2021 GTHA Carbon Emissions Inventory
Behind the Report

APPENDIX A – METHODOLOGY

Use caution when comparing results with other publications
TAF follows the guidelines in the Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories 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.

Figure 1: Definition of scope 1, 2, and 3 emissions sources

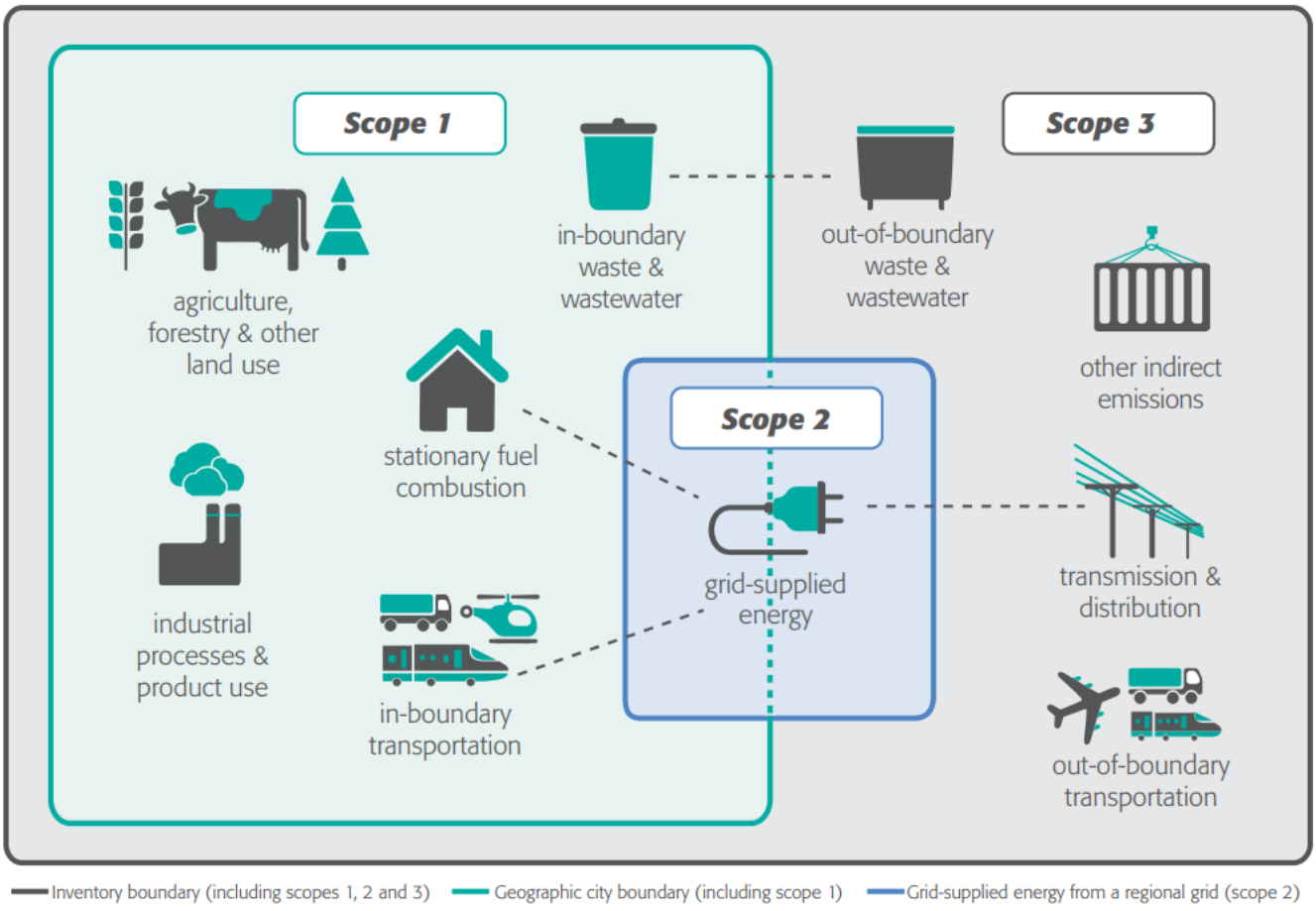
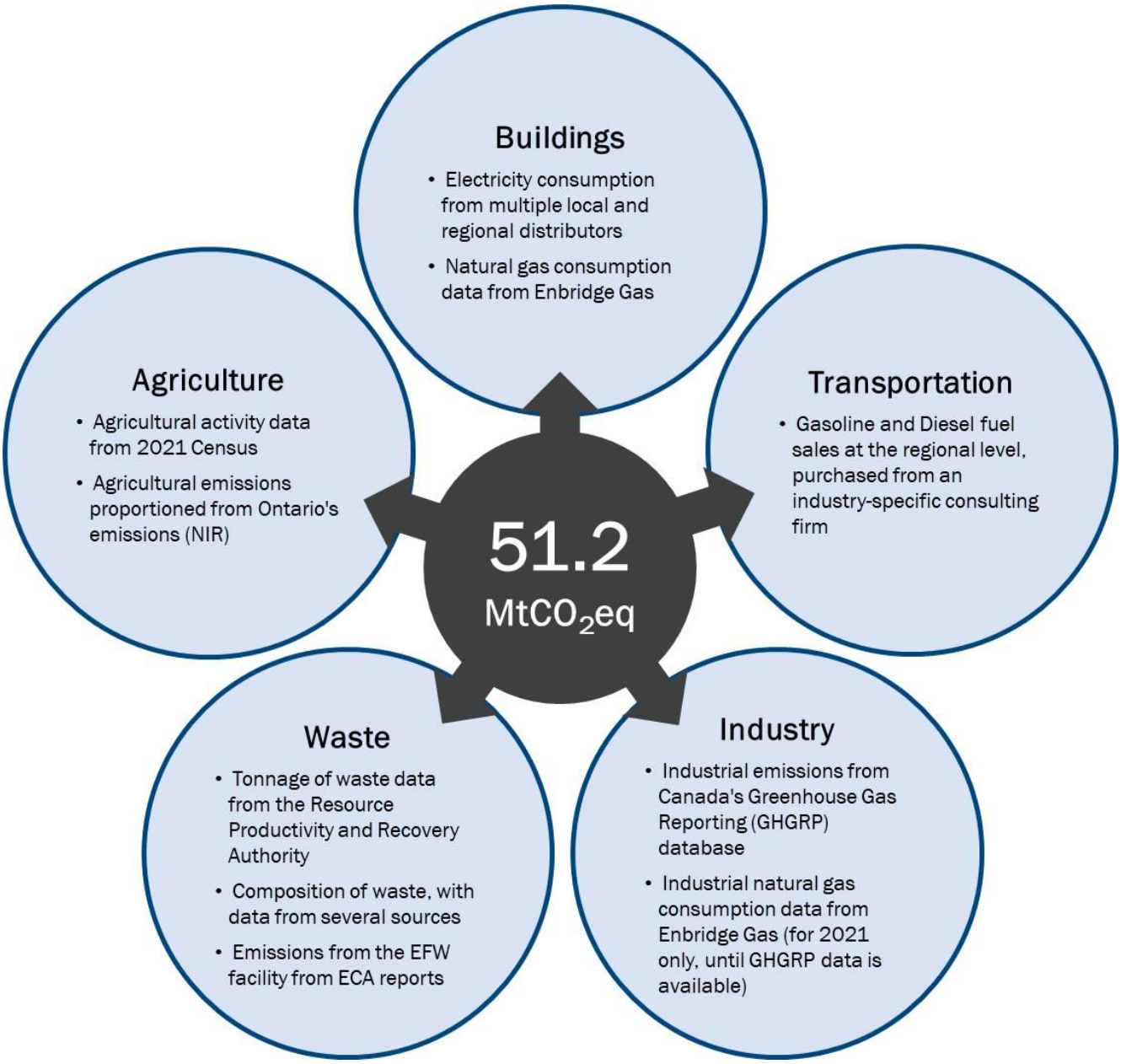


