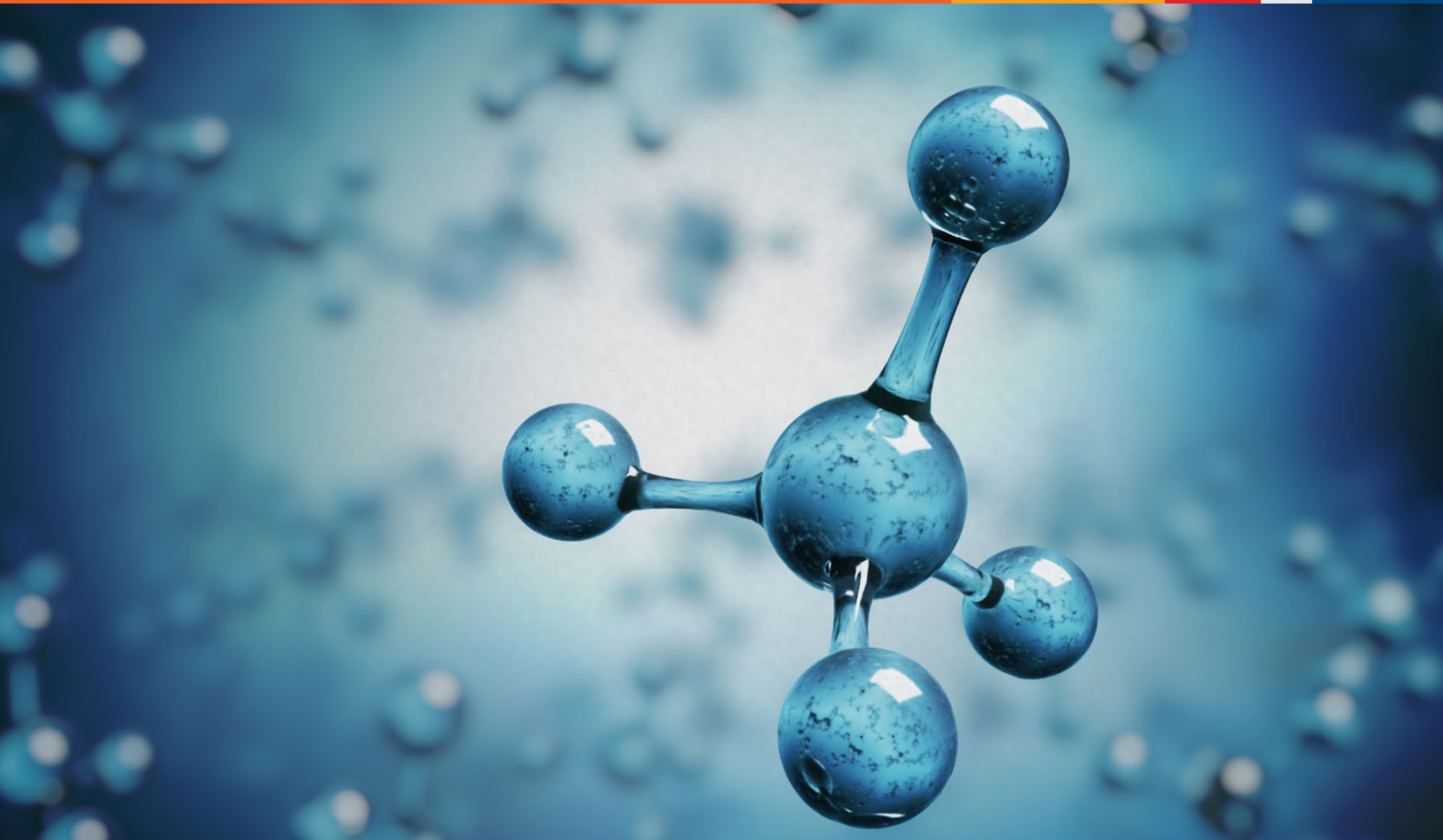
# Fugitive Methane

## New guidelines determine need to curb natural gas emissions in Ontario

**AUTHOR: JUAN SOTÉS, CARBON AND CO-BENEFITS ANALYST**



**About The Atmospheric Fund**

The Atmospheric Fund (TAF) is a regional climate agency that invests in low-carbon solutions in the Greater Toronto and Hamilton Area and helps scale them up for broad implementation. We are experienced leaders and collaborate with stakeholders in the private, public and non-profit sectors who have ideas and opportunities for reducing carbon emissions. Supported by endowment funds, we advance the most promising concepts by investing, providing grants, influencing policies and running programs. We're particularly interested in ideas that offer benefits beyond carbon reduction such as improving people's health, creating local green jobs, boosting urban resiliency, and contributing to a fair society.

May 2022

**THE ATMOSPHERIC FUND**
75 Elizabeth Street
Toronto, ON  M5G 1P4

**Media Contact:**
Julie Leach
**jleach@taf.ca** | 416-393-6382
**taf.ca**

@AtmosphericFund

Be the first to receive notification of TAF publications like this one by subscribing to our e-newsletter:
**taf.ca/subscribe**

*The views expressed here are those of The Atmospheric Fund and do not necessarily reflect the views of the City of Toronto , the Province of Ontario, or the Government of Canada.*

# Content



# Executive Summary

## Methane emissions are larger and more harmful than we thought.

Greenhouse gas emissions from natural gas combustion, a potent fossil gas mostly made of methane, is responsible for 40% (20 megatonnes) of the carbon emissions in the Greater Toronto and Hamilton Area. However, this number does not account for the "fugitive" methane that leaks from extraction, fracking, pipelines, and distribution (the full life cycle of natural gas). What's becoming most alarming to scientists who study greenhouse gases and their climate impacts, is just how much methane is leaking during the life cycle and how potent these emissions are for the climate.

This report provides guidelines and natural gas emissions factors that are based on a fugitive methane leakage rate of 2.7% and a combination of Global Warming Potential (GWP) timeframes. A timeframe of 100 years (GWP100) should be used for emissions inventories and a timeframe of 20 years (GWP20) should be used for all other scenarios.

**Based on our research and conservative estimates, the fugitive methane rate is at least 2.7%, double what is currently reported in the National Inventory Report (NIR).** While this may seem like a relatively small amount of leakage, this guideline shows that the climate effects of small methane leaks quickly add up to staggering impacts, particularly in the short term.

**Using a more accurate methodology, we found that emissions from fugitive methane are over 90% higher than what is currently being reported.** Right now, fugitive methane is rarely included when quantifying emissions, and many guidelines significantly underestimate its climate impact. We urge practitioners to immediately update their methodologies to help inform evidence-based climate action.

We intend for this guideline and these lifecycle emissions factors to enable better evaluation of emissions and impacts of projects and programs that affect natural gas consumption.

Natural gas's share of electricity generation in Ontario is about to quadruple, partly because of nuclear reactors soon coming offline for refurbishment or retirement, and partly to fulfill rising electricity demand. And just as these gas plants are ramping up, we are also increasing the amount of fracked gas imported from the United States, which emits more fugitive methane than domestic gas from Western Canada (though fugitive methane is underreported there too). It is important to have better factors to correctly estimate this impact.

