METHODOLOGY FOR 2023 INVENTORY

Use caution when comparing results with other publications

TAF follows the Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories (GPC) guidelines and uses as many primary data sources as possible[1]. However, differences in data sources, availability and methodologies make results difficult to compare to other publications.

TAF's Scope 1, 2 and 3 definitions align with the GPC (see Figure 1). Based on the GPC, Scope 1 carbon emissions result from sources located within a city boundary; Scope 2 are emissions resulting from the use of grid-supplied electricity within a city boundary; and Scope 3 are emissions that occur outside a city boundary as a result of activities taking place within the city boundary.

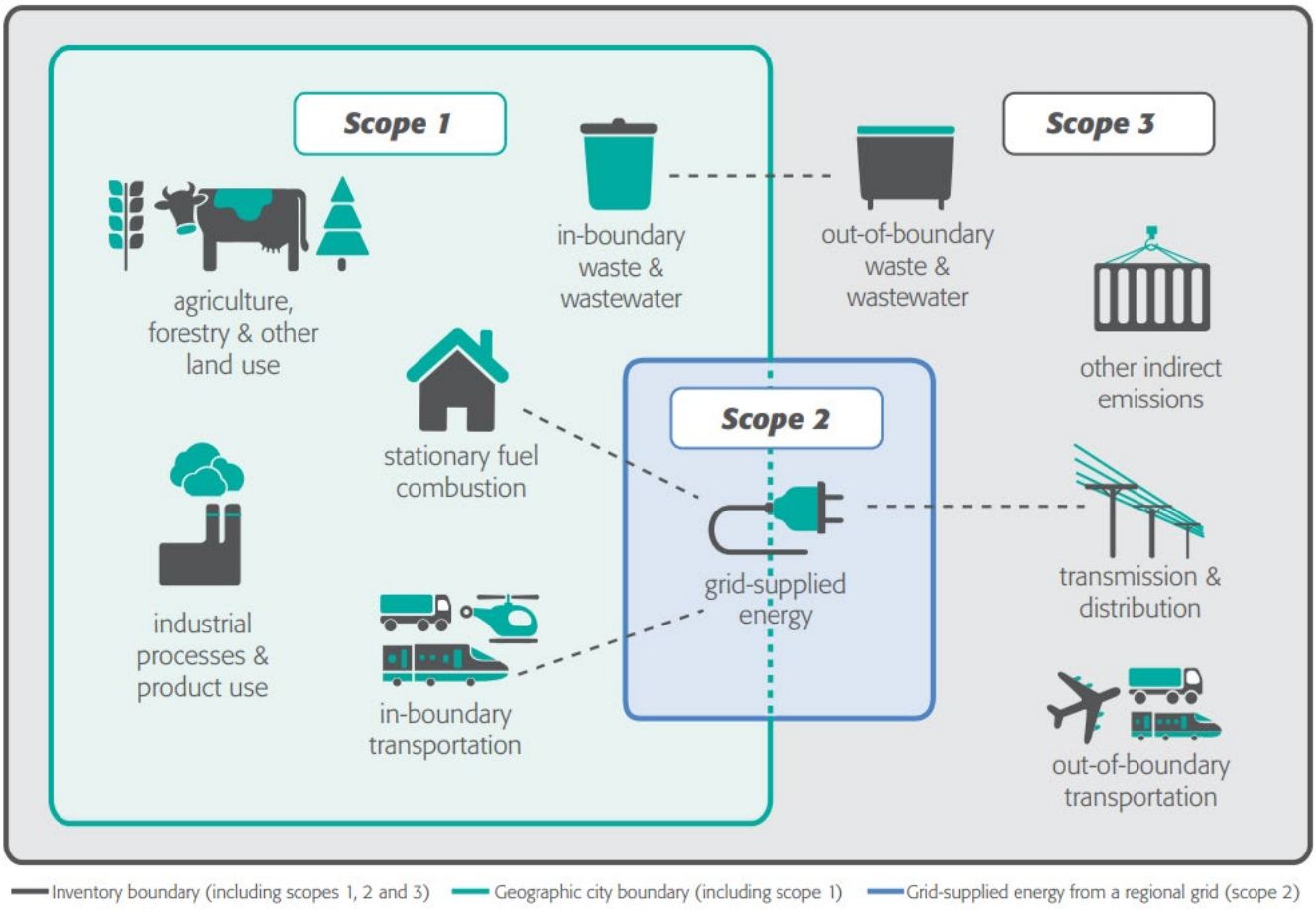

Figure 1: Scope 1, 2, and 3 emissions sources

A list of specific emission sources used in TAF's inventory are shown in Figure 2.

[1] The Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories

Figure 2: Emission sources and supplementary data used in TAF's inventory

Sector	Source
Building	• Natural Gas consumption data from Enbridge • Electricity consumption from local and regional distributors' data • Energy and Water Reporting and Benchmarking data (EWRB) from Ontario's public data catalogue
Transportation	• Gasoline and Diesel fuel sales at the regional level, purchased from an industry-specific consulting firm • Aviation turbo fuel • Passenger movement from StatsCan • EV charging data from the Ministry of Transportation Ontario • Transit data from Transit agencies reports • Active transportation data from Google Environmental Explorer
Industrial	• Industrial emissions from Canada's large emitters database
Waste	• Tonnage of waste data from the Resource Productivity and Recovery Authority • Composition of waste and Methane capture from cities reports • Energy-from-waste facilities reports
Agriculture	• Agricultural activity data from census • Agricultural emissions proportioned from NIR for Ontario

Building Sector

Natural gas and electricity consumption are the main sources of emissions for buildings in the Greater Toronto and Hamilton Area (GTHA). While they technically fall under the umbrella term "Stationary Energy," they are part of the building sector consumption in this inventory. According to Natural Resources Canada's Comprehensive Energy Use Database, 92% of residential, 96% of commercial/institutional, and 57% of industrial energy use comes from these two energy sources in

