City of Toronto

2019 Community-Wide Consumption-Based Emissions Inventory Report

July 2023

TORONTO

EcoDataLab

Table of Contents

Cover image courtesy of Andre Furtado on Pexels.com

Table of Figures

Table of Tables

Glossary

Activity data	Activity data refers to the data associated with an activity that leads to GHG emissions. In this report, activity data includes household expenditures and energy use.
Baseline	The reference year against which annual emissions reductions/increases are measured over time.
Consumption category	In the community-wide CBEI, emissions are categorized into five consumption categories: transportation, housing, food, goods, and services.
Consumption-based emissions inventory (CBEI)	A consumption-based emissions inventory (CBEI) is a calculation of all GHGs associated with producing, transporting, and using products and services consumed by a particular community or entity in a given time (typically one year).
Carbon dioxide equivalent (CO_2e)	A unit that allows emissions of various greenhouse gases (such as carbon dioxide [CO_2], methane [CH_4], and nitrous oxide [N_2O]) to be expressed as a single unit of measurement.
Direct emissions	Emissions from sources that are directly owned or controlled by residents, such as fuel combustion in a furnace or vehicle.
Embodied emissions	Emissions associated with the production, manufacturing, and transportation of a good or service, including raw materials extraction, processing, manufacturing, transportation, and disposal.
Emissions	Refers to greenhouse gas emissions (see *GHG*)
Emission factor	An emission factor is a measure of the mass of GHG emissions (typically in CO_2e) relative to a unit of activity.
Global Warming Potential (GWP)	A measurement of how much a particular GHG contributes to global warming relative to carbon dioxide (CO_2). It is used to convert tonnes of a GHG to the equivalent tonnes of carbon dioxide (CO_2e) to express total emissions using a common unit.
Goods and services	The phrase “goods and services” refers to everything exchanged in the economy. This is distinct from either the “goods” or “services” categories of consumption, which refer specifically to a limited set of goods or

	services, respectively, which are not included in the other categories of transportation, housing, or food.
Greenhouse Gases (GHGs)	Compound gases that trap heat and emit longwave radiation in the atmosphere causing the greenhouse effect.
Indirect emissions	Emissions that are the result of activities from assets not owned or controlled by households, but that are indirectly affected by household activities, such as fuel combustion in a power plant to provide electricity to household, or emissions from fertilizer production used to grow food eaten by households.
Lifecycle emissions	Emissions associated with the full life of a good or service, including material extraction, processing, production, transport, sale, use, and disposal.
Megatonnes (Mt)	A megatonne, abbreviated as Mt, is a metric unit equivalent to one million (10^6) tonnes.
Net Zero emissions	Net zero emissions occurs when the amount of greenhouse gases released into the atmosphere and amount removed from the atmosphere are equal.
Sector-based emissions inventory (SBEI)	Toronto's sector-based emissions inventory measures GHGs attributable to emissions-generating activities taking place within the geographic boundary of the city, as well as some indirect emissions from waste produced in the city, and the transmission of electricity into the city in a given time period (typically one year).
Sub-category	Each CBEI emissions category consists of multiple sub-categories.
Tonne (t)	One metric tonne (1,000 kilograms)
Upstream emissions	Emissions associated with the production, transport, and sale of goods or services, prior to purchase by the ultimate consumer.
Use phase emissions	The burning of fossil fuels (such as gasoline or natural gas) for transportation or home heating energy.
Vehicle fuel economy	The fuel required (in litres) to travel a given distance (100 kilometres).
VKT	Vehicle kilometers travelled.

Executive Summary

This summary provides an overview of the City of Toronto's first community-wide consumption-based emissions inventory. In 2019, Toronto's community-wide consumption-based emissions were roughly 39 megatonnes (Mt) of carbon dioxide equivalent (CO_2e). With 1,141,709 households in the city, this is roughly 34 tonnes of CO_2e (tCO_2e) per-household, or about 14 tCO_2e per-person. In contrast, the Canadian average was estimated at about 37 tCO_2e per-household.

These consumption-based emissions are estimates of the greenhouse gas (GHG) emissions attributable to all consumption by Toronto residents. Consumption-based emissions can occur anywhere in the world, and include both direct and indirect emissions resulting from consumption by residents of the city. By contrast, Toronto's sector-based emissions inventory looks at emissions that occur physically within city limits, or as a direct result of local activity (such as electricity use or waste generation). In 2019, Toronto's sector-based emissions were 15.6 $MtCO_2e$, roughly 40 per cent of the consumption-based emissions.