**Considering the full life cycle effects of natural gas shows that there is little difference between the climate impacts of natural gas and coal in the short term, debunking the myth of natural gas as a "clean bridge fuel" in the broader energy transition away from fossil fuels.**

### What's in a name?

Natural gas, or "fossil gas", is a greenhouse gas made up almost entirely of methane. When combusted to heat buildings or produce electricity, it turns into $CO_2$, whereas when it leaks directly into the atmosphere it is far more potent. Methane is a short-term pollutant, meaning that it stays in the atmosphere for a shorter time than other greenhouse gases like carbon dioxide. However, it traps heat in the atmosphere more effectively, making its global warming potential up to 85 times more powerful than $CO_2$.

# Guidelines for Accounting for Fugitive Methane

## Methane leakage (fugitive emissions) from the natural gas life cycle is about 2.7%

Quantifying the full impact of natural gas consumption requires looking beyond combustion emissions, since much of the emissions come from other stages of the natural gas life cycle. Methane leaks into the atmosphere during extraction, transmission, and local distribution. Canada's National Inventory Report currently reports only a 1.3% leakage rate. We have established a set of criteria to account for each stage of the life cycle, which results in a 2.7% leakage rate. This fugitive rate is the basis for the emissions factors discussed in this guideline.

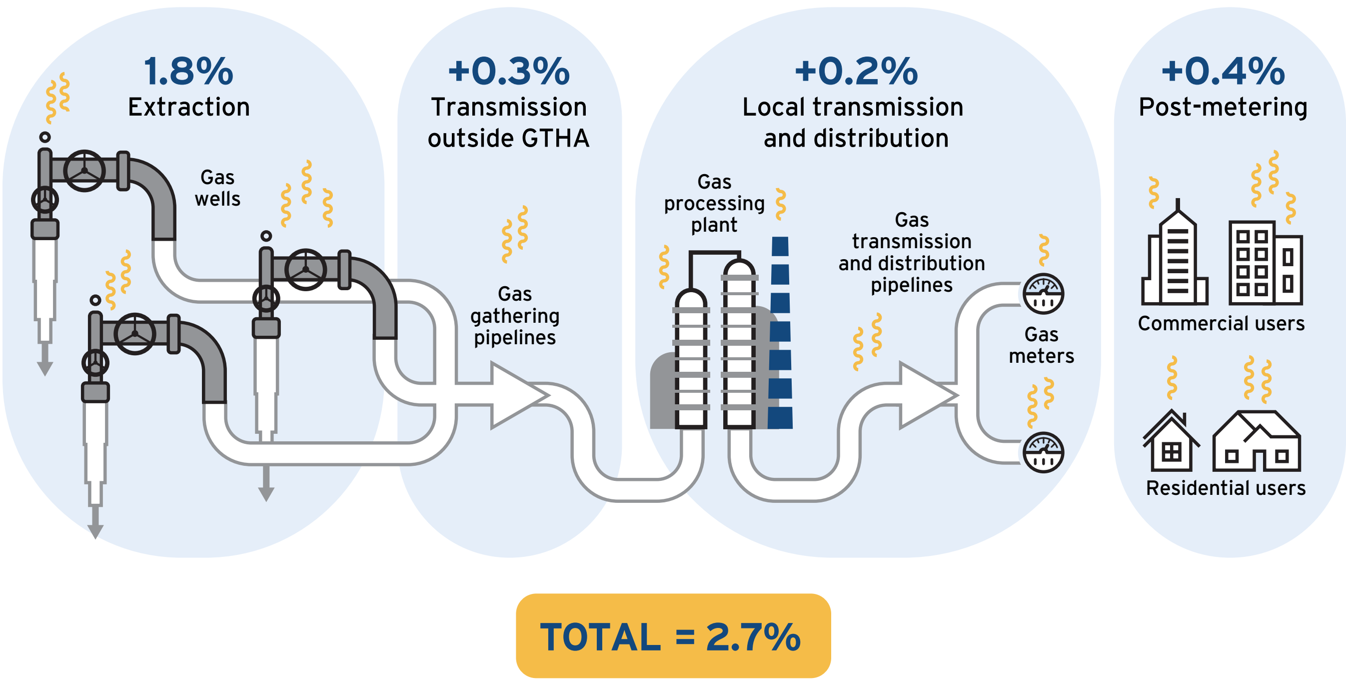



**Figure 1:** Estimated rates of methane leakage (fugitive emissions) from the natural gas life cycle (for consumption in Ontario)

There is significant variability in literature when estimating fugitive leakage rates, ranging from less than 0.5% to more than 10%. And upstream natural gas emissions are so significant that even small differences in measurement can have big impacts. For example, underestimating a fugitive methane rate at 1.3% would mistakenly justify natural gas as a useful bridge fuel in the transition to clean energy. However, adjusting the fugitive methane rate to over 2.8% would suggest that natural gas emissions are worse than coal, making it impossible to achieve our climate targets with a continued reliance on natural gas.

## Including fugitive methane almost doubles emissions associated with natural gas consumption

Fugitive methane emissions are not usually considered in project evaluation, aside from a small amount of leakage currently reported under Scope 1 emissions in inventories. This number represents the leakage that occurs during local transmission and distribution within the boundaries of the inventory. However, this significantly underestimates the true leakage amounts.

When we look at the full life cycle of natural gas, including extraction and longer distance transmission, we see a 40%-90% increase in total emissions (as measured in the equivalent amount of carbon dioxide emissions, and dependent on the timeframe used).

## Using an accurate timeframe to estimate methane emissions further demonstrates their potency

The standard time frame for measuring the impact of methane leakage in the atmosphere is 100 years (referred to as Global Warming Potential 100, shortened to GWP100[1]), but we are recommending using a *combination* of a 100-year timeframe for greenhouse gas emissions inventories and a 20-year timeframe (GWP20) for all other cases. The impact of the recalculation is significant; where methane was considered 30 times more potent than carbon dioxide using a 100-year timeframe, a 20-year timeframe demonstrates it is closer to 85 times more potent.

Methane can trap more heat than $CO_2$, but it only lasts about 12 years in the atmosphere. Comparing impacts of both gases over 100 years gives $CO_2$ an extra 88 years trapping heat to "catch up" with the impact of methane, undermining the gap between them in the short-term[2].