Ontario[2]. TAF does not account for propane, heating oil, wood, and coal emissions since these are a minimal portion (less than 3%) of emissions in buildings.

TAF sources natural gas data from Enbridge Gas, including residential, commercial and industrial level data. Enbridge Gas data does not include grid-connected gas plants, which are captured under electricity emissions.

Electricity data is obtained from local distribution companies (LDCs) and the Ontario Energy Board's Reporting and Record Keeping Requirements (RRR). The RRR reports electricity distribution by LDC, with some LDCs providing electricity to more than one municipality.

While electricity consumption in this sector can include EV charging, street lighting, or even transit operations, we do not disaggregate those sources due to inconsistencies in available data across the region. Further, we do not consider electricity imports or exports in this inventory. It is worth noting that Ontario exports significantly more electricity than it imports, particularly to jurisdictions with greater emissions intensity, such as New York and Michigan.

We treat gas plants as inputs into the electricity emissions sector and then assign emissions to individual regions based on their consumption (Scope 2). If we treated gas plants as industrial emissions (Scope 1), regional emissions would increase for some regions like Peel and Halton and decrease for the City of Toronto.

We use the latest available natural gas emissions factors from Canada's National Inventory Report (NIR) and apply them to annual natural gas consumption (see Fossil Fuel Emission Factors table in TAF's downloadable data file). The electricity emission factors are estimated using a combination of IESO's electricity generation outputs[3] and NIR's natural gas emission factors.

Starting in 2020, TAF noticed a difference in electricity generated by natural gas combustion reported by IESO and NIR. Table 1 shows the electricity emissions factors from natural gas combustion and the percent difference between the two sources by year. In 2022, IESO reported 40% higher electricity generation by natural gas combustion than NIR, resulting in 32% higher emissions. IESO's generation data are based on settlement purposes, whereas NIR reports data derived from StatsCan's facility owner survey data. In our inventory TAF uses IESO electricity generation data and will continue to monitor differences when the 2023 NIR report is released.