Figure 2: Overview of data sources of emissions used to compile the 2021 inventory



Building Sector

Natural gas and electricity consumption are the main sources of emissions for buildings in the 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 of building emissions.

TAF sources natural gas data from Enbridge Gas and electricity data 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 used the latest available natural gas emissions factor from Canada's National Inventory Report (NIR) and applied it to 2021 natural gas consumption (Table A1). The 2021 electricity emission factor was estimated using a combination of IESO's electricity generation outputs[3] and NIR's natural gas emission factors. For consistency in the comparisons, electricity emissions factors are recalculated for 2015-2020 (Table A1).

Table A1: Natural gas and electricity emission factors, 2015-2021

Year	Natural Gas (kgCO2eq/m3), NIR	Natural Gas LCA* (kgCO2eq/m3), TAF	Electricity (gCO2eq/kWh), TAF	Electricity LCA* Multiplier, TAF
2015	1.911	2.461	44.86	1.381
2016	1.915	2.465	40.40	1.376
2017	1.916	2.466	18.56	1.385
2018	1.921	2.471	29.46	1.386
2019	1.921	2.471	29.43	1.388
2020	1.921	2.471	30.65	1.389
2021	1.921	2.471	39.27	1.392

Transportation Sector

TAF calculates transportation emissions using gasoline and diesel fuel sales data from Kent Group Limited, 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[4]. To minimize uncertainty in estimates, retail diesel has not been extrapolated as trends are not typically correlated with retail gasoline. Our transportation emissions data does not account for private sales, railway, marine, transit, or local aviation emissions.

Ontario's renewable fuel standard requires at least 10% of gasoline sold to be from a renewable source starting in 2020[5] (was 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.[6]

We allocate 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 to identify the potential difference an alternative methodology might make, but the effect of including the origin-destination variable is negligible.

Table A2 shows 2021 gasoline and diesel emissions, by municipality. We use the 2020 National Inventory Report's gasoline and diesel emission factors to estimate the 2021 transportation emissions[8].

Table A2: Transportation fuel emissions by fuel and region, 2021

Year	Region	Gasoline Emissions (tCO_2eq)	Diesel Emissions (tCO_2eq)	Total Fuel Emissions (tCO_2eq)
2021	Durham Region	1,500,283	138,213	1,638,496
2021	Halton Region	1,163,313	136,803	1,300,116
2021	Hamilton	1,181,523	120,562	1,302,085
2021	Peel Region	2,964,692	319,779	3,284,472
2021	Toronto	3,434,845	312,813	3,747,658
2021	York Region	2,816,205	314,937	3,131,141
2021	**GTHA Total**	**13,060,861**	**1,343,108**	**14,403,969**

Fuel sales data accounts for 90% of total transportation emissions in the GTHA, including gasoline passenger cars and trucks, gasoline commercial vans, pickup trucks, and commercial diesel trucks. It excludes diesel from heavy commercial trucks which account for 7% of total transportation emissions prior to 2020 and 11% in 2020 (the remainder is from transit emissions)[9]. To account for heavy commercial trucks, we multiplied fuel sales emissions by 1.08 for 2015-2019 and by 1.13 in 2020. Since the vehicle mix information was not available for 2021 at the time of this analysis, we assumed that it has partially bounced back to pre-pandemic levels. The resulting multiplier for 2021 is 1.11, calculated as a weighted average of 2020 (75%) and pre-2020 (25%) fuel sale emissions.

Waste Sector

TAF uses the methane commitment approach, where the lifetime emissions of waste disposed in a given year is counted in that year, even though emissions will occur over many[10]. 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 Greenhouse Gas Protocol for Community-Scale Emissions Inventories.

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. Residential waste tonnage in 2021 is extrapolated from previous years using population growth since Resource Productivity & Recovery Authority (RPRA)[11] data was unavailable at the time of writing. Recalculations will be made in future updates once RPRA data becomes available. Commercial and industrial waste tonnage is extrapolated using Statistics Canada Disposal of Waste by Source Table 38-10-0032-01[12].

TAF uses the following table 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.