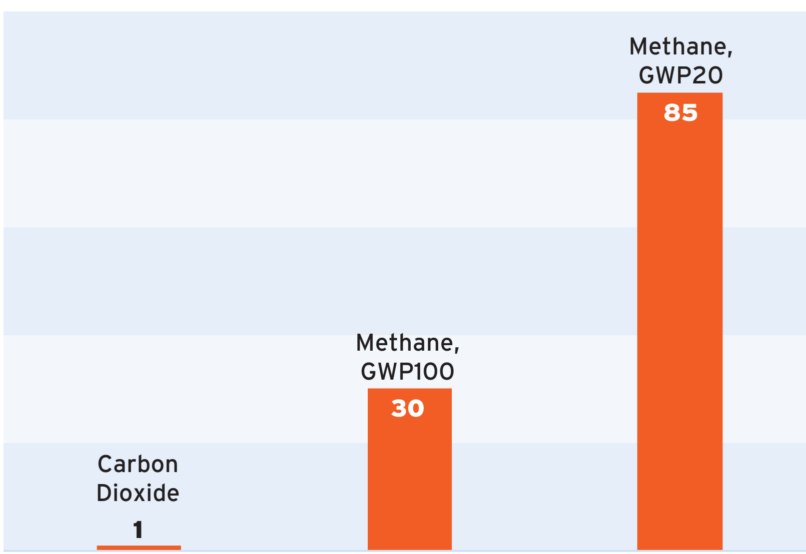



**Figure 2:** Estimated Global Warming Potential (GWP), carbon dioxide and methane emissions using 20-year (GWP20) and 100-year (GWP100) timeframes

[1] The Global Warming Potential (GWP) metric examines each greenhouse gas's ability to trap heat in the atmosphere compared to carbon dioxide ($CO_2$) measured over a specified time frame. For more information, see Appendix A

[2] More detailed analysis on GWPs in the Appendix A

To more accurately represent the impact of natural gas consumption, including fugitive emissions, we propose using either GWP100 or GWP20 based on the following scenarios:

- **Modelling activities that impact natural gas consumption: use GWP20**
- **Reporting greenhouse gas emission inventories: use GWP100**

Figure 3 shows the impact to full life cycle emissions using the two timeframes: an approximate 39% increase using GWP100 and a 92% increase using GWP20, compared to combustion-only emissions.[3]

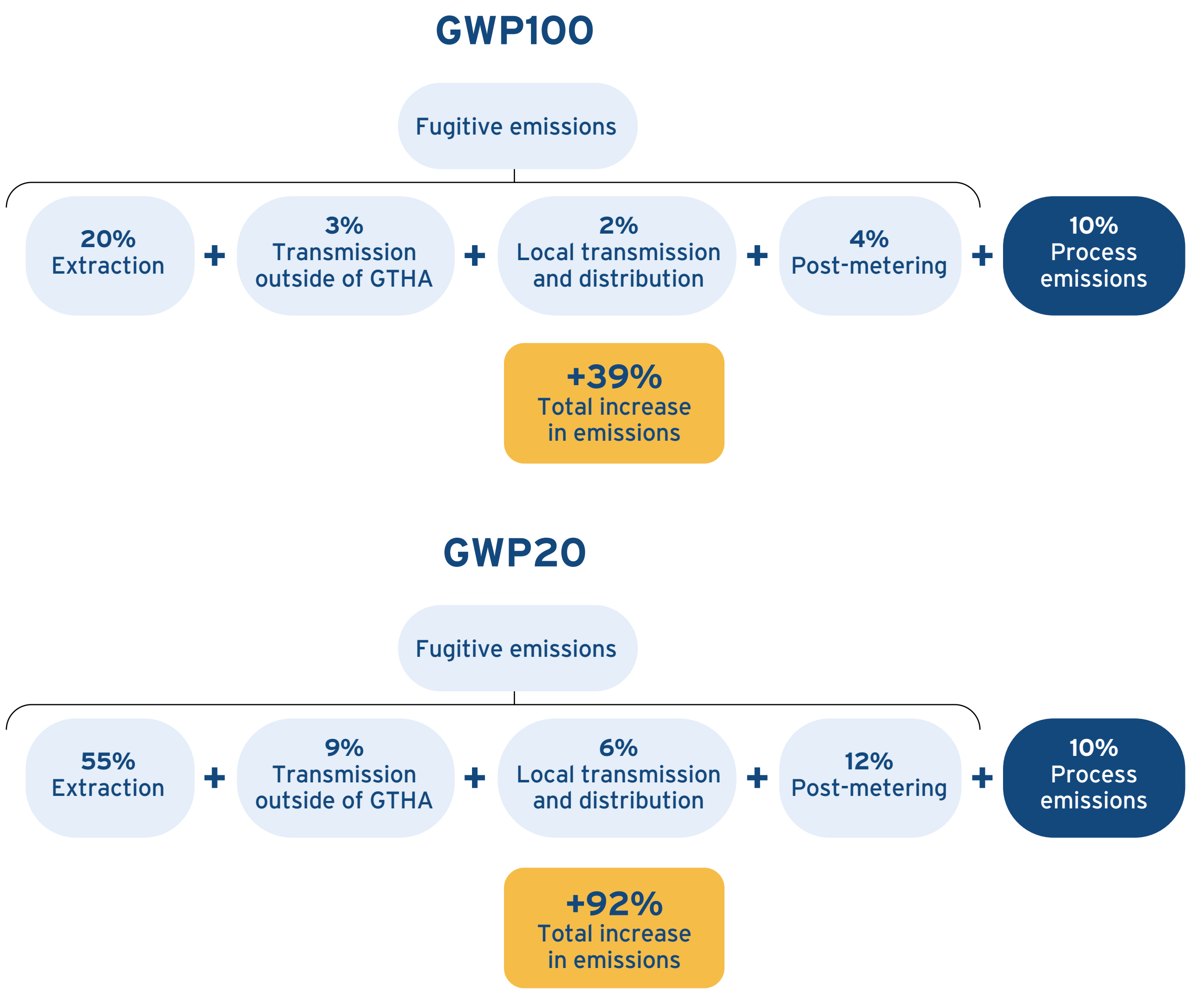



**Figure 3:** Percentage increase in natural gas life cycle emissions compared to combustion-only emissions

3 These percentage increases are based on all LCA emissions, not only fugitive. Methane leaks, however, are the biggest contributor, responsible for over two-thirds of the increase over combustion

# Emissions Factors and Their Applications

Natural gas is used for various purposes, including space and water heating, electricity generation, and heavy industry, and is sourced from different places. We have developed a set of fugitive emissions factors that include the full life cycle assessment (LCA) impact of this fossil fuel in Ontario with the purpose of more accurately accounting for fugitive emissions and applying them appropriately in different scenarios. We recommend using different factors and timeframes when evaluating the following scenarios:

- **Projects without impacts to natural gas pipeline infrastructure**
- **Projects that impact natural gas pipeline infrastructure**
- **Renewable natural gas projects**
- **Emissions inventories**

Emissions factors for each scenario depend on the GWP timeframe and fugitive methane leakage at several LCA stages.

The emissions factor for inventories includes combustion *and* fugitive emissions while the emissions factors for the remaining scenarios are based on the full LCA (including process emissions[4]).

[4] Total process emissions cannot be disaggregated between extraction, transmission, and distribution with current data sources. Due to this limitation, the total process emissions are added to every LCA analysis in this report, even for emission factors that that do not account for the full process. Therefore, the potential emissions reductions for RNG projects and projects without changes to natural gas pipelines are slightly overestimated.