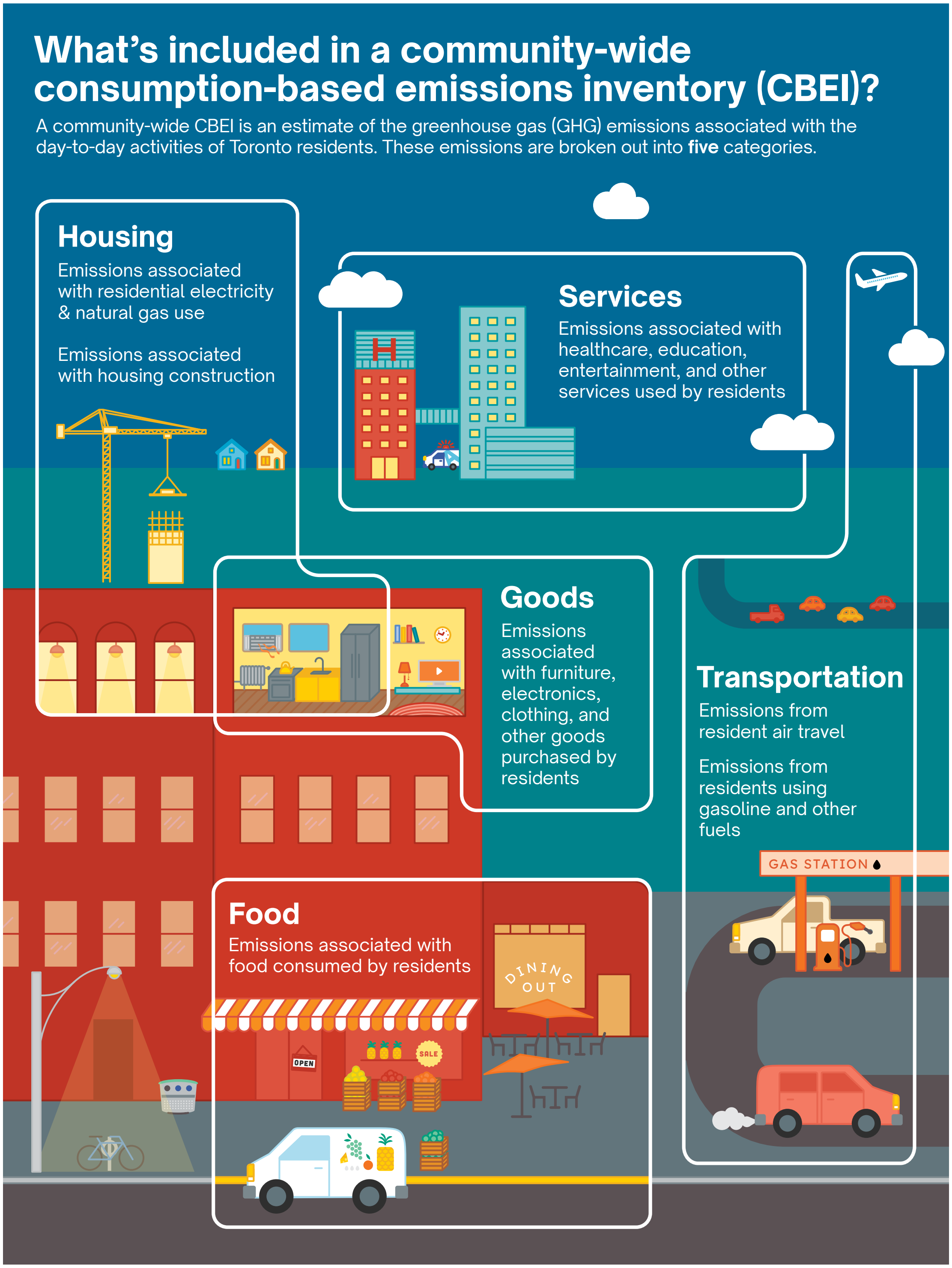
Toronto's consumption-based emissions are broken down into five categories: food (24 per cent), transportation (23 per cent), services (22 per cent), housing (19 per cent), and goods (12 per cent). Within these five categories, the sub-categories of natural gas (15 per cent), gasoline (15 per cent), healthcare (14 per cent), eating out (six per cent), and meat and dairy (a combined eight per cent) were among the largest, comprising 58 per cent of total consumption-based emissions.

The City of Toronto's existing TransformTO Net Zero Strategy, Net Zero Existing Buildings Strategy, Electric Vehicle Strategy, Cycling Network Plan, and Toronto Green Standard v4 are likely to achieve at least a 30 per cent reduction in consumption-based emissions by 2040, based upon full, on-time implementation. With additional efforts to reduce emissions from meat consumption and air travel, as well as supporting more local production and consumption, consumption-based emissions could potentially be reduced by as much as 50 per cent by 2040.

Introduction

A community-wide consumption-based emissions inventory (CBEI) is an estimate of the greenhouse gas (GHG) emissions associated with the activity of all residents of a geographic area, such as the city of Toronto. It is similar to a personal household carbon footprint estimate, except it is calculated for all households in a jurisdiction. Consumption-based emissions can occur anywhere in the world, and include both direct and indirect emissions resulting from consumption by residents of the city, as shown in Figure 1.

Figure 1. What's included in a community-wide CBEI?



Consumption-based emissions are modeled based on local variables, such as income and vehicle ownership, which are used to estimate consumer spending and energy usage[1]. These estimates of consumer spending are then linked with corresponding GHG emission factors to estimate consumption-based emissions. A CBEI includes emissions associated with businesses, but only to the extent that those businesses are providing goods or services to residents (and are as such captured in household spending).