Table A3: Waste composition, assumptions, and data sources

Source / Report	Sector	Methane Generation Potential (L_0) (tCH_4 per ton of waste)	DOC	Degradable Organic Content (DOC) Category					
				Food (A)	Garden/ Plant (B)	Paper (C)	Wood (D)	Textiles (E)	Industrial Waste (F)
Toronto Environmental Alliance (Toronto Environmental Alliance, 2016)	Single Family	0.054	0.1619	0.41	N/A	0.20	N/A	0.06	0.04
Toronto Environmental Alliance (Toronto Environmental Alliance, 2016)	Multi-family	0.064	0.1926	0.54	N/A	0.24	N/A	0.04	0.04
Torrie Smith Associates (2017)	Non-residential	0.07	0.2114	0.22	0.02	0.35	0.08	N/A	N/A

For the residential sector, TAF uses the waste composition provided by the Toronto Environmental Alliance to calculate the DOC. The single-family and multi-family compositions were weighted based on the proportion of each building type in the GTHA to create a single DOC value.

The 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[13].

We assume the efficiency of landfill gas recovered is 75%, as suggested by the US EPA (United States Environmental Protection Agency)[14]. Canada's National Inventory report[15] estimates a reduction of emission of about 37% from landfill gas recovery, but the percentage in the GTHA is presumed to be much higher than that based on the quantity of methane the region's landfills capture, hence our use of the US EPA's value. OX, F, DOC_f, and MF values use the appropriately recommended values of 0.1, 0.5, 0.6, and 1, respectively[16].

The GTHA has two energy-from-waste facilities, the Durham York Energy Centre and Peel region's Emerald Energy from Waste Inc. In 2020, 22% of the Durham York Energy Centre's capacity was used to process waste from York Region, while 78% was used to process waste from Durham region. The same proportions were used to project the 2021 emissions. In 2020, the Durham York Energy Centre generated 125,819 MWh of electricity, of which 107,243 MWh was exported to the grid[17]. In 2021, the turbine generated 122,250 MWh of electricity, of which 104,520 MWh were exported to the grid[18]. 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[19]. 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 N20 /kg waste for aerobic digestion (composting), as well as 1 g CH4/kg waste and 0 g N20/kg waste for anaerobic digestion.

Agriculture Sector

We calculated emissions by proportioning Ontario's agricultural emissions in Canada's National Inventory Report based on Statistics Canada's Census of Agriculture. Emissions from livestock and manure management are scaled based on cattle head counts[20], while agriculture soils are scaled based on farmland area[21]. 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.

Industrial Sector

Historic emissions are taken from Canada's 2020 Greenhouse Gas Reporting Program (GHGRP), which includes large emitters (>10,000 tCO_2eq/year) and some smaller emitters that may voluntarily report[22]. The 2021 database was unavailable at the time of writing this inventory, so emissions were estimated based on the change in industrial natural gas consumption in each region. The GTHA industrial emissions will be updated as primary source data becomes available.

We have expanded the scope of reported industrial emissions to include CO_2 and N_2O from wastewater treatment plants. While CH_4 from wastewater treatment is not included, it is biogenic and assumed to be either flared or used to offset the natural gas consumed in industrial plants.

TAF assumes the emissions from power generating facilities are already included in the electricity grid emissions, and combined heat and power plants emissions are captured by natural gas consumption data. While the remaining emissions should be from industrial processes, some natural gas emissions may be double counted as GHGRP data does not disaggregate the sources of emissions.

APPENDIX B – RECALCULATION

Any methodology or data set updates in 2021 have been applied to previous years (2015-2020) to ensure consistency and make meaningful comparisons between years.

Table A4: Recalculated emissions, 2015-2020

Sector	2015 Emissions (tCO_2eq)	2016 Emissions (tCO_2eq)	2017 Emissions (tCO_2eq)	2018 Emissions (tCO_2eq)	2019 Emissions (tCO_2eq)	2020 Emissions (tCO_2eq)
Natural Gas	21,182,462	19,417,274	20,044,472	22,219,797	22,070,625	19,971,315
Electricity	2,631,094	2,398,627	1,058,311	1,769,156	1,726,481	1,773,537
Transportation	17,233,120	17,568,263	18,891,421	19,038,781	19,219,755	15,682,971
Waste	1,876,358	1,768,428	1,762,405	1,810,852	1,806,257	1,870,101
Industrial	10,225,461	10,603,495	10,744,474	10,566,942	10,356,934	9,205,927
Agriculture	413,376	418,512	415,852	407,587	416,880	465,221
Total	**53,561,871**	**52,174,598**	**52,916,935**	**55,813,115**	**55,596,932**	**48,969,071**

