Out-of-State Greenhouse Gas Emissions from Loss, Release, and Flaring of Natural Gas Imported to California: 2018-2023

December 23, 2025

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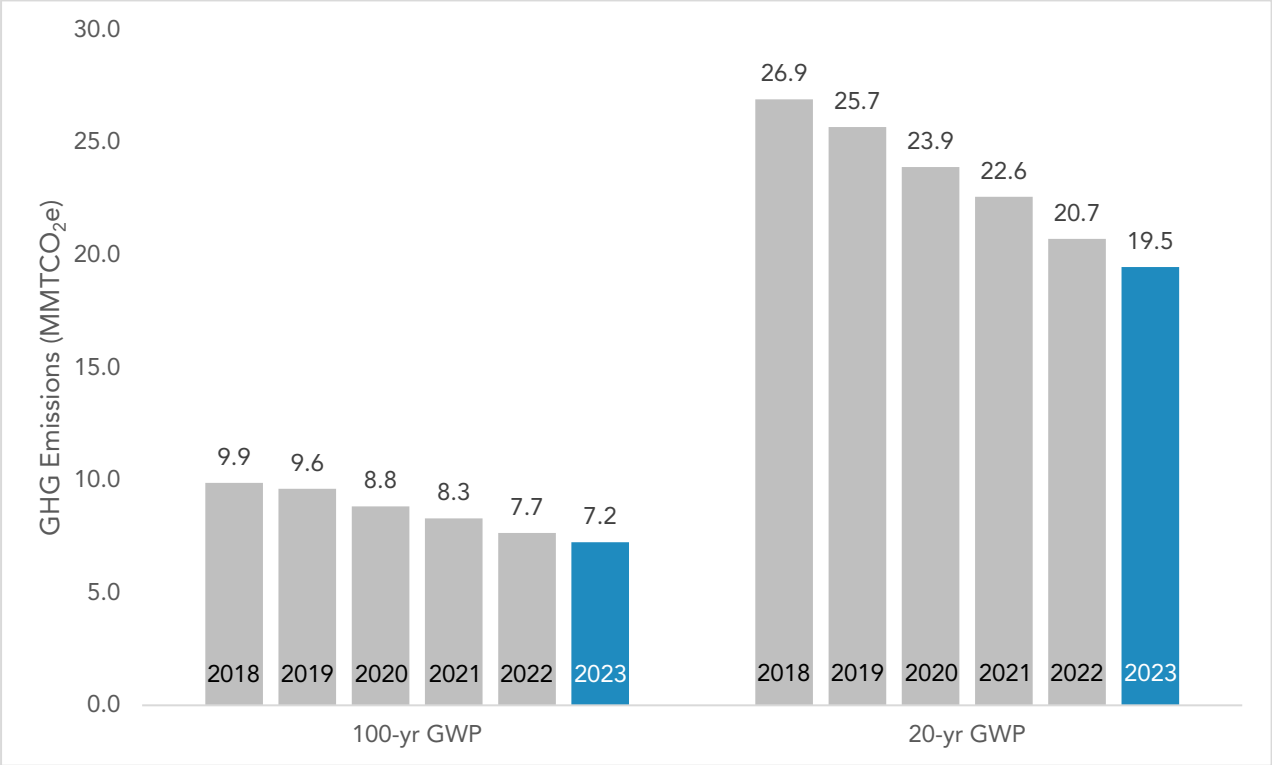
Contents

Summary

Assembly Bill (AB) 2195 (Chau, Chapter 371, Statutes of 2018) requires the California Air Resources Board (CARB) "to quantify and publish annually the amount of greenhouse gas emissions resulting from the loss or release of uncombusted natural gas to the atmosphere and emissions from natural gas flares during all processes associated with the production, processing, and transporting of natural gas imported into the state from out-of-state sources." This report details the methods and calculations CARB uses to estimate out-of-state greenhouse gas (GHG) emissions for imported NG as required by AB 2195 and provides annual results for data years 2018-2023.