## Projects without impacts to natural gas pipeline infrastructure

**GWP Timeframe:** 20 years

**Emissions Factor:** 3.13 kg $CO_2e/m^3$ (accounting for fugitive methane increases typically reported emissions by 55% compared to only accounting for combustion).

When a project increases or reduces natural gas consumption without changing existing natural gas pipeline infrastructure, only the extraction phase of fugitive emissions need be considered. Examples of these projects include boiler retrofits (reducing gas consumption) and natural gas-fired electricity generation (increasing gas consumption). Transmission and distribution leakage are not affected since the amount of gas in the pipelines is dependent on the number of customers (e.g., length of the pipelines, number of connections) rather than changes in demand.

| Timeframe: GWP20 | Fugitive emissions | | | Process | Combustion | Total |
|---|---|---|---|---|---|---|
| | Extraction | Upstream transmission | Local transmission, distribution, and post metering | | | |
| EFs ($kgCO_2e/m^3$) | 1.04 | N/A | N/A | 0.19 | 1.90 | 3.13 |
| Reported Emissions Increase over Combustion | +55% | | | +10% | N/A | **65%** |

**Example:** In 2019, Ontario's Demand Side Management (DSM)[5] programs avoided 1,322 million $m^3$ of natural gas consumption at a cost of $72.7 million.

Accounting only for **combustion emissions**, DSM programs helped avoid:

1,322,000,000 $m^3$ x 1.90 $kgCO_2e/m^3$ x 0.001 T/kg = 2,510,478 $TCO_2e$ = **2.5 Mt $CO_2e$ in 2019**
Cost per tonne of $CO_2e$ avoided: **$29/tonne**

Factoring in **extraction and process emissions**, the program actually avoided 65% more:

1,322,000,000 $m^3$ x 3.13 $kgCO_2e/m^3$ x 0.001 T/kg = 4,133,951 $TCO_2e$ = **4.1 Mt $CO_2e$ in 2019**
Cost per tonne of $CO_2e$ avoided: **$18/tonne**

[5] https://www.oeb.ca/sites/default/files/EGI-2019-Draft-DSM-Annual-Report-20200529.pdf

## Projects that impact natural gas pipeline infrastructure

**GWP Timeframe:** 20 years

**Emissions Factor:** 3.65 kg $CO_2e/m^3$ (accounting for fugitive methane increases typically reported emissions by 82% compared to only accounting for combustion).

Adding or removing connections from the natural gas grid has a structural impact that efficiency projects do not. For example, fuel-switching projects at a large scale or any natural gas grid expansion will affect transmission and distribution-related emissions. And for fuel switching projects in particular, the number of customers disconnecting from the grid is the key consideration:

- If one or a handful of buildings are disconnecting from the grid, the impact on pipeline infrastructure will be negligible, and a 3.13 kg $CO_2e/m^3$ emissions factor should be used (see previous section).
- If a significant number of customers add connections to the grid (e.g., an entire new neighbourhood), there is a potential increase in transmission- and distribution-related emissions attributed to expanding the system. The higher emissions factor presented in this section (3.65 kg $CO_2e/m^3$) should be used.

Similarly, the higher emissions factor (3.65 kg $CO_2e/m^3$) should be used to assess the emissions impact of removing natural gas connections. It is also important to qualitatively assess the carbon lock-in effect and the risk of additional pipeline infrastructure becoming a stranded asset, both of which are not captured in this emissions factor.

| Timeframe: GWP20 | Fugitive emissions | | | Process | Combustion | Total |
|---|---|---|---|---|---|---|
| | Extraction | Upstream transmission | Local transmission, distribution, and post metering | | | |
| **EFs ($kgCO_2e/m^3$)** | 1.04 | 0.17 | 0.35 | 0.19 | 1.90 | 3.65 |
| **Reported Emissions Increase over Combustion** | +82% | | | +10% | N/A | **92%** |

**Example:** An entire new single-family neighbourhood is being built and supposed to be added to the natural gas grid in Toronto, but the city is working with the developer to make it all-electric instead. The baseline natural gas consumption for the community is 236,000 $m^3$ of natural gas per year and the marginal cost of going all-electric for the project is $5,500,000 CAD. By transitioning away from gas, these associated emissions are eliminated (there might be some added electricity emissions if solar panels and heat pump supply do not meet demand entirely, and there will be additional life cycle emissions from the manufacturing of solar panels, excluded from this example for simplicity purposes). Modelling the impact over the first 20 years (assuming constant fugitive emissions over the next 20 years):

Avoided **combustion emissions** over a year:

236,000 $m^3$ x 1.899 $kgCO_2e/m^3$ x 0.001 T/kg = 448 $TCO_2e$/year
448 $TCO_2e$/year x 20 years = **8,963 $TCO_2e$ over 20 years**

Avoided **combustion + LCA emissions** (fugitive and process) over a year:

236,000 $m^3$ x 3.65 $kgCO_2e/m^3$ x 0.001 T/kg = 860 $TCO_2e$/year
Cost per tonne of $CO_2e$ avoided: **$18/tonne**

860 $TCO_2e$/year x 20 years = **17,209 $TCO_2e$ over 20 years**

The difference in emissions accounting will also affect the economic analysis. Using the updated factor results in spending $320/$TCO_2e$ to avoid those emissions over 20 years, compared to $614/$TCO_2e$ tonne for combustion-only emissions. Better emissions accounting will result in better business case evaluations, accounting for the actual benefits of fuel switching.

## Renewable natural gas projects

**GWP Timeframe:** 20 years

**Emissions Factor:** 3.30 kg $CO_2e/m^3$ (accounting for fugitive methane increases typically reported emissions by 64% compared to only accounting for avoided combustion).

| Timeframe: GWP20 | Fugitive emissions | | | Process | Combustion | Total |
|---|---|---|---|---|---|---|
| | Extraction | Upstream transmission | Local transmission, distribution, and post metering | | | |
| **EFs ($kgCO_2e/m^3$)** | 1.04 | 0.17 | 0.35 | 0.19 | 1.90 | 3.65 |
| **Reported Emissions Increase over Combustion** | | +82% | | +10% | N/A | **92%** |

Projects like renewable natural gas (RNG) can offset extraction and upstream emissions by avoiding the need for natural gas from Alberta or the US. These projects will also offset combustion emissions, since RNG combustion emissions are considered biogenic (e.g., they come from natural sources). However, fugitive methane emissions during local distribution remain identical to those from natural gas.

**Example:** An organics processing facility in the GTHA can produce 5 million $m^3$ of RNG per year by capturing methane from organic waste. If this RNG is injected into the natural gas grid, we can assume that it will displace an equivalent amount of natural gas.