Table A5: Recalculated emissions – change from 2020 inventory, 2015-2020

Sector	2015	2016	2017	2018	2019	2020
Natural Gas	0.6%	0.8%	1.5%	1.7%	1.7%	2.2%
Electricity	3.5%	-0.8%	-7.6%	-1.5%	-1.6%	-1.1%
Transportation	-5.1%	-5.1%	0.0%	0.0%	0.0%	2.8%
Waste	0.0%	0.0%	0.0%	0.0%	0.0%	1.6%
Industrial	0.3%	0.6%	0.4%	0.8%	0.3%	2.6%
Agriculture	-10.6%	-10.8%	-10.7%	-10.6%	-3.2%	10.2%
Total	**-1.3%**	**-1.5%**	**0.4%**	**0.7%**	**0.7%**	**2.4%**

APPENDIX C – WEATHER NORMALIZATION

Natural gas consumption is very sensitive to weather conditions as it is commonly used for space and water heating in the residential and commercial sectors. We weather normalize gas consumption by calculating a normalization factor which compares a given year's total heating degree days (HDD) against a 30-year average. An HDD is calculated by taking the difference between the average exterior daily temperature and 18°C[3]. All HDDs each year are then added together.

Table A6: Heating degree days, 2015-2021

Year	Heating Degree Days (at 18ºC)
1981 - 2010, Average	**3,498**
2015	3,769
2016	3,464
2017	3,518
2018	3,765
2019	3,929
2020	3,516
2021	3,340

Table A7: Change in heating degree days, 2015 and 2021

Year	Change in HDD
2015 - 2016	-8.1%
2016 - 2017	1.6%
2017 - 2018	7.0%
2018 - 2019	4.4%
2019 - 2020	-10.5%
2020 - 2021	-5.0%

Weather normalization also requires estimating the fraction of natural gas used for heating. A report from the Ontario Energy Board and IESO[23] provides the following values.

Table A8: Proportion of natural gas used for heating, by building type

Building Type	Percentage of Natural Gas
Residential	74%
Commercial	79%
Industrial	20%

To estimate the fraction of natural gas used for heating in each region, we applied the proportion of residential, industrial, and commercial natural gas consumption obtained from Enbridge gas utility data.

Table A9: Natural gas used for space heating, by building type and region

Region	Natural Gas Use			Average use for space heating
	Residential	Commercial	Industrial	
City of Toronto	57.8%	30.7%	11.5%	69.3%
Peel Region	46.0%	26.9%	27.2%	60.7%
York Region	63.7%	28.6%	7.7%	71.3%
Durham Region	59.3%	21.4%	19.3%	64.7%
City of Hamilton	25.0%	20.0%	55.0%	45.3%
Halton Region (Burlington)	34.0%	19.0%	46.0%	49.4%
GTHA Average	**47.6%**	**24.4%**	**27.8%**	**60.1%**

The fraction of natural gas use that is weather normalized corresponds to the average proportion of natural gas used for space heating. This fraction is divided by the yearly HDD and multiplied by the 30-year average. Depending on the weather, normalization can have a significant effect on emissions.

Table A10: Natural gas emissions by region, 2017-2021 (unadjusted)

Region	2017	2018	2019	2020	2021
City of Toronto	7,430,819	8,203,160	8,204,436	7,449,307	7,328,794
Peel Region	3,910,621	4,318,549	4,302,338	3,913,423	3,949,421
York Region	2,696,988	3,046,444	3,077,540	2,778,338	2,729,991
Durham Region	1,581,744	1,760,847	1,681,194	1,437,608	1,452,021
City of Hamilton	2,580,437	2,784,428	2,810,251	2,636,956	2,723,713
Halton Region	1,843,862	2,106,370	1,994,866	1,755,683	2,119,826
GTHA Total	**20,044,472**	**22,219,797**	**22,070,625**	**19,971,315**	**20,303,766**

Table A11: Natural gas emissions by region, 2017-2021 (weather normalized)