Table 1: Electricity generated by natural gas

	2020	2021	2022
IESO AEF (gCO2eq/kWh)	36	44	51
NIR AEF (gCO2eq/kWh)	33	36	38

[2] Natural Resources Canada - Secondary Energy Use and GHG Emissions by Energy Source

[3] Weather Dashboard for Toronto

Difference (%)	9%	23%	32%

Natural gas consumption is primarily used for space heating and domestic hot water, with the former largely dependent on weather conditions. TAF weather normalizes gas consumption by calculating a normalization factor, which compares a given year's total heating degree days (HDD) against a 30-year average. The HDD is calculated by taking the difference between the average exterior daily temperature and 18°C[3]. Weather normalization also requires estimating the fraction of natural gas used for space heating. To estimate this fraction, we used the share of residential, industrial and commercial natural gas consumption from Enbridge gas utility data and then adopted the proportion of natural gas used in space heating within each sector from the Ontario Energy Board Achievable Potential Study report[4] (see TAF's downloadable data file).

Transportation Sector

TAF calculates transportation emissions using gasoline and diesel fuel sales data from Kalibrate, which captures ~99% of public gas stations in the GTHA. Diesel fuel from bulk contracts and cardlock sales is not included in this dataset, which means that actual diesel emissions are higher than reported. While gasoline sales in the GTHA account for 42% of Ontario's total consumption (an expected value based on population and economic activity), our diesel sales data accounts only for 10% of the province's consumption[5]. To minimize uncertainty in estimates, retail diesel has not been extrapolated, as trends are not typically correlated with retail gasoline consumption. Our transportation emissions data does not account for private sales, railway, or marine.

Ontario's renewable fuel standard requires at least 10% of gasoline sold to be from a renewable source starting in 2020[6] (5% prior to 2020). We assume that 10% of gasoline sales are from ethanol. Also, based on the Cleaner Transportation Fuels regulation, we assume 4% of diesel sales are bio-based with 30% lower emissions[5].

TAF allocates fuel sales occurring within each municipality to that municipality's inventory. An alternative method would be to attribute the emissions to the municipality in which the fuel is consumed. We analyzed the Transportation Tomorrow Survey[7] origin-destination data from 2016[8] to identify the potential difference an alternative methodology might make, but the effect of including the origin-destination variable is negligible.

We use the most up to date NIR gasoline and diesel emission factors to estimate the annual transportation emissions (see TAF's downloadable data file)[9].

In the GTHA, 69% of total transportation emissions are from gasoline passenger cars and trucks, 7% from gasoline commercial vans and pickup trucks, and 9% from light commercial diesel trucks[9]. All of these sources are included in the fuel sales data used in TAF's inventory. Fuel sales data excludes diesel

[4] IESO - 2019 Achievable Potential Study
[5] Statistics Canada - Sales of Fuel Used for Road Motor Vehicles
[6] Government of Ontario - Cleaner Transportation Fuels
[7] University of Toronto Data Management Group - TTS Reports
[8] The latest TTS data was initially scheduled for release in the Fall of 2021. However, due to the COVID-19 pandemic, the release was postponed to 2022. The results for 2022 are not yet publicly available.
[9] Canada - 2022 National Inventory Report

from heavy commercial trucks (12% of total transportation emissions) and transit (3% of total emissions)[10]. To account for heavy commercial trucks and transit, we estimate the total emissions by dividing the fuel sales by 0.85%. The share of heavy trucks and transit are 10% in 2019 (and previous years), 14% in 2020, and 15% in 2021. Since this data is not available for 2022-2023, we assumed the vehicle mix is similar to 2021.

We track transit ridership for various transit authorities in GTHA, including Durham Region Transit (DRT)[11], Burlington Transit[12], Milton Transit[13], Oakville Transit[14], Mississauga Transit (MiWay)[15], Brampton Transit[16], York Region Transit (YRT)[17], Hamilton Street Railway (HSR)[18], TTC[19] and Metrolinx[20,21]. And we also track active transportation data, including cycling and walking, using the Google Environmental Insight Explorer (EIE) data[22].