A CBEI provides a new perspective on local GHG emissions, and for many cities captures a broader range of emissions than a sector-based emissions inventory (SBEI). Community-wide CBEIs measure GHGs attributable to all household consumption, across five categories of transportation, housing, food, goods, and services. Under a CBEI approach, all global GHG emissions are allocated to final demand (i.e., households and government activities). The community-wide CBEI accounts for the full lifecycle emissions of all goods and services consumed by residents.

While emissions from waste are not directly analyzed in this report, the use of recycled materials in production of new products is factored into the emissions associated with the production of those goods. In addition, with modern waste diversion programs and landfill gas capture systems, the net lifecycle effect of waste disposal and diversion (when accounting for avoided emissions and carbon sequestration) is close to or below zero. For example, the U.S. Environmental Protection Agency (EPA) estimates that the GHG emissions from materials sent to landfill is negative for items such as newspapers, yard trimmings, lumber, and PLA (a type of plastic), as well as for food scraps sent to compost. (Negative emissions means that more CO_2 is stored than emitted from the process of disposing it). A recent CBEI analysis for King County, WA used the U.S. EPA’s Waste Reduction Model (WARM) to estimate emissions from household waste and found that overall emissions were -0.06 tCO2e per household per year[2], with a total diversion rate of roughly 50.5 per cent.

---

[1] In the Toronto community-wide CBEI, residential electricity and natural gas emissions is based on direct utility data. However, household gasoline usage is still a modeled estimate.

[2] King County CBEI, https://your.kingcounty.gov/dnrp/climate/documents/2022/king-county-consumption-ghg-emissions-inventory-and-wedge-report-09-2022.pdf

Meanwhile, as of 2022, Toronto had a combined residential diversion rate of 52.5 per cent[3], among the highest levels in North America[4]. As a result, while a similar analysis was not conducted in this study, Toronto's greater levels of residential diversion are likely to also result in roughly zero or negative consumption-based emissions associated with waste.

In contrast to the CBEI, an SBEI measures only GHGs attributable to emissions-generating activities taking place within the geographic boundary of the city, as well as some indirect emissions from waste produced in the city, and transmission of electricity into the city boundary in a given time period (typically one year)[5].

Tracking consumption-based emissions over time provides unique opportunities to develop targets, policies, and programs that can help shift Toronto residents towards more responsible production and consumption. These opportunities will go beyond existing opportunities and strategies identified through the SBEI.

This community CBEI report serves as a baseline CBEI study focusing on the calendar year 2019, based upon the best currently available data for Toronto. This report includes an assessment of Toronto's consumption-based emissions, including high-level policy and program recommendations and an evaluation of existing and potential policies to reduce emissions in specific consumption categories of interest at the community level. In addition to this community-wide CBEI report, the City of Toronto is also preparing a corporate CBEI and a specialized Buildings & Infrastructure Emissions Analysis, to comprehensively review consumption-based emissions from City government operations, and from the construction and maintenance of buildings and linear infrastructure.

The appendices to this report include additional information on the methodology used to develop the inventory, as well as opportunities for action by individual Toronto residents to reduce emissions. As CBEIs evolve, future iterations of the

---

[3] City of Toronto, Solid Waste Reports & Diversion Reports https://www.toronto.ca/services-payments/recycling-organics-garbage/solid-waste-reports/
[4] Data for other cities from WasteDive, https://www.wastedive.com/news/zero-waste-cities-us-goal-tracker/635401/
[5] City of Toronto 2020 Sector-Based Greenhouse Gas Emissions Inventory : https://www.toronto.ca/wp-content/uploads/2023/01/8e55-2020-Sector-based-Greenhouse-Gas-Emissions-Inventory.pdf

CBEI may use adjusted or more refined methodologies to make more accurate emissions estimates.

The City of Toronto (the City) has ambitious targets to reduce sector-based greenhouse gas (GHG) emissions by 45 per cent from 1990 levels by 2025, 65 per cent from 1990 levels by 2030, and to reach net zero by 2040. These targets are based on a sector-based GHG inventory, which is generated on an annual basis to better understand the impact of collective community action in reducing emissions to address the climate crisis. With this initial baseline report for consumption-based emissions, the City hopes to set separate, but parallel, targets to reduce consumption-based emissions.

2019 Community-wide CBEI Results

In 2019, the average household in Toronto was responsible for roughly 34 tCO_2e annually, or about 14 tCO_2e per-person[6]. In contrast, the Canadian average was estimated at about 37 tCO_2e per-household. With 1,141,709 households in the city, this is a total of roughly 39 $MtCO_2e$ in 2019 attributable to residents of Toronto.

Figure 2 provides a high-level overview of the city's average per-household emissions in 2019 across five consumption categories. The actual emissions of any particular household, however, could vary significantly from this average. Differences in household size, spending, housing, travel, and other discretionary and non-discretionary factors will affect an individual household's emissions.

[6] Based upon an average household size of 2.43 people per-household. (Source: StatCan, interpolation between 2016 and 2021).