5,000,000 $m^3$/year x 3.30 kg $CO_2e/m^3$ x 0.001 T/kg = **16.500 $TCO_2e$** avoided combustion and upstream fugitive emissions every year

The benefits of these projects can vary based on location and amount of local fugitive emissions. In some circumstances where local fugitive leakage rates are very high, an RNG project may not proceed because the avoided emissions are minimal. To accurately assess the local impact of RNG, it is important to consider both local leakage and emissions from regular organic waste:

1. **Organic waste is untreated**
   - Methane leakage to be subtracted from expected benefits.
   - Significant emissions reductions are expected (avoided landfill methane emissions are high)
2. **Organic waste is partially treated**
   - Treatment options can include flaring (the controlled burning of natural gas), anaerobic digestion with methane capture, or production of agricultural fertilizer. In practice, capturable waste methane is extremely limited and is more likely to be diverted from a flare than from direct atmospheric release. From a climate perspective, this limits the potential of RNG.
   - Methane leakage to be subtracted from expected benefits.
   - Avoided emissions could be offset completely. A more comprehensive analysis of local rates and efficiencies would be needed.
3. **Methane is generated with power to gas technology**
   - Local fugitive and combustion emissions calculations should be added to the emissions of the electricity needed for the conversion (first to hydrogen and then to methane).
   - Since this is synthetic methane, which would not be emitted in the atmosphere under natural conditions, there are no climate benefits to its use beyond the avoided upstream leaks.

While the GWP100 for organic methane is 28 compared to 30 for methane, it is important to note that RNG also contributes to locking in of natural gas infrastructure that could delay the adoption of cleaner energy sources.

## Emissions inventories

**GWP Timeframe:** 100 years

**Emissions Factor:** 2.45 $kgCO_2e/m^3$ (accounting for fugitive methane increases typically reported emissions by 29% over combustion compared to only accounting for Scope 1)

In the GTHA, natural gas Scope 1 emissions (combustion plus local leakage) currently account for about 40% of total emissions. Since fugitive emissions (Scope 3) are 10 times higher than Scope 1, ignoring them underestimates total emissions, potentially undermining climate action priorities. We recommend that Scope 1 (combustion and local fugitives) and Scope 3 (upstream fugitives) emissions be reported individually[6]:

| Timeframe: GWP20 | Fugitive emissions | | | Process | Combustion | Total |
|---|---|---|---|---|---|---|
| | Extraction | Upstream transmission | Local transmission, distribution, and post metering | | | |
| **EFs ($kgCO_2e/m^3$)** | 0.37 | 0.06 | 0.12 | N/A | 1.90 | 2.45 |
| **Emissions Increase over Combustion** | +22% | | +6% | N/A | N/A | **29%** |
| **Scope** | Scope 3 | Scope 3 | Scope 1 | N/A | Scope 1 | |

[5] Process emissions are not included here because the purpose of this emissions factor is to reflect the impact of fugitive methane in the inventory

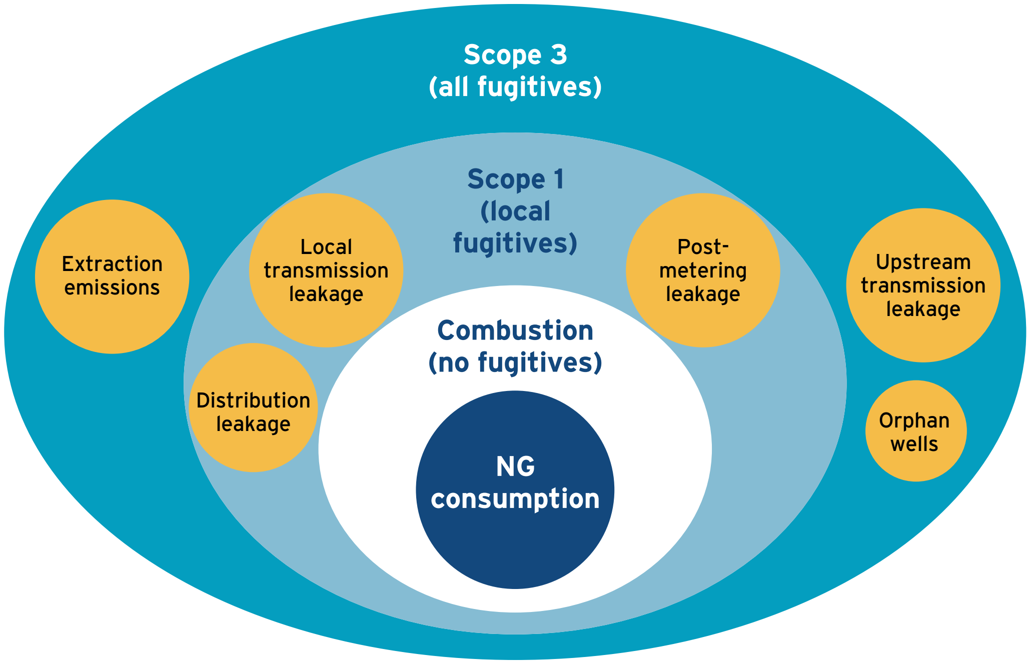



**Figure 4:** Life cycle of natural gas

**Example:** Accounting for Scope 1 natural gas fugitive emissions in the GTHA using 0.04 $kgCO_2e/m^3$ adds an extra 2% to combustion emissions, equivalent to the total agricultural emissions in the region. Including Scope 3 emissions would further increase natural gas related emissions by 22%, for a total of a 25% increase based on 100-year timeframe. Short-term impacts of fugitive emissions would be three times higher.

**Scope 1** (Combustion):
10,462[7] million $m^3$ x 1.899 kg $CO_2e/m^3$ = 19.8 Mt $CO_2e$

**Scope 1** (local fugitive emissions):
+ 10,462 million $m^3$ x 0.12 kg $CO_2e/m^3$ = 1.27 Mt $CO_2e$

Total Scope 1 = 21.07 Mt $CO_2e$

**Scope 3** (upstream fugitive emissions):
10,462 million $m^3$ x (0.37+0.06) kg $CO_2e/m^3$ = 4.46 Mt $CO_2e$

Total Scope 1
+ Scope 3

= **25.5 Mt $CO_2e$** 29% increase over combustion-only accounting for natural gas

[7] TAF's most recent inventory for the GTHA (2018) reported 10,462 million $m^3$ of natural gas consumed in the region. **https://taf.ca/gtha-carbon-emissions/**

# Fuel Comparisons

A full LCA analysis is also important when comparing the climate impacts of different fuels. In this case of natural gas, fugitive emissions are a comparatively large component of its total LCA emissions (almost as significant as its combustion), particularly over a 20-year timeframe.

While looking at the long-term impact (GWP100), natural gas is still a cleaner option compared to other fossil fuels. However, the short-term approach (GWP20) shows that natural gas emissions are very similar to other fossil fuels. For example, there is a very small difference between the climate impacts of natural gas and coal, an irony given that natural gas is often touted as a 'low-carbon' alternative to coal. This lifecycle analysis casts doubt on the potential of using natural gas as a short-term bridge fuel while getting on track to achieve our climate targets.