Aviation Emissions

To estimate aviation emissions for Pearson Airport, we used the most recently available plane fuel consumption (2.74 billion litres, reported in 2016)[23] and the aviation turbo fuel emission factor from the NIR. Using this method, the estimated baseline emissions for 2016 are 7.1 MtCO2eq. We then project the 2017-2023 emissions using StatsCan's annual number of air passengers' traffic[24].

TAF obtains the annual fuel use for Billy Bishop Airport from the City of Toronto and estimates the emissions using the aviation turbo fuel emission factor from the NIR.

Emissions from other GTHA airports (Hamilton International Airport, Buttonville Municipal Airport, and Oshawa Executive Airport) as well as private airports, are not accounted for due to the lack of available data.

While we allocate aviation emissions to the municipality where each airport is physically located, these services benefit the whole GTHA and beyond.

Waste Sector

TAF uses the methane commitment approach, where the lifetime emissions of waste disposed each year are counted in that year, even though emissions will occur over many years[1]. Waste emissions are attributed to the municipality that produced the waste, not where the waste is disposed. Captured and flared methane is considered biogenic methane and is estimated to have net zero emissions. The formulas for this method are based on the GPC protocol.

---

[10] TEPs model - University of Toronto
[11] DRT
[12] Burlington Transit
[13] Milton Transit
[14] Oakville Transit
[15] MiWay
[16] Brampton Transit
[17] YRT
[18] HSR
[19] TTC
[20] Metrolinx
[21] APTA
[22] Google EIE
[23] GTAA Toronto Pearson Master Plan
[24] Air passengers' traffic

The methane commitment method requires two main data sources: waste tonnage disposed of in landfills and the degradable organic carbon (DOC) portion of the waste. TAF sources the residential waste tonnage disposed in landfill data from Resource Productivity & Recovery Authority (RPRA)[25]. Commercial and industrial waste tonnage is extrapolated using Statistics Canada Disposal of Waste by Source Table 38-10-0032-01[26]. The City of Toronto's 2022 data was not included in the RPRA database. Therefore, the ratio of waste emissions changes between 2022 and 2021 was obtained from the City of Toronto's Environment and Climate department to estimate the 2022 emissions. The 2023 waste emissions are extrapolated from 2022 using population growth as a proxy.

TAF uses Table 2 for DOC values calculated using standard factors, waste audits, and composition data for each type of waste. Assumptions are made when 'other' is listed as a category in the waste audit. For the residential sector, TAF uses the waste composition provided by each region to calculate the DOC. Regions' waste composition audit data are only available for collected curbside garbage/black bins and not are necessary the same as the waste composition ends up at landfill. Non-residential waste composition is provided by Torrie Smith Associates and Kelleher Environmental as supplemental data to their report on Greenhouse Gas Emissions and the Ontario Waste Management Industry[27].

Table 2: Waste composition data sources and values

Region/ Source	Sector	Year	Methane Generation Potential (L0) (tCH4 per ton of waste)	Fraction of Landfill Methane Recovery (frec)	Degradable Organic Carbon (DOC)	DOC Category					
						Food (A)	Garden /Plant (B)	Paper (C)	Wood (D)	Textiles (E)	Industrial Waste (F)
Halton	Res	2022	0.032	0.75	0.079	0.24	N/A	0.07	0.00	0.05	0.04
Hamilton	Res	2022	0.020	0.51	0.049	0.16	N/A	0.05	0.00	0.02	N/A
Peel	Res	2022	0.044	0.85	0.111	0.26	0.04	0.13	0.01	0.04	N/A
Toronto	Res	2016	0.071	0.82	0.178	0.26	0.08	0.05	0.15	0.09	0.11
York	Res	2021	0.044	0.75	0.109	0.15	0.02	0.10	0.05	0.09	N/A
Torrie Smith Associate (2017)	Non-Res	2014	0.085	0.75	0.211	0.22	0.02	0.35	0.08	N/A	N/A

To estimate the Methane Generation Potential (L0), we use the DOC along with the fraction of methane in landfill gas (F, 0.5), fraction of DOC that is ultimately degraded (DOCf, 0.6), and Methane Correction Factor (MCF, 1). Then we apply the estimated L0, Fraction of Landfill Methane Recovery (frec), and Oxidation Factor (OX, 0.1) landfill waste tonnage to estimate the landfill's waste emissions.

