Out-of-State Greenhouse Gas Emissions from Loss, Release, and Flaring of Natural Gas Imported to California: 2018-2019

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Contents

1 Summary

In 2018, Assembly Bill (AB) 2195 (Chau) was enacted to address emissions associated with natural gas from out-of-state sources. AB 2195 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 document presents CARB's estimates for data years 2018 and 2019, with calculations demonstrated using the 2019 data. Figure 1 summarizes the greenhouse gas (GHG) emissions estimate trends for both 100-yr and 20-yr global warming potential (GWP) time horizons for all years for which we have posted these data. These data are intended for informational purposes and do not establish any metrics with respect to the greenhouse gas emissions targets promulgated under AB 32 (Nunez) or Senate Bill (SB) 32 (Pavley).

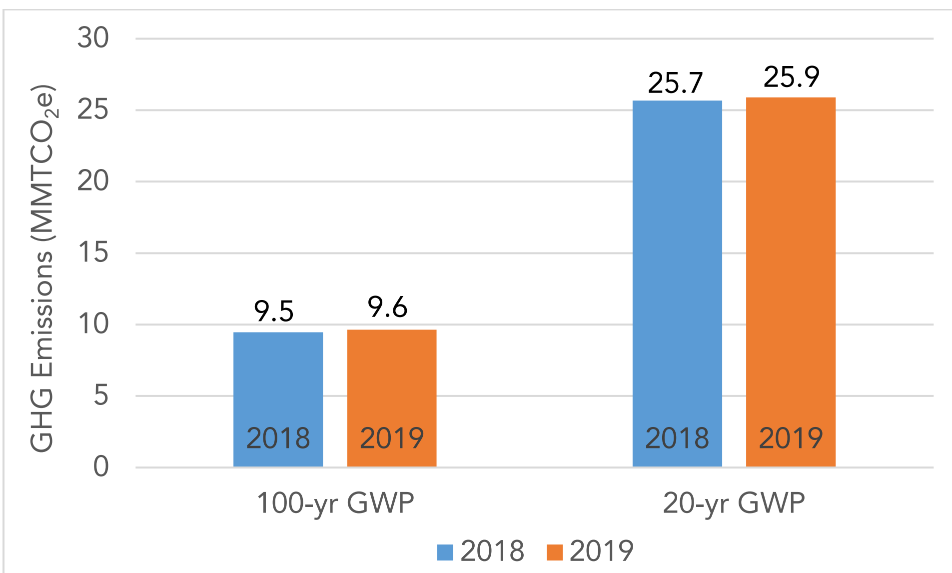

Figure 1 Estimate of 2018-2019 Out-of-State GHG Emissions from Releases of Uncombusted Gas and Flaring Associated with Natural Gas Consumed in California

Although these out-of-state emissions are not intended for inventory purposes, comparisons to CARB's Greenhouse Gas Emission Inventory could 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 2019 in-state GHG emissions from combustion of natural gas totaled 111.7

MMT CO_2e. The 2019 in-state methane emissions from fugitives and venting of natural gas during its transmission and distribution, including post-meter residential gas leaks, totaled 5.0 MMT CO_2e.

2 Introduction and Background

The California Air Resources Board developed the Short-Lived Climate Pollutant (SLCP) Reduction Strategy in 2017 to reduce emissions of some 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 time 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 time period[1].

The SLCP Strategy is a roadmap for reducing emissions of short-lived climate pollutants. Among other targets, the plan is designed to reduce CH_4 emissions by 40 percent by 2030 (from 2013 levels). The plan focuses on reductions of GHG emissions, but many of the strategies also reduce co-pollutants such as criteria pollutants and toxic air contaminants. SB 1383 (Lara) directed CARB to begin implementing this strategy and codified the CH_4 emission reduction target.

The SLCP Strategy establishes a goal of reducing methane emissions from in-state oil and gas operations by 40 percent by 2025, ramping up to 45 percent by 2030. The plan notes that additional reduction beyond those targets would most feasibly come from reducing in-state demand for oil and natural gas.