Figure 2. Toronto Average Household Consumption-Based Emissions by Category (2019)

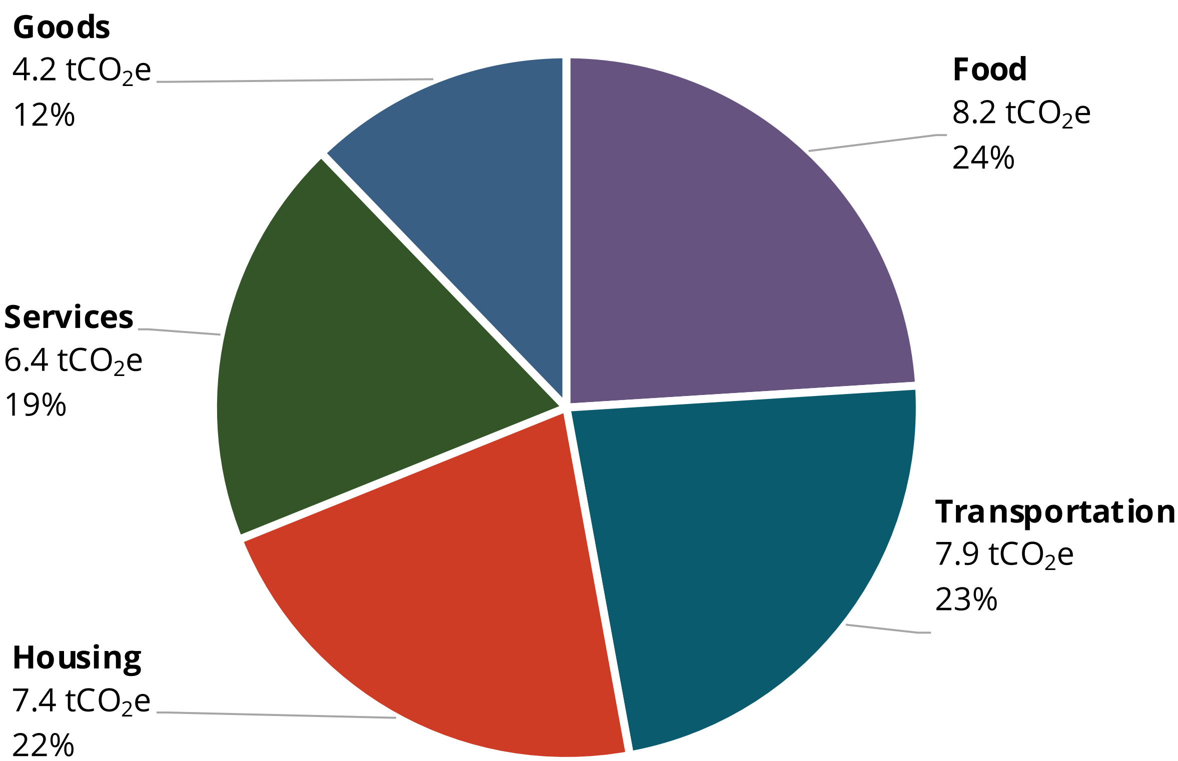
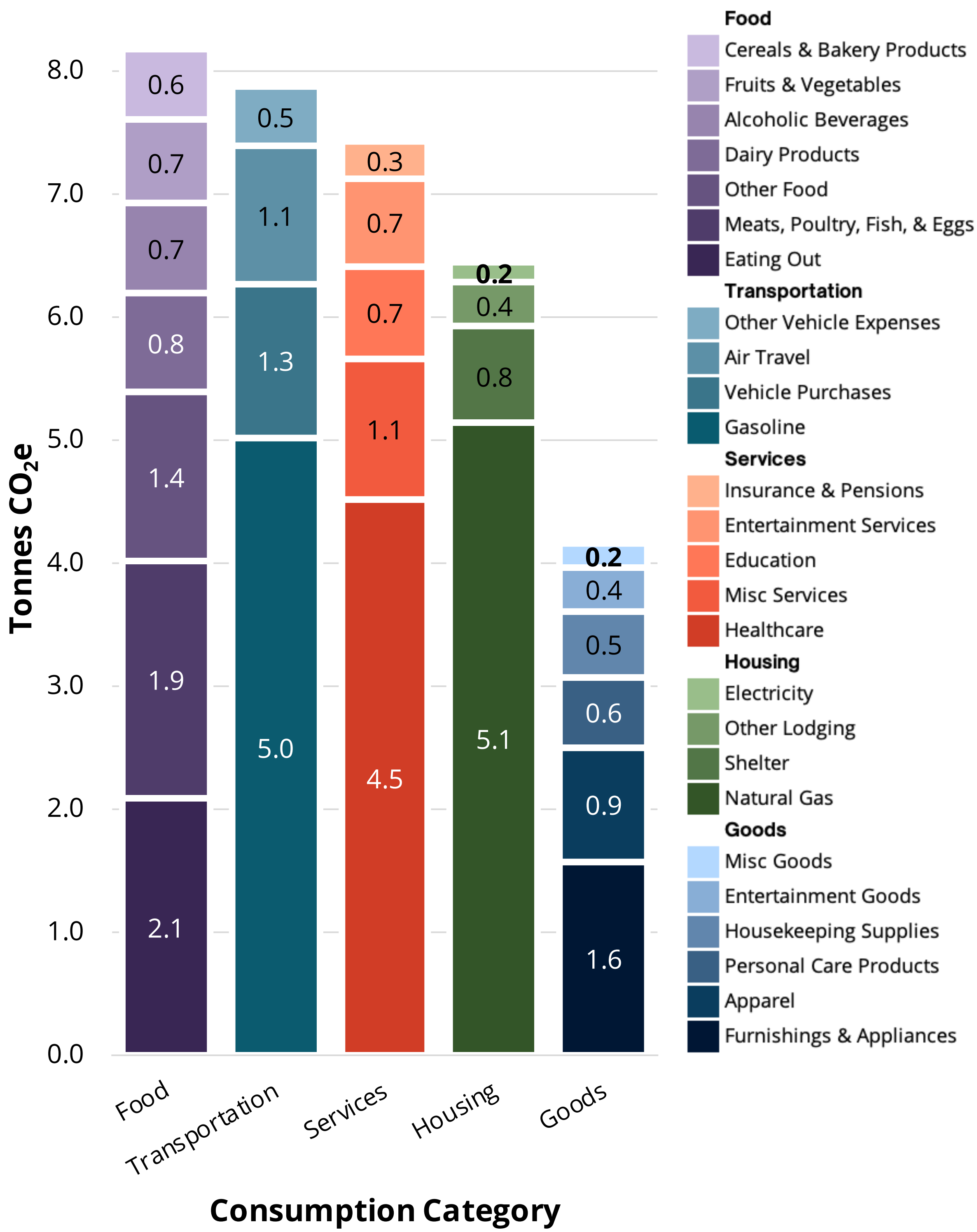