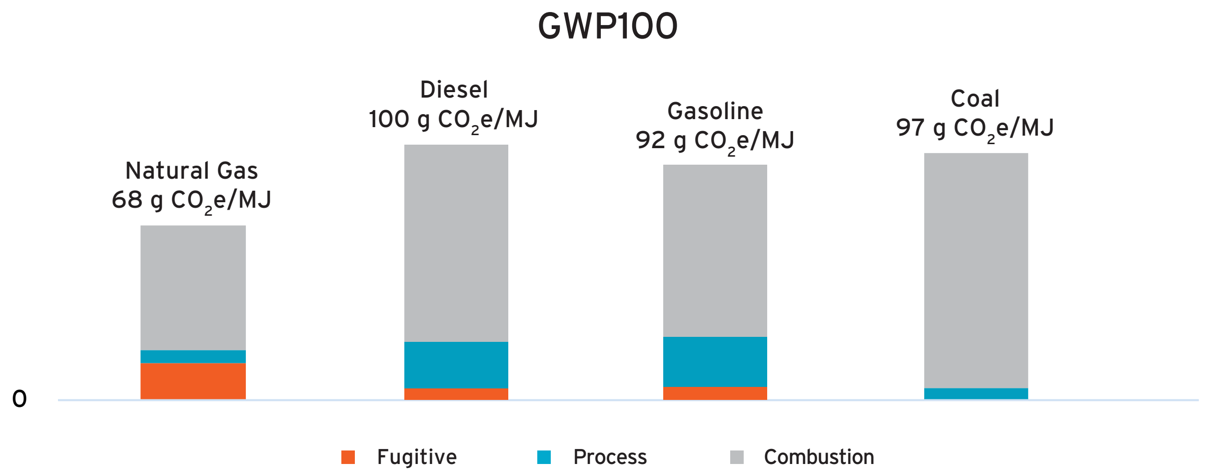



**Figure 5:** Comparison of the long-term impact of common fossil fuels, GWP100

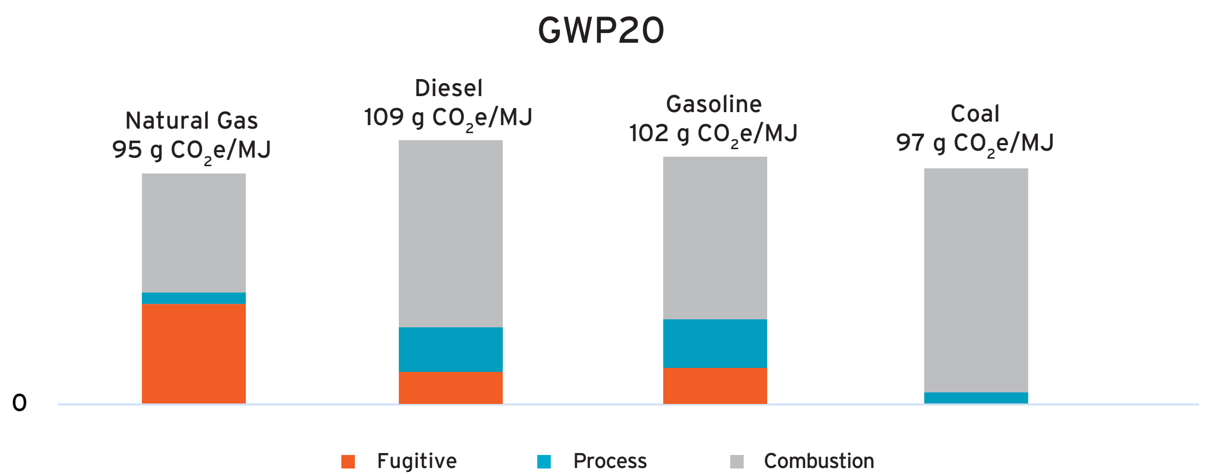



**Figure 6:** Comparison of the medium-term impact of common fossil fuels, GWP20

# The Big Picture

## Natural gas use is not compatible with a safe climate

Examining the full life cycle of natural gas demonstrates that maintaining or expanding natural gas use is not compatible with our climate targets.

Reducing methane emissions is key to averting quickly approaching climate change tipping points. According to a recent report from the IPCC, governments have until 2030 to take the actions that will determine if global temperatures stay below 2°C. Dramatically reducing methane emissions now would help slow the rise of global temperatures during this crucial short-term window.

TAF is immediately applying this improved methodology which will inform our project evaluations and help us to prioritize initiatives that reduce or eliminate natural gas consumption. These findings are intended to inform policy frameworks towards phasing out natural gas, evaluating impacts of climate programs, and improving carbon emissions quantification work.

While these guidelines are based on the best available information, more research is needed to measure and better estimate the true leakage rates of natural gas in the transmission system. This is also important at the local level, where gaps exist in the current understanding of distribution and post-metering methane emissions.

# Recommendations for Policymakers

## Phasing out fossil fuels and reducing impacts of fugitive methane are critical to meeting our climate targets.

### Commit to phasing out natural gas for electricity generation by 2030 or as soon as possible thereafter, and immediately stop development of new natural gas pipelines

Investment in conservation, renewable generation, and storage solutions can support the effective phase-out of natural gas. Projects to expand natural gas pipeline infrastructure should halt immediately as they lock in emissions and impede the transition to renewables. As the cost of fossil fuels increases and alternatives decrease, current research demonstrates that new natural gas infrastructure projects are bound to become stranded assets[8,9].

### Develop accurate greenhouse gas emissions inventories

To assess an accurate impact of natural gas, the full life cycle should be accounted for, particularly in emission inventories such as the National Inventory Report.

### Set more ambitious federal methane reduction targets and develop a clear framework to achieve them

Canada's current target of a 45% reduction in fugitive emissions by 2025 needs a clear framework to get us there as well as long-term planning to keep reducing these leaks. There are already reports advocating for a 75% reduction by 2030[10]. In addition, alignment between the U.S. and Canada regulations is needed to reduce our reliance on cheaper American fracked gas (which is already 75% of natural gas consumption in Ontario).

### Reduce fugitive methane using tools available today

Reducing methane emissions from the oil and gas industry is one of the cheapest, fastest, most effective climate solutions in Canada. Putting a price on methane emissions is an available and proven economic tool[11]. Specific recommendations focusing on the largest sources of fugitive emissions can be found in **this report by the Pembina Institute**.

[8] https://www.desmogblog.com/2019/09/13/cheap-renewable-energy-natural-gas-power-plants-pipelines-obsolete

[9] https://rmi.org/insight/clean-energy-portfolios-pipelines-and-plants

[10] https://www.pembina.org/reports/case-for-raising-ambition-in-methane.pdf

[11] https://davidsuzuki.org/wp-content/uploads/2019/08/DSF_Methane_When_the_Price_is_Right.pdf

# Appendix A: Global warming potential of short-term pollutants

Methane, the primary constituent in natural gas, is a leading greenhouse gas (GHG) after $CO_2$. Like other GHGs, methane's impact on global warming depending on its potential to capture energy and how long it remains in the atmosphere. A recent report by IPCC[12] assessed the importance of this short-lived pollutant. Although $CO_2$ dominates long-term warming, **methane and other short-lived GHGs[13] can contribute significantly to limiting warming to 1.5°C above pre-industrial levels**.