However, the SLCP Strategy is focused on measures to reduce emissions from in-state production only, whereas approximately 90 percent of the NG used in California is imported from other states or countries (CEC 2020). 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.

The growing interest in emissions associated with out-of-state NG have led to policies to better characterize such emissions. AB 1496 (Thurmond) requires CARB to monitor and measure high emission hotspots in the State and carry out a life-cycle GHG emissions analysis of imported natural gas. Additionally, AB 2195 (Chau) mandates CARB publish an annual estimate of GHG emissions associated with the “loss or

[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.

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.

This report describes the methods, calculations, results, and discussion of the out-of-state GHG emissions estimate for imported NG as required by AB 2195. The emissions calculated in this report are not included in CARB's Greenhouse Gas Inventory and are not factored into targets for in-state GHG emission reductions.

It is important to note that 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 natural gas or emissions from flaring. For example, emissions from fuel combustion to power gas transmission compressors or to regenerate glycols during gas dehydration would not be included.

3 Methods

The sources of data used in this report are summarized in Table 1. Further details are provided in the following sections. 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.

Table 1 Data Sources

Type	Specification	Source	Data Years
US NG production	Gross withdrawals from gas, shale gas, and coalbeds wells	EIA (2021a)	2018-2019
California NG imports	Total interstate and international receipts	EIA (2021b)	2018-2019
US NG-related CH_4 emissions	All processes except distribution and LNG	US EPA GHGI (2021)	2018-2019
US NG-related CO_2 and N_2O emissions	Flaring processes only (excludes LNG)	US EPA GHGI (2021)	2018-2019
Global warming potential	100-yr and 20-yr time horizons	IPCC Fourth Assessment Report (AR4)	2007

Although natural gas 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 natural gas streams are not included for purposes of calculating emissions due to the release of uncombusted natural gas.

3.1 Emissions Data

Emissions data were obtained from the US Environmental Protection Agency (US EPA) *Inventory of Greenhouse Gas Emissions and Sinks* (GHGI) *1990-2019*. Specifically, 2018 and 2019 process-level emissions data for CH_4, CO_2, and nitrous oxide (N_2O) were obtained from *Annex 3.6: Methodology for Estimating* CH_4*,* CO_2*, and* N_2O *emissions from Natural Gas Systems* (US EPA 2021).

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

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

Consistent with the definition of uncombusted natural gas 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 were 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 natural gas 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.

[2] Distribution was excluded because we interpret AB 2195 as seeking the GHG emissions associated with imported natural gas that occur outside of California, and distribution occurs within the state. Adding distribution emissions would increase the emissions estimates by ~9% for both the 100-yr and 20-yr timescales.