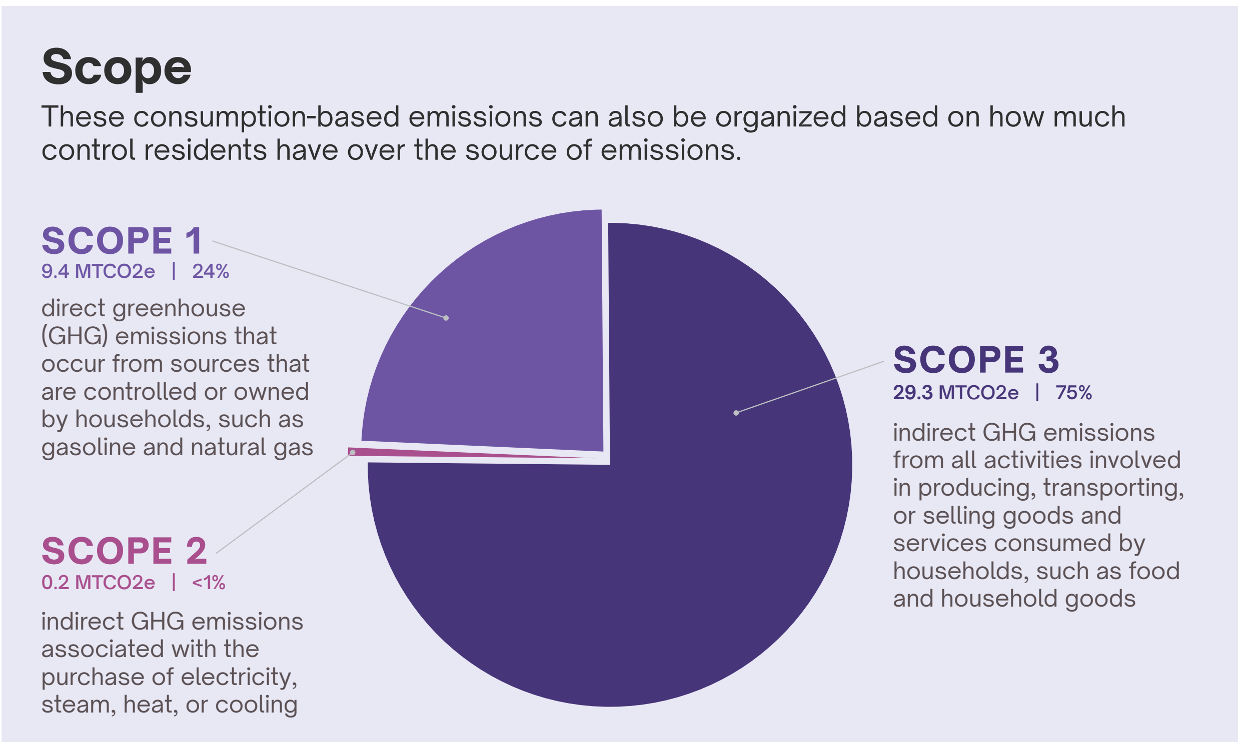
Figure 3 provides a detailed breakdown of these household level consumption-based emissions across 27 sub-categories.

Figure 3. Toronto Average Household Consumption-Based Emissions by Category and Sub-category (2019)



In addition to viewing emissions by category and sub-category, emissions can also be evaluated on a scope 1, 2, or 3 basis. “Scope 1” emissions are direct greenhouse (GHG) emissions that occur from sources that are controlled or owned by households (e.g., emissions associated with fuel combustion in boilers, furnaces, vehicles). “Scope 2” emissions are indirect GHG emissions associated with the purchase of electricity, steam, heat, or cooling[7]. Meanwhile, “Scope 3” emissions, in the context of a community-wide consumption-based inventory, are the result of activities involved in producing everything consumed by households. The vast majority of emissions in the CBEI are Scope 3 emissions, as shown in Figure 4 below.