To enable comparisons between GHGs, different metrics have been developed, the most common being Global Warming Potential (GWP). Since gases have different lifetimes, the comparison changes significantly depending on the GWP timeframe. This is especially important for gases that do not last long in the atmosphere, known as short-term pollutants.

The most common time frame to compare the impact of different gases is 100 years (GWP100), and is often used in carbon markets. It was adopted as a metric to implement the multi-gas approach embedded in the United Nations Framework Convention on Climate Change (UNFCCC) and made operational in the 1997 Kyoto Protocol. The second most common time frame is 20 years (GWP20), often used to estimate the impact of short-term pollutants like methane in a timeframe consistent with current climate targets like net zero by 2050.

Choosing a short timeframe for methane will dilute the long-term impacts of $CO_2$, whereas selecting a long timeframe will largely ignore the short-term consequences[14]. GWP20 better reflects the role of short-lived climate pollutants which buys crucial time for $CO_2$ reductions to limit global warming to 1.5-2°C.  There are also risks of triggering multiple climate tipping points before we reach the 1.5°C or 2°C thresholds. Therefore, a shorter time frame can better capture impacts that could trigger these tipping points.

Given the benefits and drawbacks to both timeframes, TAF recommends using GWP100 for inventories and GWP20 for all other scenarios. We also recommend reporting which time frame is used to facilitate clear interpretation of results.

[12] https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_High_Res.pdf

[13] While other short-term pollutants are not considered the largest contributors to climate change, curtailing their use could buy us time to reduce $CO_2$ emissions without triggering multiple climate tipping points. Attention should be paid to reducing CFC and HCF refrigerants and their end-of-life processing

[14] https://pubs.rsc.org/en/content/articlelanding/2018/em/c8em00414e#!divAbstract

# Appendix B: Methodology

## Methane emission sources

One of the most comprehensive methane inventories to date, FLAME-GTA[15], indicates that the two biggest sources methane in the GTHA are: 1) management and treatment of solid and liquid waste (representing 75% of total methane emissions); and 2) natural gas leaks (representing 12% of total methane emissions).

While solid waste is the main source of methane, its emissions are properly captured in GHG inventory accounting[16] (like TAF's 2018 inventory[17]). On the other hand, methane leaks across the full life cycle of natural gas are not and thus the focus of this guideline.

Methane emissions have been rising rapidly over the past decade[18], in a trend that correlates with the explosion of natural gas fracking in the United States and Canada. While high uncertainty around measurements persists, fracking is broadly accepted to generate higher methane emissions than conventional extraction techniques. This causes its LCA emissions to be almost as detrimental as coal.

While conventional extraction techniques are more prevalent in Canada than in the United States, the forecasted increase of fracking in both countries is dramatic, as can be seen in Figure 1. This indicates that most of our natural gas in the next decades will come from fracked gas.

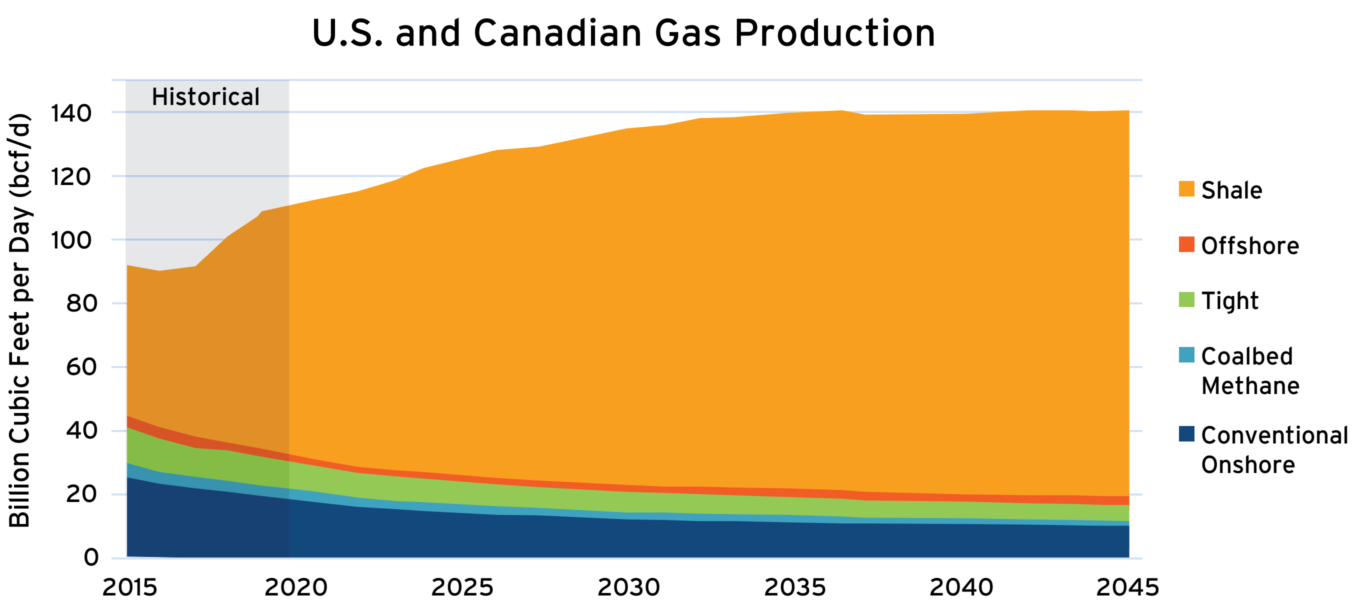



**Figure B1:** Forecasted US and Canada gas production[19]

[15] **https://www.sciencedirect.com/science/article/pii/S1352231021001370**

[16] The importance of those sources will also increase in inventories if switching from GWP100 to GWP20.

[17] Available at: **https://taf.ca/gtha-carbon-emissions/**

[18] **https://bg.copernicus.org/articles/16/3033/2019/**

[19] EB-2020-0066, Exhibit JT1.7; EB-2021-0004, 2021 Annual Gas Supply Plan Update, Enbridge Gas Inc., February 1, 2021, p. 11

Canadian gas sources are considered cleaner in extraction and transmission when compared to their United States' counterparts. Natural gas has been historically sourced from western Canada, but the revolution of fracking has significantly reduced the price of gas from the United States, encouraging Enbridge to diversify sources and change this dynamic (currently over 75% of the gas consumed in Ontario come from the US).

Natural gas markets are complex, and it is not possible to precisely establish the source of gas purchased in a given hub, but the current trends indicate that **most of the natural gas consumed in Ontario over the next decade will be extracted by fracking in the US**. Increasing proportion of fracked gas and emissions at those extraction sites can offset pipeline improvements over the next decades.

## Where do methane leaks occur?

Methane gas leaks happen across the full lifecycle of natural gas. A comprehensive description of the different process steps and associated fugitive emissions can be found in the NIR[20], detailing a bottom-up approach. The NIR is one of the best oil and gas inventories in the world, containing more than 7.5 million point-source emission records and referenced in many evaluations and policy decisions across Canada. However, multiple studies in Canada and the United States indicate that NIR's assumed leakage rate (currently estimated at 1.3%) underestimates the real contribution to the increase in atmospheric methane concentrations.