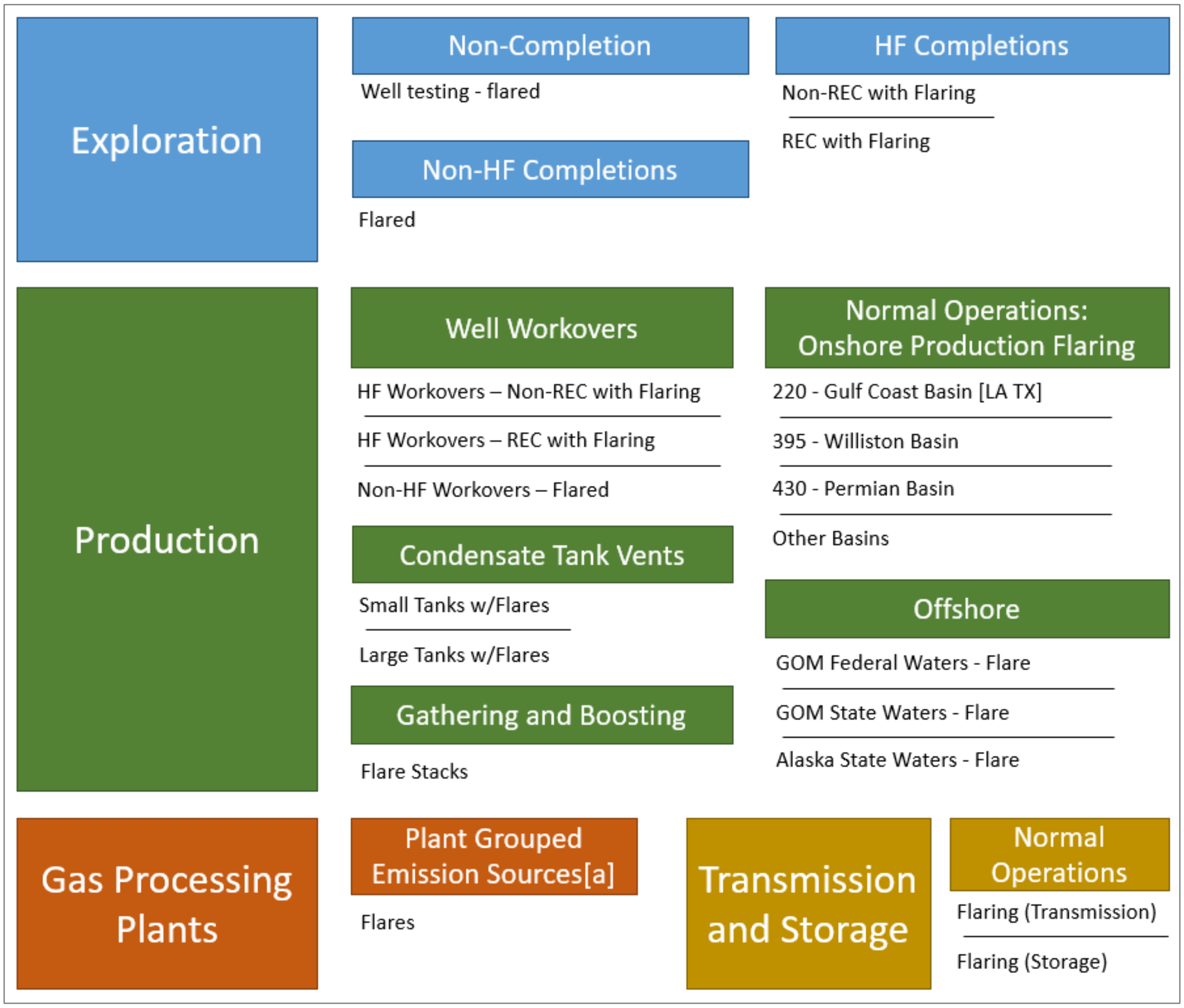

Figure 2 Flaring processes included for CO_2 and N_2O emissions (note: REC = reduced emissions completion; HF = hydraulic fracturing; GOM = Gulf of Mexico).

3.2 Natural Gas Withdrawals and California Imports

National NG gross withdrawals for 2018 and 2019 were obtained from the Energy Information Administration (EIA 2021a). For the calculations in this report, the total of gas wells, shale gas wells, and coalbed wells was used. NG production from oil wells was excluded because the emissions estimates from the GHGI only included emissions from wells with a high gas-to-oil ratio (GOR)[3].

[3] The US EPA GHGI uses a GOR of >100 Mcf/bbl in its definition of a natural gas 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 suggested the impact of the definition mismatch appears to be in the range of approximately 10-25% of the carbon intensity for processes included in this estimate (venting, fugitives, and flaring emissions only).

Interstate and international movements of natural gas into California in 2018 and 2019 were obtained from the EIA (2021b). All imports (domestic and international) were summed, without subtracting any exports. The calculations in this report assume the same GHG intensity for all imported gas even though regional and field-specific differences exist in production, processing, and transportation.

