	<i>41</i>	<i>41</i>
<i>Dehydrators</i>	<i>3,203</i>	<i>3,125</i>	<i>844</i>	<i>785</i>	<i>327</i>	<i>259</i>	<i>415</i>	<i>173</i>	<i>1</i>	<i>5</i>	<i>5</i>
<i>Meters/Piping</i>	<i>18,516</i>	<i>18,068</i>	<i>4,881</i>	<i>4,537</i>	<i>1,888</i>	<i>1,498</i>	<i>2,396</i>	<i>999</i>	<i>9</i>	<i>31</i>	<i>31</i>
Kimray Pumps	278	166	166	166	167	166	166	166	166	166	166
Produced Water	1,023	1,023	1,023	1,023	1,023	1,023	1,023	1,023	1,023	1,023	1,023
Total	155,886	160,342	91,679	92,302	86,427	87,587	88,780	100,364	82,782	84,380	84,380

^a EPA removed Gas STAR reductions entirely for sources with more than 10 years of negative calculated emissions: compressor blowdowns and compressor starts.

^b EPA reduced GAS STAR reductions for dehydrator vents (2010-2011) to prevent negative calculated emissions.

C-2. Annual Transmission and Storage Segment Adjusted Gas STAR Reductions, by GHGI Emission Source, for 1990-2020 (mt CH₄).

GHGI Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Dehydrator Vents ^a	0	0	0	0	0	0	0	0	0	0
Engines	0	0	0	2,803	6,007	9,108	11,438	13,495	35,790	37,132
Pipeline Leaks ^a	0	0	0	0	0	0	0	0	0	0
Station Venting	0	0	0	1,071	429	1,164	1,650	916	1,239	1,113
Total	0	0	0	3,874	6,436	10,272	13,088	14,410	37,029	38,246

GHGI Source	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Dehydrator Vents ^a	0	0	0	0	0	0	0	0	0	0
Engines	38,732	44,477	56,309	57,719	65,869	70,824	73,845	80,627	86,944	98,272
Pipeline Leaks ^a	0	0	0	0	0	0	0	0	0	0
Station Venting	2,246	3,766	2,590	6,563	5,069	2,032	9,255	1,664	6,140	3,350
Total	40,978	48,243	58,900	64,282	70,938	72,856	83,101	82,291	93,084	101,622

GHGI Source	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Dehydrator Vents ^a	0	0	0	0	0	0	0	0	0	0	0
Engines	86,793	87,773	91,931	91,575	95,736	97,156	97,258	97,084	115,091	132,410	132,410
Pipeline Leaks ^a	0	0	0	0	0	0	0	0	0	0	0
Station Venting	3,475	2,541	3,258	3,556	3,243	3,639	18,151	25,998	28,402	21,418	21,418
Total	90,268	90,314	95,189	95,131	98,980	100,796	115,408	123,082	143,493	153,828	153,828

^a EPA removed Gas STAR reductions entirely for sources with more than 10 years of negative calculated emissions: dehydrator vents and pipeline leaks.

C-3. Annual Distribution Segment Adjusted Gas STAR Reductions, by GHGI Emission Source, for 1990-2020 (mt CH₄).

GHGI Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Pressure Relief Valve Releases	0	0	0	0	0	0	0	0	193	0
Pipeline Blowdowns	0	0	0	963	1,813	1,258	1,555	3,407 ^a	1,468	1,550
Mishaps (Dig-ins)	0	0	0	0	0	13	18	39	38	61
Total	0	0	0	963	1,813	1,272	1,573	3,446	1,699	1,611

GHGI Source	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Pressure Relief Valve Releases	0	0	1,092 ^a	0	0	1	10	0	143	0
Pipeline Blowdowns	1,502	1,607	3,111	2,645	3,609	3,855 ^a	3,973 ^a	3,024	3,034	2,652
Mishaps (Dig-ins)	13	42	51	100	343	618	816	2,382	1,101	1,495
Total	1,516	1,650	4,254	2,744	3,952	4,474	4,798	5,406	4,278	4,147

GHGI Source	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Pressure Relief Valve Releases	0	0	0	0	0	0	0	0	0	0	0
Pipeline Blowdowns	3,021	2,200	1,988	2,170	1,871	2,282	2,022	2,334	2,801	2,202	2,202
Mishaps (Dig-ins)	1,593	5,441	1,415	1,891	2,054	1,978	2,188	1,420	1,331	1,383	1,383
Total	4,614	7,642	3,403	4,062	3,925	4,260	4,209	3,754	4,133	3,586	3,586

^a EPA reduced GAS STAR reductions for pressure release valves (2002) and pipeline blowdowns (1997, 2005-2006) to prevent negative calculated emissions.