Figure 1 below provides the GHG emissions estimates for both 100-yr and 20-yr global warming potential (GWP) time horizons for all years since this reporting requirement began. The 2023 calculated estimates are 7.2 million metric tons of carbon dioxide equivalents (MMT CO_2e) for the 100-yr GWP time horizon and 19.5 MMT CO_2e for the 20-yr GWP time horizon values, and are provided in blue in Figure 1. These data are intended for informational purposes and do not establish any metrics with respect to the GHG emissions targets established under AB 32 (Núñez and Pavley, 2006), Senate Bill (SB) 32 (Pavley, 2016), AB 1279 (Muratsuchi, 2022), or any other legislation or Executive Order.

Figure 1. Estimate of 2018-2023 out-of-state GHG emissions from releases of uncombusted gas and flaring associated with natural gas consumed in California.



Although these out-of-state emissions are not intended for inventory purposes, comparisons to CARB's AB 32 Greenhouse Gas Emissions Inventory (CARB 2025) may be useful to convey their general magnitude compared to emissions from other parts of the natural gas life-cycle that occur in-state. All inventory values are presented in terms of 100-yr GWP. The 2023 in-state GHG emissions from combustion of natural gas totaled 105.6 million metric tons of carbon dioxide equivalents (MMT CO_2e). The 2023 in-state methane emissions from fugitive sources and venting of natural gas during its transmission and distribution, including post-meter residential gas leaks, totaled 5.2 MMT CO_2e.

Background

CARB developed the Short-Lived Climate Pollutant (SLCP) Reduction Strategy in 2017 as a roadmap to reducing emissions of certain particularly potent GHGs (CARB 2017). Among those is methane (CH_4), which is the primary component of natural gas (NG). Methane is approximately 25 times more effective than carbon dioxide (CO_2) at trapping heat over a 100-year period. Because CH_4 has a shorter atmospheric lifetime, it is even more potent

over shorter periods with approximately 72 times the impact of CO_2 over a 20-year period.[1] Among other targets, the SLCP Reduction Strategy is designed to reduce CH_4 emissions by 40 percent of 2013 levels by 2030 ramping up to 45 percent by 2030. Many of the strategies also reduce co-pollutants such as criteria pollutants and toxic air contaminants. SB 1383 (Lara, 2016) directed CARB to begin implementing this strategy and codified the CH_4 emission reduction target.

The SLCP Reduction Strategy is focused on measures to reduce emissions from in-state production only, however nearly 90 percent of the NG used in California is imported from other states or countries (CEC 2024). When NG is imported to California, most of the upstream emissions occur outside of the State. Therefore, imported NG is not subject to California regulations or programs for processes occurring outside of State boundaries. Understanding the out-of-state emissions associated with imported NG could help inform California policies and goals to reduce emissions associated with NG consumption and dependence on imported fossil energy.

AB 2195 mandates that CARB publish an annual estimate of GHG emissions associated with the "loss or release of uncombusted natural gas to the atmosphere and emissions from natural gas flares" for all out-of-state gas that is imported to California.

The emissions calculated in this report are not included in CARB's Greenhouse Gas Emissions Inventory (CARB 2025) and are not factored into targets for in-state GHG emission reductions. In addition, this report does not cover all GHG emissions from upstream processes for out-of-state NG. Emissions associated with the combustion of fuels used throughout the NG supply chain are excluded as they are not considered releases of NG or emissions from flaring. For example, emissions from fuel combustion to power gas transmission compressors or to regenerate glycols during gas dehydration are not included.

Methods

The sources of data used in this report are summarized in Table 1. Emissions, production, and import datasets all include time series data for previous years. The latest vintage of each dataset was used to adjust calculations for previous years when appropriate.

[1] These figures are based on the IPCC Fourth Assessment Report (AR4) from 2007. Research since then has suggested that the GWP of CH_4 is higher. The AR4 figures are used herein for easier comparison to other reports and inventories that use AR4 GWPs.