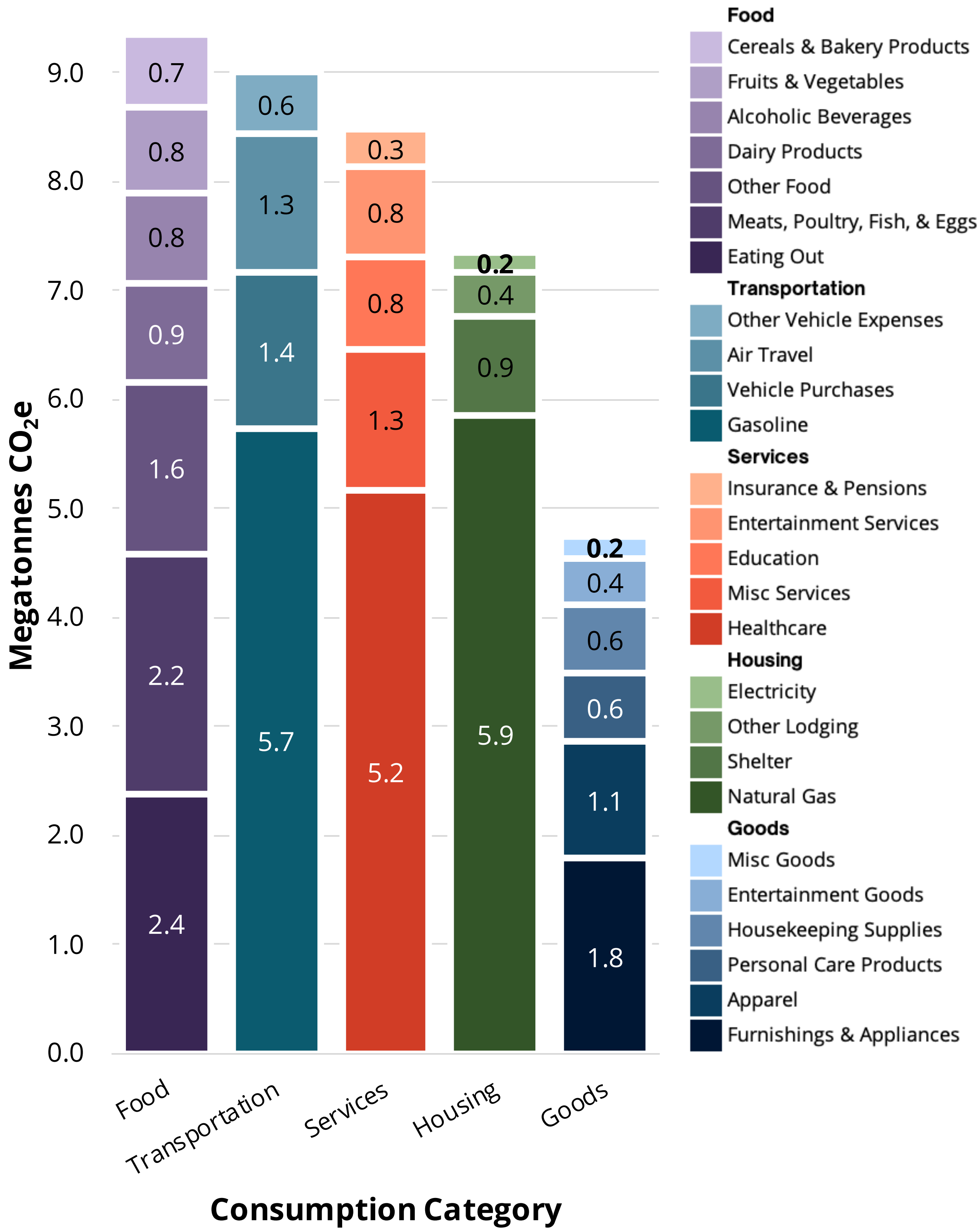
Figure 4. Household Consumption-Based Emissions by Scope (2019)



Toronto’s total consumption-based emissions are calculated by taking the average household’s emissions and multiplying it by the total number of households. Figure 5 shows the detailed sub-category breakdown chart, scaled for all of Toronto (i.e., average household emissions multiplied by the number of households in Toronto).

[7] U.S. Environmental Protection Agency, “Scope 1 and Scope 2 Inventory Guidance” https://www.epa.gov/climateleadership/scope-1-and-scope-2-inventory-guidance

Figure 5. Toronto Community-wide Consumption-Based Emissions by Category and Sub-category (2019)