3.3 Global Warming Potentials

Global warming potentials for CH_4 and N_2O were obtained 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 CO2e/g substance)	20-yr GWP (g CO2e/g substance)
CH_4	25	72
N_2O	298	289

Emissions are reported in both 100-yr and 20-yr GWPs. The figure based on a 100-yr GWP is intended to show relatively long-term impacts, while the 20-yr GWP is meant to depict shorter-term impacts.

4 Calculations and Results

This section shows the calculations performed using the 2019 data, the latest year available. Calculations for 2018 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.

Total CH_4 emissions were calculated as the sum of net emissions[4] from exploration, production, gas processing, and transmission and storage. The total US 2019 emissions for process included in the scope of this analysis were 5,784 kilotonnes (kt) CH_4, which equals 144,605 kt CO_2e on a 100-yr basis or 416,462 kt CO_2e on a 20-yr basis.

[4] Emissions reductions from "Gas STAR Reductions" and "Regulatory Reductions" were subtracted from the total potential emissions to obtain the net emissions, consistent with the EPA's methodology.

Total US 2019 CO_2 emissions from flaring were 16,448 kt CO_2. Total US 2019 N_2O emissions from flaring were 0.031 kt N_2O, which equals 9 kt CO_2e on both 100-yr and 20-yr bases.

United States non-associated NG production (gross withdrawals from gas, shale gas, and coalbed wells) for 2019 totaled 36,268,115 million standard cubic feet (mmscf). Interstate and international imports of natural gas into California totaled 2,169,963 mmscf in 2019.

The equation below shows the general format for calculating 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.

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

where,
E_{CH4} = US NG Sector CH_4 emissions (kt CO_2e)
E_{CO2} = US NG Sector CO_2 emissions (kt CO_2e)
E_{CO2} = US NG Sector N_2O emissions (kt CO_2e)
$Production_{US}$ = US non-associated NG production (mmscf)
$Import_{CA}$ = NG volume imported to California (mmscf)
Conversion = conversion factor from kt to MMT
CA Import Emissions = out-of-state GHG emissions from NG imported to California (MMT CO_2e)

<u>Out-of-State Natural Gas GHG Emissions: 100-yr timescale</u>

Based on this analysis, the 2019 annual GHG emissions on a 100-yr GWP timescale are 9.6 MMT CO_2e, calculated as shown below. Of this total, 11% is from flaring processes.

$$\frac{(144{,}605 + 16{,}448 + 9)\ kt\ CO_2e}{36{,}268{,}115\ mmscf} * 2{,}169{,}963\ mmscf * \frac{1\ MMT}{1000\ kt} = 9.6\ MMT\ CO_2e$$

<u>Out-of-State Natural Gas GHG Emissions: 20-yr timescale</u>

The 2019 annual GHG emissions on a 20-yr GWP timescale are 25.9 MMT CO_2e, calculated as shown below. Of this total, 5% is from flaring processes.

$$\frac{(416{,}462 + 16{,}448 + 9)\ kt\ CO_2e}{36{,}268{,}115\ mmscf} * 2{,}169{,}963\ mmscf * \frac{1\ MMT}{1000\ kt} = 25.9\ MMT\ CO_2e$$

5 Discussion

The total estimated out-of-state GHG emissions associated with imported NG for data year 2019 were slightly higher than those for data year 2018 (see Figure 3). Although the GHG emissions intensity was lower in 2019, California imports were higher leading to the increase in overall GHG emissions. This is true for both 100-yr and 20-yr GWP, though Figure 3 only shows the results for 100-yr GWP.