Region	2017	2018	2019	2020	2021
City of Toronto	7,401,835	7,800,302	7,580,999	7,423,171	7,569,364
Peel Region	3,897,266	4,132,863	4,016,105	3,901,402	4,062,926
York Region	2,686,169	2,892,568	2,837,020	2,768,312	2,822,158
Durham Region	1,575,989	1,680,175	1,562,017	1,432,902	1,496,486
City of Hamilton	2,573,858	2,695,045	2,670,666	2,630,909	2,782,154
Halton Region	1,838,739	2,032,678	1,886,880	1,751,295	2,169,397
GTHA Total	**19,973,856**	**21,233,630**	**20,553,687**	**19,907,991**	**20,902,485**

Weather normalization alters the quantity by which natural gas emissions increased or decreased per capita.

Table A12: Change in natural gas emissions by region, 2017-2021 (unadjusted)

Region	2017 - 2018	2018 - 2019	2019 - 2020	2020 - 2021
City of Toronto	9.9%	-0.4%	-9.6%	-2.1%
Peel Region	9.3%	-1.3%	-9.9%	0.0%
York Region	11.7%	-0.1%	-10.7%	-2.8%
Durham Region	9.6%	-6.0%	-15.8%	-0.5%
City of Hamilton	6.6%	-0.2%	-7.2%	2.1%
Halton Region	12.3%	-6.9%	-13.4%	18.8%
GTHA Total	**9.8%**	**-1.6%**	**-10.3%**	**0.8%**

Table A13: Change in natural gas emissions, by region 2017-2021 (weather normalized)

Region	2017 - 2018	2018 - 2019	2019 - 2020	2020 - 2021
City of Toronto	4.9%	-3.3%	-2.5%	1.5%
Peel Region	5.0%	-3.8%	-3.8%	3.1%
York Region	6.5%	-3.0%	-3.5%	0.8%
Durham Region	5.0%	-8.4%	-9.6%	2.9%
City of Hamilton	3.5%	-2.1%	-2.6%	4.5%
Halton Region	8.7%	-8.7%	-8.7%	21.9%
GTHA Total	**5.3%**	**-4.1%**	**-4.0%**	**4.1%**

APPENDIX D – RESULTS

Table 1: Total emissions by sector, 2021

Sector	Total Emissions (tCO_2eq)
Natural Gas	20,303,766
Electricity	2,273,221
Transportation	16,048,692
Waste	1,887,568
Industrial	10,208,641
Agriculture	459,978
Total	**51,181,867**

Table 2: Total emissions by region, 2021

Region	Total Emissions (tCO_2eq)
City of Toronto	13,536,613
Peel Region	10,502,744
York Region	6,894,745
Durham Region	5,726,731
City of Hamilton	10,246,134
Halton Region	4,274,900
GTHA Total	**51,181,867**

Table 3: Total emissions per capita by region, 2021

Region	Total Emissions per Capita (tCO_2eq)
City of Toronto	4.84
Peel Region	7.24
York Region	5.88
Durham Region	8.22
City of Hamilton	18.00
Halton Region	7.16
GTHA Total	**7.03**

Total primary and LCA emissions in 2021, by sector and region, are detailed in the downloadable data tables for this report.

REFERENCES

[1] The Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories
[2] Natural Resources Canada - Secondary Energy Use and GHG Emissions by Energy Source
[3] IESO - Generator Output Fuel Type Monthly Report
[4] Statistics Canada - Sales of Fuel Used for Road Motor Vehicles
[5] Government of Ontario - Cleaner Transportation Fuels
[6] Government of Ontario – Greener diesel regulation
[7] University of Toronto Data Management Group - TTS Reports
[8] Canada - 2021 National Inventory Report
[9] TEPs model - University of Toronto
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[11] Resource Productivity & Recovery Authority - Datacall
[12] Statistics Canada - Disposal of Waste, by Source Table 38-10-0032-01
[13] Greenhouse Gas Emissions and the Ontario Waste Management Industry
[14] US EPA Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks
[15] Canada National Pollutant Inventory Submissions 2021
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[20] Cattle inventory on farms, Census of Agriculture, 2021
[21] Land use, Census of Agriculture, 2021
[22] Greenhouse Gas Reporting Program (GHGRP) - Facility Greenhouse Gas (GHG) Data
[23] IESO - 2019 Achievable Potential Study