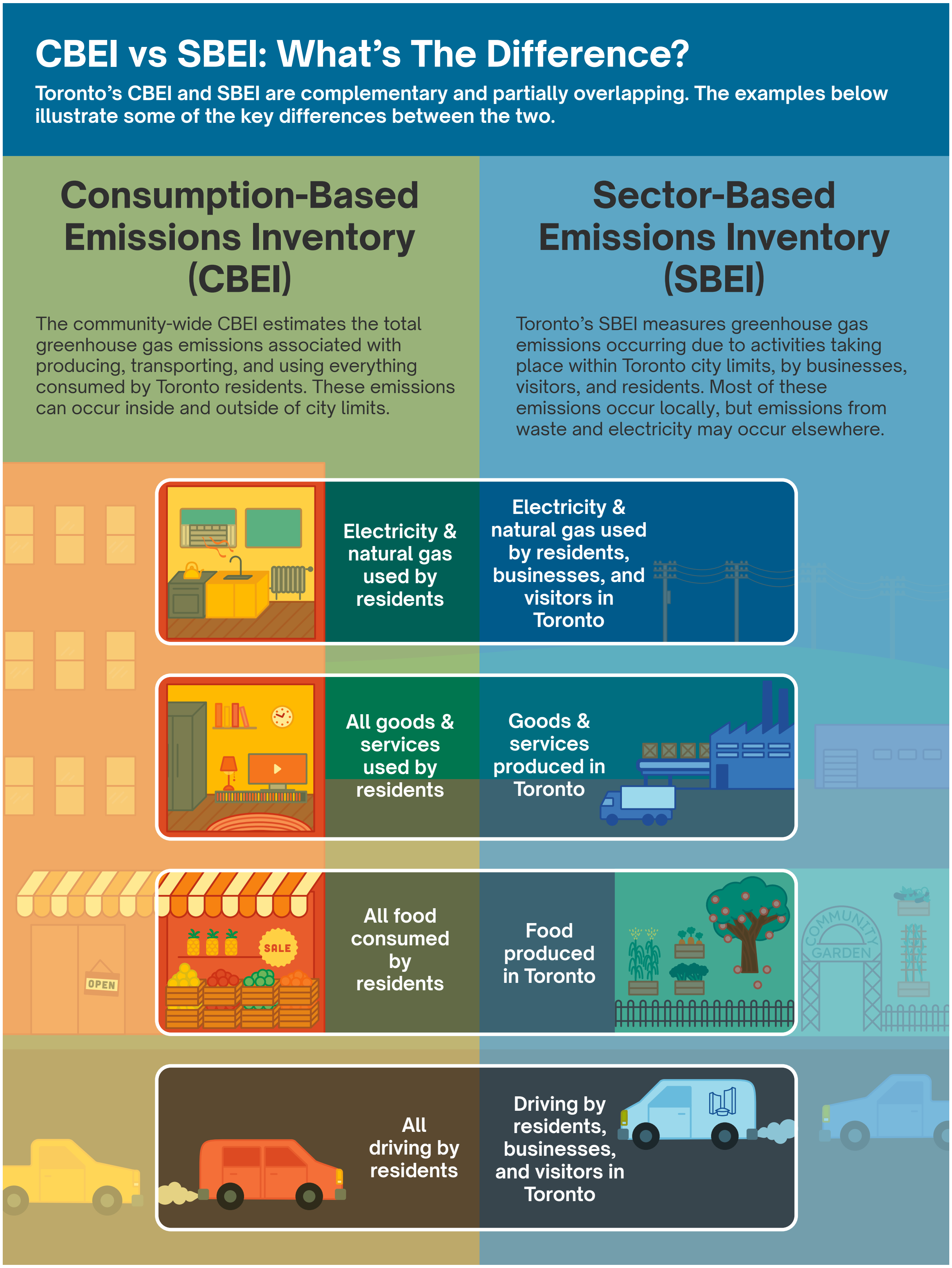
Consumption-Based Emissions Approach

CBEIs and SBEIs are complementary tools, though they differ in their approaches.

In an SBEI, a city looks at all emissions that occur as a result from activity within the city's borders. These are predominantly direct emissions occurring locally, though also include emissions associated with local electricity use and waste generation where the emissions may occur outside the city borders. In contrast, CBEIs consider emissions that occur anywhere in the world, both direct and indirect emissions resulting from consumption by residents of the city.

Sector- and consumption-based approaches are complementary and partially overlapping. Both look at residents' local, direct emissions (e.g. from driving or home heating). A sector-based inventory will also consider the local, direct emissions from businesses and visitors, as well as the indirect emissions associated with electricity used inside the city. However, a sector-based inventory will ignore other emissions occurring from production or consumption outside the city's boundaries that may be for the benefit of residents of the city. Meanwhile, a consumption-based inventory will omit the local emissions from business and visitor activities that do not serve residents, and instead account for the emissions associated with producing everything that city residents purchase or consume. These consumption-based emissions may occur anywhere in the world. Figure 6 shows how these emissions might overlap or differ.

Figure 6. Sector-based vs. Consumption-based Emissions Inventory: What's The Difference?



These consumption estimates are developed using a model that primarily considers six key household characteristics, listed in the table below.

These household characteristics generally have clear, direct effects on consumption. For instance, larger homes generally take more energy to heat or cool, while more people per-household also means more food consumed per-household.