Table 1. Data Sources

Type	Specification	Source	Data Years
U.S. NG production	Gross withdrawals from gas, shale gas, and coalbeds wells	EIA (2025a)	2018-2023
California NG imports	Total interstate and international receipts	EIA (2025b)	2018-2023
U.S. NG-related CH_4 emissions	All processes except distribution and LNG	U.S. EPA GHGI (2025)[2]	2018-2023
U.S. NG-related CO_2 and N_2O emissions	Flaring processes only (excludes LNG)	U.S. EPA GHGI (2025)[3]	2018-2023
Global warming potential	100-yr and 20-yr time horizons	IPCC Fourth Assessment Report (AR4)	2007

Although NG may have other GHG constituents, in this report "uncombusted natural gas" is interpreted to mean CH_4 only. Therefore, the usually small amounts of other GHGs, such as CO_2, that are present in some raw NG streams are not included for purposes of calculating emissions due to the release of uncombusted NG.

Emissions Data

CARB staff uses emissions data from the U.S. Environmental Protection Agency (U.S. EPA) *Inventory of U.S. Greenhouse Gas Emissions and Sinks (GHGI) 1990-2023* (U.S. EPA 2025). Specifically, 2018-2023 process-level emissions data for CH_4, CO_2, and nitrous oxide (N_2O) are from *Annex 3.6: Methodology for Estimating CH_4, CO_2, and N_2O Emissions from Natural Gas Systems* (U.S. EPA 2025).

[2] For the 2025 report the EPA datasets were provided to CARB by the Environmental Defense Fund (EDF).
[3] Ibid.

For the purposes of AB 2195, only the following data are considered:

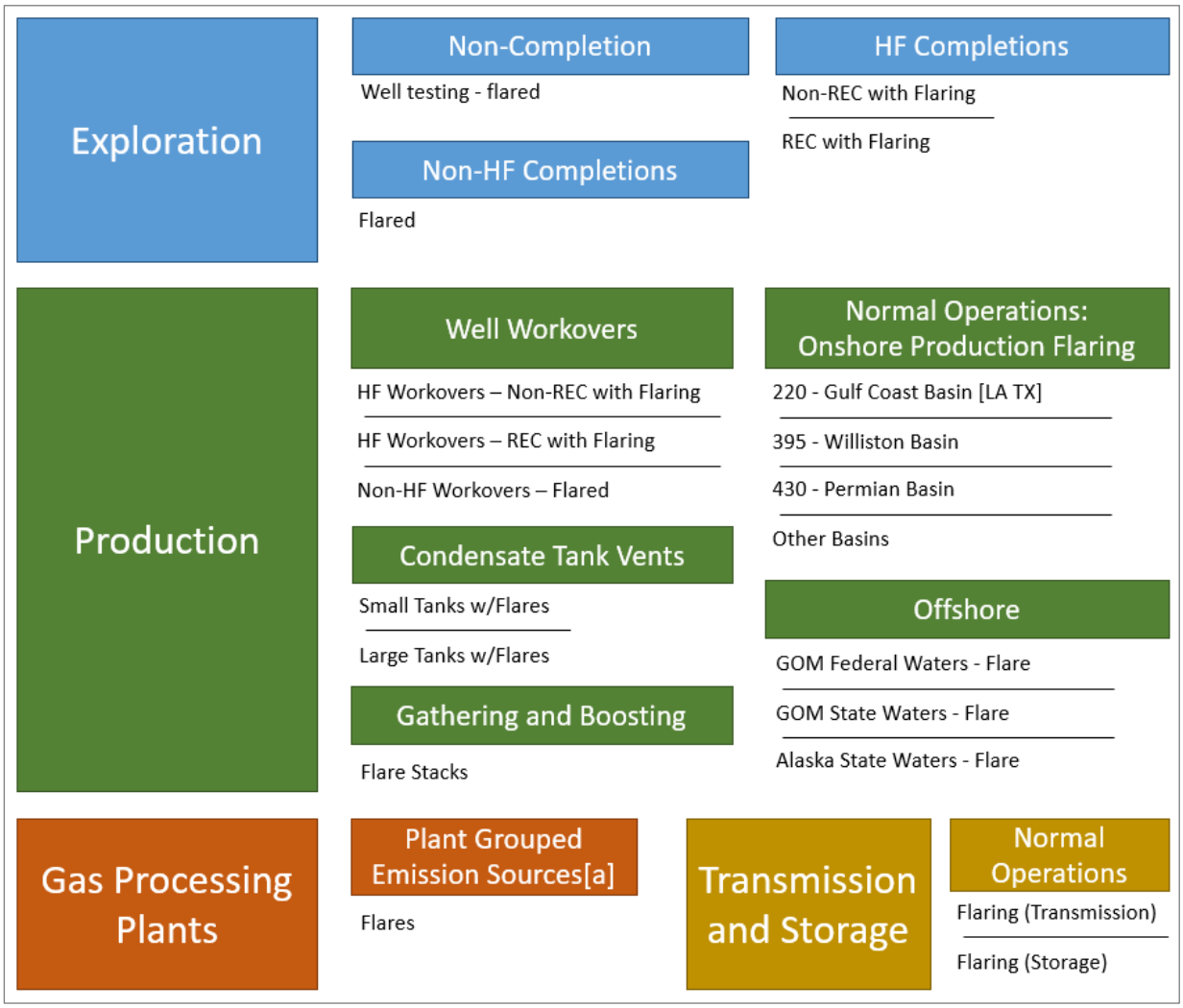
1. CH_4 emissions associated with exploration, production, processing, and transportation of NG. This includes transmission and storage, but not distribution.[4] It also includes CH_4 emissions from flaring.
2. CO_2 and N_2O emissions from NG flares associated with exploration, production, processing, and transportation of NG (Figure 2).