[25] Resource Productivity & Recovery Authority - Datacall

[26] Statistics Canada - Disposal of Waste, by Source Table 38-10-0032-01

[27] Greenhouse Gas Emissions and the Ontario Waste Management Industry

We assume the efficiency of landfill methane gas recovered is 75% prior to 2021, as suggested by the US Environmental Protection Agency (EPA)[28]. While Canada's NIR[29] estimates a reduction of emission of about 42% from landfill gas recovery, the percentage in the GTHA is presumed to be much higher than that based on the quantity of methane the region's landfills capture. Therefore, the US EPA's value is likely much more representative of GTHA conditions.

In 2021, the City of Toronto and the Regional Municipality of Peel have reported improvement in their methane capture rates to 82% and 85%, respectively. TAF uses these rates for 2021-2023 inventory years.

The GTHA has two energy-from-waste facilities: the Durham York Energy Centre and Peel region's Emerald Energy from Waste Inc. In 2022, 21% of the Durham York Energy Centre's capacity was used to process waste from York Region, while 79% was used to process waste from the Durham region. In 2022, the turbine generated 117,792 MWh of electricity, of which 99,980 MWh were exported to the grid[30]. Emissions from Emerald Energy are included in the industrial sector emissions due to the lack of information on the amount of waste sent to incineration.

We also include CH_4 and N_2O emissions from organic waste treatment, both aerobic and anaerobic. Organic waste data was obtained from the RPRA. The type of organic waste processing is determined by reviewing the waste management plans of each region and directly consulting with municipality waste management departments. The emission factors applied are 4 g CH4/kg waste and 0.3 g N2O/kg waste for aerobic digestion (composting), as well as 1 g CH4/kg waste and 0 g N2O/kg waste for anaerobic digestion.

Residential waste emissions in 2023 are extrapolated from previous year using population growth since the RPRA data was not released in time for TAF's inventory. Recalculations are made in future updates once RPRA data becomes available for a given year.

Agriculture Sector

We estimate agricultural emissions by proportioning Ontario's agricultural emissions reported in the NIR using Statistics Canada's Census of Agriculture. Emissions from livestock and manure management are scaled based on cattle head counts[31], while agriculture soils are scaled based on farmland area[32]. We extrapolated 2022 cattle head counts and farmland area using the change between 2016 and 2021 Census of Agriculture data. We do not include resource inputs like the manufacturing of fertilizer. Additionally, we do not calculate emissions from land use change or forestry activities due to insufficient data.

Since the NIR and Statistics Canada's Census of Agriculture data for 2023 were not released in time for TAF's inventory, we estimated the 2023 agricultural emissions using the same annual change for the GTHA between 2022 and 2021. This method is also well aligned with the change in population

[28] US EPA Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks
[29] Canada - 2022 National Inventory Report
[30] Durham York Energy Centre - 2022 Annual Report
[31] Cattle inventory on farms, Census of Agriculture, 2021
[32] Land use, Census of Agriculture, 2021

growth between 2022 and 2023. To estimate city-level emissions, the Census farm area and livestock data from StatsCan[33,34] was utilized to prorate the region's emissions to the city level.

Industrial Sector

Historic emissions are taken from Canada's 2022 Greenhouse Gas Reporting Program (GHGRP), which includes large emitters (>10,000 tCO_2eq/year) and some smaller emitters that may voluntarily report[35]. The 2023 database was not released in time for TAF's inventory, so emissions were projected using proxies related to Ontario cement manufacturing jobs and total manufacturing jobs, as well as GTHA steel production estimates provided by Climate Trace. Industrial emissions will be updated as primary source data becomes available.