When developing this guideline, TAF made an effort to conciliate NIR's data with the latest research, adjusting fugitive values across the extraction, transmission and distribution processes. The emission values here combine information from the NIR and other bottom-up sources, with top-down data from several studies. Given an underlying understanding that Canadian processes are cleaner than those in the US, extraction and upstream transmission from these two regions have been analyzed individually.

### Extraction

The rise of fracking significantly influences the selection of extraction rates both in Canada and the US. Given the range of values encountered, the precise measure of extraction fugitive emission is highly uncertain. Post-production emissions are also intended to be captured in this section.

Additional sources of methane emissions like orphan wells are not fully captured in this factor and requires additional research.

#### *Canada*

The fugitive emission rate obtained with NIR data for extraction in Alberta (where most of the Canadian gas consumed in Ontario comes from) is close to one per cent. Methodological challenges to obtain this value are acknowledged in the inventory. Multiple studies challenge this value, including a recent study[21] with eight-year estimates considering methane emissions from oil and gas operations in western Canada to be 60 per cent higher. Aligning with previous analysis, this guideline uses a 1.6% fugitive emissions rate for extraction activities in Canada.

The NIR is working on several initiatives, including satellite-based data, to gradually adjust its bottom-up model to include atmospheric measurements. A change in methodology is not expected for at least another two years.

[20] Including the methodology used to estimate those emissions in Part 1 of the report chapter 3.3.4 (page 82) and Part 2 chapter A3.2.2.1 (page 44)

[21] **https://www.edf.org/climate/methane-research-series-16-studies**

### *US*

The US inventories and independent studies show slightly higher emissions rates than Canada. The most comprehensive studies to date, compiled by EDF[22], indicate an extraction fugitive rate of 1.9 per cent (including production, gathering and processing). This guideline adopts this rate for extraction activities in the US.

## Transmission

While there are discrepancies between sources, the uncertainty of measuring transmission fugitive emissions is low compared to other parts of the LCA.

### *Canada*

Transmission bottom-up data has been obtained from NIR and an inventory developed for the Canadian Energy Partnership for Environmental Innovation (CEPEI, a special program under the Canadian Gas Association). Both sources provide an emission rate between 0.1 per cent and 0.2 per cent. Most scientific studies focus on extraction, acknowledging uncertainties and methodology limitations, and encourage rounding the value up to 0.2 per cent.

CEPEI is continuously working to improve leak detection and is in the process of establishing a predictive model to better assess losses.

### *US*

The literature shows slightly higher emission rates than Canada. This guideline also uses a value of 0.3 per cent for the US, consistent with the literature.

## Local transmission and distribution

Enbridge and the NIR provide values for local transmission and distribution based on bottom-up studies, indicating values between 0.1 per cent and 0.2 per cent.

This value is significantly lower than studies in Boston, for example, where the local distribution system is estimated to have a fugitive rate of 2.6 per cent. The key factors in the fugitive rate for local transmission and distribution are the pipeline's age and materials. Enbridge and CEPEI assess the pipeline system in Ontario as relatively new and consistent with low fugitive rates. A recent study by University of Toronto[23] confirms local transmission and distribution values in Ontario are equivalent to US cities with low rates. However, the precise value remains unclear.

Considering the available data, TAF has adopted a rate of 0.2 per cent in this guideline. This value remains highly variable because data for local transmission and distribution lack granularity.

## Post metering

There is lack of research about post-metering emissions, but the few studies we have found indicate that leaking is taking place in buildings' pipelines, water heaters[24], gas stoves[25], etc. TAF is adopting a 0.4% leakage rate post metering, acknowledging that significantly more research is needed to obtain a reliable value.

[22] https://www.edf.org/climate/methane-research-series-16-studies

[23] https://pubs.acs.org/doi/10.1021/acs.est.0c05386

[24] https://pubs.acs.org/doi/10.1021/acs.est.9b07189?ref=PDF

[25] https://insideclimatenews.org/news/27012022/gas-stoves-methane-emissions/?utm_source=InsideClimate+News&utm_campaign=c-9f4ae988d-&utm_medium=email&utm_term=0_29c928ffb5-c9f4ae988d-328963926

## Combined LCA Leakage

Taking into account that three quarters of Ontario's natural gas supply comes from the US, the full lifecycle fugitive emissions rate calculated for this guideline is 2.7 per cent. While specific studies guide the estimated fugitive rate, more than 50 values have been reviewed to develop a sensitivity analysis. These values have been obtained with different methodologies, bottom-up and top-down, looking at the full LCA or only a part of the cycle. Some studies advocate for lower emission rates, while others including a comparative study[26] of continental atmospheric methane and fugitive rates from the oil and gas sector advocate for rates above three per cent.

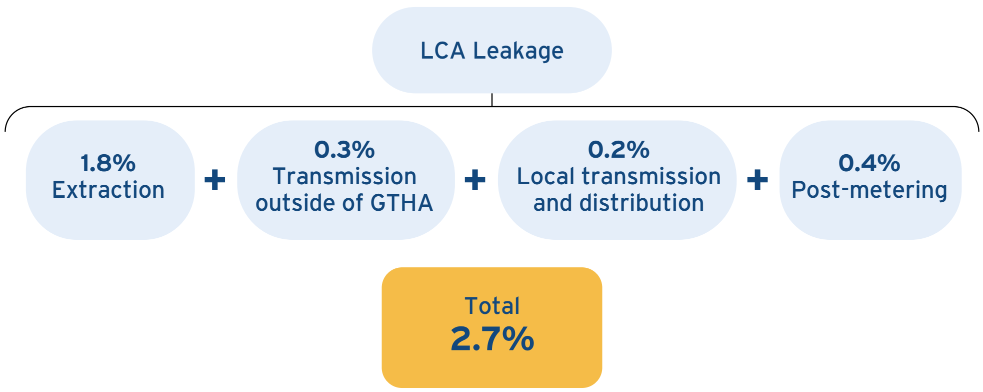



**Figure B2:** Combined LCA leakage in the GTHA

While a number of studies and approaches have been considered, the 2.7 per cent value presented here still carries a significant amount of uncertainty. Work to match bottom-up and top-down measurements are underway, and we anticipate this will lead to a better understanding of quantifying atmospheric methane in the future.

Here is a summary table with the different variables regarding GWP and LCA section in the elaboration of EFs for each of the activities detailed in the guideline:

| | GWP | Extraction | Upstream transmission | Local Transmission & Distribution |
|---|---|---|---|---|
| **Projects without changes to natural gas pipeline infrastructure** | 20 | Included | Not included | Not included |
| **Projects that change natural gas pipeline infrastructure** | 20 | Included | Included | Included |
| **Renewable natural gas projects** | 20 | Included | Included | Detailed analysis required |
| **Emission inventories** | 100 | Optional (Scope 3) | Optional (Scope 3) | Included (Scope 1) |

[26] https://www.nature.com/articles/s41586-020-1991-8