Consistent with the definition of uncombusted NG described previously, sources of CO_2 besides flaring (e.g., CO_2 venting from acid gas removal, completions, and workovers) are not included. This analysis also assumes that all gas imported to the state is in the form of compressed natural gas (CNG) through interstate pipelines. Thus, emissions from out-of-state liquefied natural gas (LNG)-related processes are excluded, though there may be some LNG imports to California.

As mentioned previously, this analysis does not consider emissions associated with the combustion of fuels in the NG supply chain. For example, water may be removed from NG in a glycol dehydrator; regenerating the glycol requires the application of heat and the resulting CO_2 emissions from providing that heat are not included herein.

[4] Distribution was excluded because we interpret AB 2195 as seeking the GHG emissions associated with imported NG that occur outside of California, and distribution occurs within the state. Adding distribution emissions would increase the emissions estimates by approximately 8-10% depending on the year and GWP time horizon.

Figure 2: Flaring processes included for CO2 and N2O emissions (note: REC = reduced emissions completion; HF = hydraulic fracturing; GOM = Gulf of Mexico).



Natural Gas Withdrawals and California Imports

National NG gross withdrawals for 2018-2023 are from the Energy Information Administration (EIA 2025a). The calculations in this report use total NG production from gas wells, shale gas wells, and coalbed wells. These calculations exclude NG production from oil wells because the production stage emissions estimates from the Natural Gas Systems GHGI

only include emissions from wells (and associated equipment) with a high gas-to-oil ratio (GOR).[5,6]

Interstate and international movements of NG into California in 2018-2023 are from the EIA (2025b). The calculations in this report sum all imports (domestic and international), without subtracting any exports. These calculations assume the same GHG intensity for all imported gas even though regional and field-specific differences exist in production, processing, and transportation.

Global Warming Potentials

Global warming potentials for CH_4 and N_2O are from the Intergovernmental Panel on Climate Change's (IPCC) *Fourth Assessment Report* (AR4). Both 20-year and 100-year time horizons were used, as shown in Table 2 (IPCC 2007).

Table 2. Global Warming Potentials of CH_4 and N_2O

Substance	100-yr GWP ($g\ CO_2e/g$ substance)	20-yr GWP ($g\ CO_2e/g$ substance)
CH_4	25	72
N_2O	298	289

The 100-yr GWP values are intended to show relatively long-term impacts, while the 20-yr GWP values are meant to depict shorter-term impacts.

[5] The U.S. EPA GHGI uses a GOR of >100 Mcf/bbl in its definition of a NG well (versus an oil well). The EIA uses >6 Mcf/bbl in their definition. This definition mismatch results in an underestimation of the carbon intensity of the gas. A previous rudimentary analysis based on states with public well-level production data suggests the impact of the mismatch could be in the range of approximately 10-20% of the carbon intensity for processes included in this estimate, assuming those states are representative.