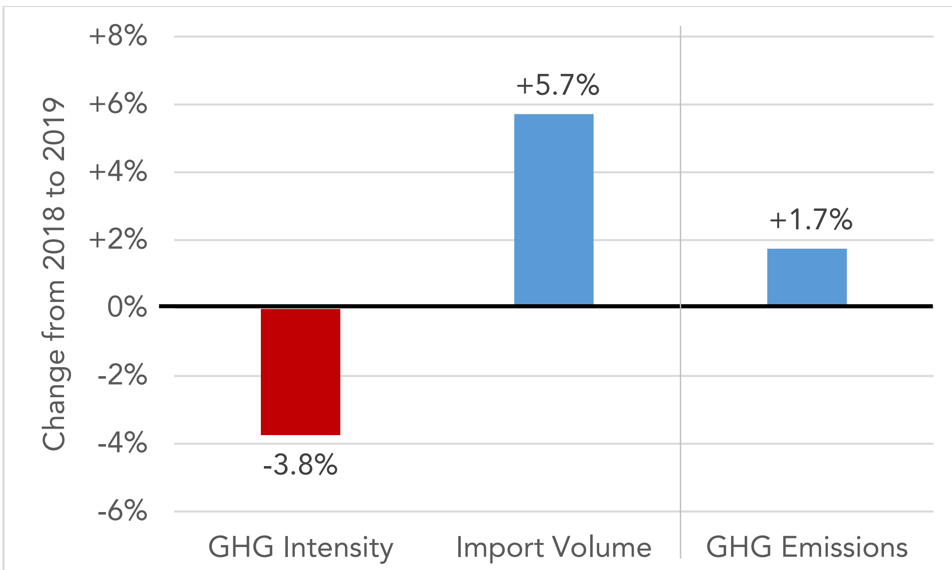

Figure 3 Change in GHG Emissions Intensity, NG Import Volume, and Total GHG Emissions from 2018 to 2019 using 100-yr GWP (note, the two bars on the left represent underlying factors leading to the total GHG emissions change in the bar on the right).

This analysis was intended to capture 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 US EPA GHGI. Numerous studies have suggested that the GHGI underestimates CH_4 emissions from the oil and gas sector, mostly based on comparisons to top-down and facility-scale measurements. For example, Alvarez et al. (2018) synthesized measurement studies across the natural gas supply chain and found measured CH_4 emissions roughly 60% higher than those in the EPA GHGI. Also of note is a recent study by Rutherford et al. (2020) which found emissions roughly 80% higher than the GHGI for the oil and gas production segment using a novel bottom-up approach.

However, the GHGI is the best currently available data source that is nationally consistent, regularly updated, and has sufficiently detailed attribution of emissions to specific processes to use in this assessment. Staff are evaluating other methods to estimate these emissions such as remote sensing studies or modeling for possible use in future editions of this report. To the extent possible, emissions estimates from previous years would be recalculated based on the new methodologies if changes are implemented.

Regional differences exist in production and processing practices, and gas from different regions is transported different distances in order to reach California. Ideally, those differences would be captured by basin-specific or region-specific carbon intensities and paired with California import volumes by basin or region. However, the available tools and studies that disaggregate by basin or region are not yet mature and/or validated enough to be used for this reporting. Future reports may include geographically resolved estimates of carbon intensity and NG import volumes.

Due to data limitations, this analysis was based on the emissions intensity of non-associated gas, that is NG which is not co-produced with significant quantities of oil. However, some of the NG consumed in California originates from basins which produce both NG and oil, which presumably includes some associated gas. Therefore, to the extent that there may be differences in the emissions intensity of associated gas and non-associated gas, this estimate would not account for those differences.

Finally, it is important to note the limitations of using the results in this report to evaluate emissions reductions based on reductions in NG consumption. The emissions intensity of NG used in the previous calculations (i.e., the first term in the equations) is the average emissions intensity. If one were to examine the effects of changes in NG consumption, use of a marginal emissions intensity is preferable. This may be relevant for NG systems, where some evidence exists to suggest that changes in gas flow volumes through unchanged infrastructure might not achieve emissions reductions that are proportional to NG consumption reductions (MacKinnon et al. 2018). Additionally, if reductions in NG demand reduce NG production, the basins which bear the production losses may not mirror the current average emissions intensity[5].

[5] Brandt et al. 2020 explored the phenomenon of "marginal fields" for oil production and found that fields which are more susceptible to demand shocks do not have the same emissions intensity as the average field. To our knowledge, similar studies have not been done for natural gas.

6 References

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