We also include carbon dioxide (CO_2) and nitrous oxide (N_2O) from wastewater treatment plants. Methane (CH_4) from wastewater treatment is not included, as it is biogenic and assumed to be either flared or used to offset the natural gas consumed in industrial plants.

Double Counting

Industrial emissions come from two main sources: a) stationary fuel combustion supplying energy to industrial activities and b) process emissions, in other words, industrial processes that chemically or physically transform materials. Industrial facilities are required to report their stationary fuel combustion as part of their process emissions if the sum of emissions from the combustion of one or more fuels exceed 0.5% of the total facility emissions[36,37]. Since GHGRP facility-level emissions data are aggregated, it is not possible to separate the process emissions, which make up 57% of Ontario's industrial emissions. Further, a large portion of these process emissions are suspected to be from natural gas. Given these challenges, there is a risk of double counting natural gas and electricity consumption from utility data (reported under the building sector) and from the large emitters' database (reported under the industrial sector).

We have taken steps to address these double counting issues. TAF assumes the emissions from power generating facilities are already included in the electricity grid emissions, and combined heat and power plants and steam plants emissions are captured by natural gas consumption data under the building sector. After excluding these double counting sources from our industrial emission estimates, the remaining double counting stems from stationary combustion emissions reported under GHGRP reporting along with the process emissions.

TAF verified which facilities report their combusted fuels to GHGRP's large emitters database. We then reviewed the NIR's fuel consumption emissions of Ontario's manufacturing and industrial process and compared that to the reported Ontario emissions in the large emitters database. Any discrepancies are associated with the fuel combustion.

Cement, lime, mineral use (i.e., glass production) and steel facilities emissions are the main contributors to Ontario's process emissions reported in the NIR report. They make up around 78% of total industrial emissions in the GTHA when accounting for both fuel combustion and process

[33] Land tenure, Census of Agriculture, 2021
[34] Cattle inventory on farms, Census of Agriculture, 2021
[35] Greenhouse Gas Reporting Program (GHGRP) - Facility Greenhouse Gas (GHG) Data
[36] Ontario Guideline for Quantification, Reporting and Verification of Greenhouse Gas Emissions
[37] Canada's Greenhouse Gas Quantification Requirements

emissions. We compared the NIR's fuel consumption emissions of Ontario's manufacturing + industrial process to the emissions in the large emitters database to estimate the fuel combustion emissions. Using these fuel combustion emissions, we estimated the specific cement, lime, mineral, and steel manufacturing fuel combustion emissions at 44%, 32%, 70%, and 38% of their total GHGRP reported emissions, respectively. The remaining portions are associated with process emissions for each industry. All other manufacturing facilities (with less contribution to GTHA industrial emissions) are assumed to have 100% fuel combustion emissions, as no process emissions are associated with those manufacturing production categories.

Since the facility-level energy consumption data is not available to estimate each facility's natural gas and electricity portion of total fuel combustion emissions, we adopted the average energy fuel consumption data per fuel type and industry class from Stats Canada[38]. Using this data, we calculated each industry's combusted fuel emissions (per fuel type) and estimated the contribution of natural gas and electricity to the total emissions.

We then estimated the double counted natural gas and electricity emissions for each facility using the below equation:

E= A x B x (C + D)
E: Facility's natural gas and electricity emissions
A: Total facility's GHGRP's reported emission
B: Fuel combustion emissions portion (44% for cement, 32% for lime, 70% for mineral use, 38% for steel, and 100% for other manufacturing facilities)
C: The natural gas percentage of total fuel combustion emissions
D: The electricity percentage of total fuel combustion emissions

After we estimated each manufacturing facility's natural gas and electricity emissions, we subtracted these double counted values from each facility's reported GHGRP data. What remains reflect the facility's process emission and all other combusted fuels emissions *except for* natural gas and electricity emissions which are reported under industrial emissions in TAF's inventory.

RECALCULATION

Any methodology or data set updates in the current reporting year have been applied to previous years to ensure consistency and allow for meaningful comparisons between years. The recalculated values are provided in the downloadable data file.

[38] Manufacturing industries, annual energy fuel consumption