[6] Beyond the production stage, the U.S. EPA GHGI Add Systems sector includes equipment receiving gas from all sources. However, analysis of the available EIA data suggests that the additional gas production volume from EIA-classified oil wells is similar to the volume that is removed from repressuring, venting, flaring, and other processes. Thus, we assume that the gas production from high-GOR wells is a reasonable proxy for the throughput volume in all stages of the gas system life cycle analyzed in this report.

Calculations and Results

This section shows the calculations performed to estimate out-of-state GHG emissions associated with NG imported into California. All data in this section come from the sources outlined in Table 1. Total CH_4 emissions are calculated as the sum of net emissions[7] from exploration, production, gas processing, and transmission and storage.

For 2023, the total U.S. emissions for processes included in the scope of this analysis were 4,745 kilotonnes (kt) CH_4, which equals 118,632 kt CO_2e on a 100-yr basis or 341,661 kt CO_2e on a 20-yr basis.

Total U.S. 2023 CO_2 emissions from flaring were 13,526 kt CO_2. Total U.S. 2023 N_2O emissions from flaring were 0.02 kt N_2O, which equals 7.28 kt CO_2e on a 100-yr basis or 7.06 kt CO_2e on a 20-yr basis.

United States NG production (i.e., gross withdrawals from gas, shale gas, and coalbed wells)[8] for 2023 totaled 41,027,992 million standard cubic feet (mmscf). Interstate and international imports of NG into California totaled 2,248,308 mmscf in 2023.

The above values were used with the equation in Figure 3 below to calculate total out-of-state emissions from NG imported to California from the loss or release of uncombusted NG and from flares in million metric tons (MMT) CO_2e in 2023. Calculations for 2018-2022 were performed using the same methods and equations based on the latest vintage of each underlying data source available at the time of the calculations (e.g., the 2025 edition U.S. EPA GHGI). Results of the calculations for every year are in Figure 1 in the Summary and the underlying data used in the calculations for all years are provided in the Appendix.

Figure 3. Equation Used to Estimate Out-Of-State GHG emissions from Natural Gas Imported to California

$$\frac{E_{CH_4} + E_{CO_2} + E_{N_2O}}{Production_{US}} \times Import_{CA} \times Conversion = CA\ Import\ Emissions$$

where,
E_{CH4} = U.S. NG Sector CH_4 emissions (kt CO_2e)
E_{CO2} = U.S. NG Sector CO_2 emissions (kt CO_2e)
E_{N2O} = U.S. NG Sector N_2O emissions (kt CO_2e)

[7] Potential emissions minus voluntary and regulatory emissions reductions, consistent with the U.S. EPA's methodology.

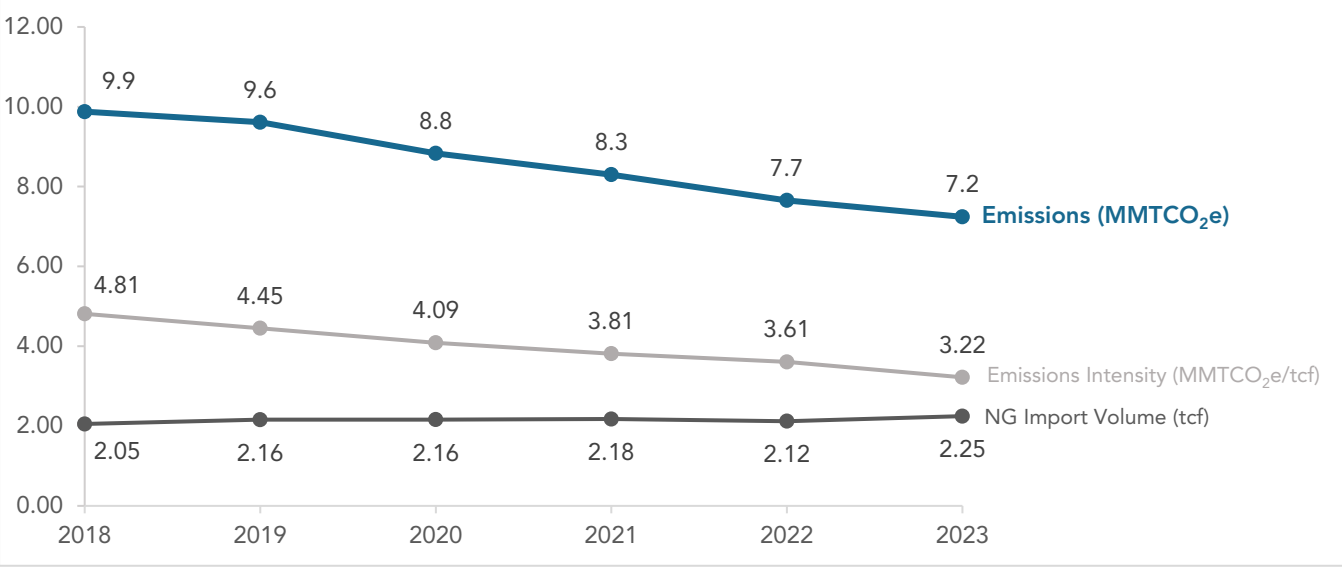
[8] This refers to "non-associated" natural gas, the volume that is not co-produced with crude oil. In the United States, the volume of "associated" natural gas, that which is produced with crude oil from the same reservoir, is insignificant and thus is not included in the estimates within this report.

$Production_{US}$ = U.S. non-associated NG production (mmscf)
$Import_{CA}$ = NG volume imported to California (mmscf)
Conversion = conversion factor from kt to MMT (1/1,000)
CA Import Emissions = out-of-state GHG emissions from NG imported to California (MMT CO_2e)

Discussion

The total estimated out-of-state GHG emissions associated with NG imported into California have decreased over data years 2018-2023 (blue line in Figure below), based on the data sources in Table 1 and the calculation methodology described in the Calculations and Results section. The primary reason for this trend was a reduction in emission intensity estimated by U.S. EPA over the time series (top gray line). As shown in Table 1 in the Summary, this is true for both 100-yr and 20-yr GWP, though Figure only shows the results for 100-yr GWP. Note: the product of the two gray lines equals the blue line, with rounding.

Figure 4. Trends in California GHG emissions, emissions intensity, and NG import volume in trillion cubic feet (tcf) from 2018 to 2023 using 100-yr GWP



This analysis was intended to estimate emissions occurring outside of California. However, based on the emission estimation method used, some of the transmission emissions may occur within the State. This indicates there may be some overlap with CARB's AB 32 GHG inventory. This emissions amount is expected to be small because of the relatively long

distances that most imported gas travels before reaching California and because transmission and storage emissions account for less than 25 percent of the total calculated out-of-state emissions.

These estimates are based on the emissions in the U.S. EPA GHGI. Numerous studies (e.g., Alvarez et al. 2018 and Rutherford et al. 2021) have suggested that the GHGI has underestimated CH_4 emissions from the oil and gas sector, mostly based on comparisons to top-down and facility-scale measurements and modeling. However, the U.S. EPA GHGI is the best currently available data source that is nationally consistent and has sufficiently detailed attribution of emissions to specific processes to use in this assessment. Staff may consider other methods to estimate these emissions in future editions of this report.

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Appendix: Data Tables

Table A-1 shows the underlying data used to make the calculations in this report for each data year. Data sources and calculation approaches are as outlined in the report.

Table A-1. Underlying Data used in Calculations for each Data Year

Data Year	CH_4 Emissions (kt CH_4)	CO_2 Emissions (kt CO_2)	N_2O Emissions (kt N_2O)	National NG Production (excluding from oil wells) (mmscf)	CA Import Volume (mmscf)
2023	4,745	13,526	0.024	41,027,992	2,248,308
2022	5,131	13,049	0.062	39,177,221	2,121,793
2021	5,205	11,975	0.025	37,268,080	2,176,587
2020	5,395	13,703	0.026	36,366,987	2,161,467
2019	5,725	17,865	0.033	36,176,662	2,160,190
2018	5,796	13,048	0.023	32,822,041	2,052,635