The table below compares the values of these characteristics in Toronto with those of the Canadian averages as of 2019, using data from Statistics Canada (StatCan). These are based on a custom interpolation derived from the 2016 and 2021 Canadian censuses:

Table 1. 2019 Household characteristics, Toronto versus Canada (StatCan)

Key Household Characteristics	Toronto Average (2019)	Canadian Average (2019)
Household Income (CAD)	$117,504	$103,593
Vehicle Ownership (registered vehicles per-household)	1.0	1.4
Household Size (people per-household)	2.43	2.48
Home Size (rooms per-household)	4.94	6.14
Home Ownership (per cent of households that own their home)	52%	67%
Educational Attainment (per cent of people with a Bachelor's degree or higher)	47%	31%

The emissions profile for Toronto is based on an average household in 2019, using the overall average household characteristics for Toronto. Most actual households in the city differ in one or more ways. For Toronto, the average household has 2.43 people, living in a 4.94-room home, with one registered vehicle and an annual income of $117,504. Forty-seven per cent of householders had a Bachelor's degree or higher. Households with different characteristics than the average household are expected to have different emissions profiles.

Individual households may estimate their carbon footprint by using personal household carbon footprint calculators, such as the one provided by the University of California at Berkeley's CoolClimate Network: www.coolclimate.org/calculator. Emissions for Canadian households may differ slightly than the default estimates presented using U.S. assumptions.

Methodology Summary

The community CBEI relies upon estimates of household spending (consumption) in various categories and sub-categories, and emission factors associated with each sub-category. Because it is not possible to know exactly what every Toronto resident is buying, or what the emissions factors are for every good and service sold to Toronto residents, the community CBEI relies on a model (a complex mathematical equation) to predict household spending by sub-category. These spending estimates are then combined with economy-wide average emissions per dollar of expenditure by sub-category to get total household emissions.

This community CBEI was prepared based upon a methodology first developed by the CoolClimate Network at the University of California, Berkeley, with adjustments to adapt this U.S.-specific model to Canadian datasets. The original U.S. model uses household characteristics to predict spending, based upon patterns identified in national surveys of household spending.

These models were adjusted to use Canadian dollars and incorporate Toronto-specific data on household energy usage and vehicle fuel economy, but otherwise remain largely the same. Toronto-specific household characteristics, from StatCan, were used as inputs, and results were scaled based on U.S. consumption data. Emissions were estimated from these modeled consumption results using the U.S. EPA's Environmentally-Extended Input-Output Model (USEEIO[8]), due to data limitations on emission factors for Canada. Nationwide Canadian consumption-based emissions were estimated using the same approach.

[8] https://www.epa.gov/land-research/us-environmentally-extended-input-output-useeio-models

For additional information on the methodology, see Appendix A – Community-wide Consumption-based Emissions Inventory Methodology. The detailed calculations are not presented in the body of this report.

Key Drivers of Consumption-based Emissions and Detailed Breakdown

In 2019, the average household in Toronto was responsible for roughly 34 tCO_2e annually, or about 14 tCO_2e per-person. With 1,141,709 households in the city, this is a total of roughly 39 $MtCO_2e$ in 2019 attributable to residents of Toronto. Referring to Figure 2 among all categories, Food, Transportation, and Services are the largest overall consumption categories, accounting for 24 per cent, 23 per cent, and 22 per cent of emissions, respectively. Together, these account for 69 per cent of total emissions. The remaining 31 per cent of emissions was comprised of Housing (19 per cent) and Goods (12 per cent).

Each of these categories also includes multiple sub-categories. Across all sub-categories, natural gas, gasoline, and healthcare were the top three, accounting for 15 per cent, 15 per cent, and 14 per cent of total emissions, respectively - a combined 44 per cent.

Table 2 provides the full breakdown of emissions by category and sub-category at the household level.

Table 2. Household Consumption-Based Emissions by Category & Sub-Category (2019)

Category & Sub-Category	Emissions (tCO_2e)	Per cent of Category	Per cent of Total
Food	***8.2***		***24%***
Eating Out	2.1	26%	6%
Meats, Poultry, Fish, & Eggs	1.9	23%	6%
Other Food	1.4	17%	4%
Dairy Products	0.8	10%	2%
Alcoholic Beverages	0.7	9%	2%
Fruits & Vegetables	0.7	8%	2%
Cereals & Bakery Products	0.6	7%	2%
Transportation	***7.9***		***23%***
Gasoline	5.0	64%	15%
Vehicle Purchases	1.3	16%	4%
Air Travel	1.1	14%	3%

Category & Sub-Category	Emissions (tCO_2e)	Per cent of Category	Per cent of Total
Other Vehicle Expenses	0.5	6%	1%
Services	***7.4***		***22%***
Healthcare	4.6	62%	14%
Misc. Services	1.2	16%	3%
Education	0.8	10%	2%
Entertainment Services	0.7	10%	2%
Insurance & Pensions	0.3	4%	1%
Housing	***6.4***		***19%***
Natural Gas	5.1	80%	15%
Shelter	0.8	12%	2%
Other Lodging	0.4	6%	1%
Electricity	0.2	2%	0%
Goods	***4.2***		***12%***
Furnishings & Appliances	1.6	38%	5%
Apparel	0.9	22%	3%
Personal Care Products	0.6	13%	2%
Housekeeping Supplies	0.5	13%	2%
Entertainment Goods	0.4	9%	1%
Misc. Goods	0.2	5%	1%

Table 3 presents this breakdown at the community-wide level, using the totals aggregated across all Toronto households.

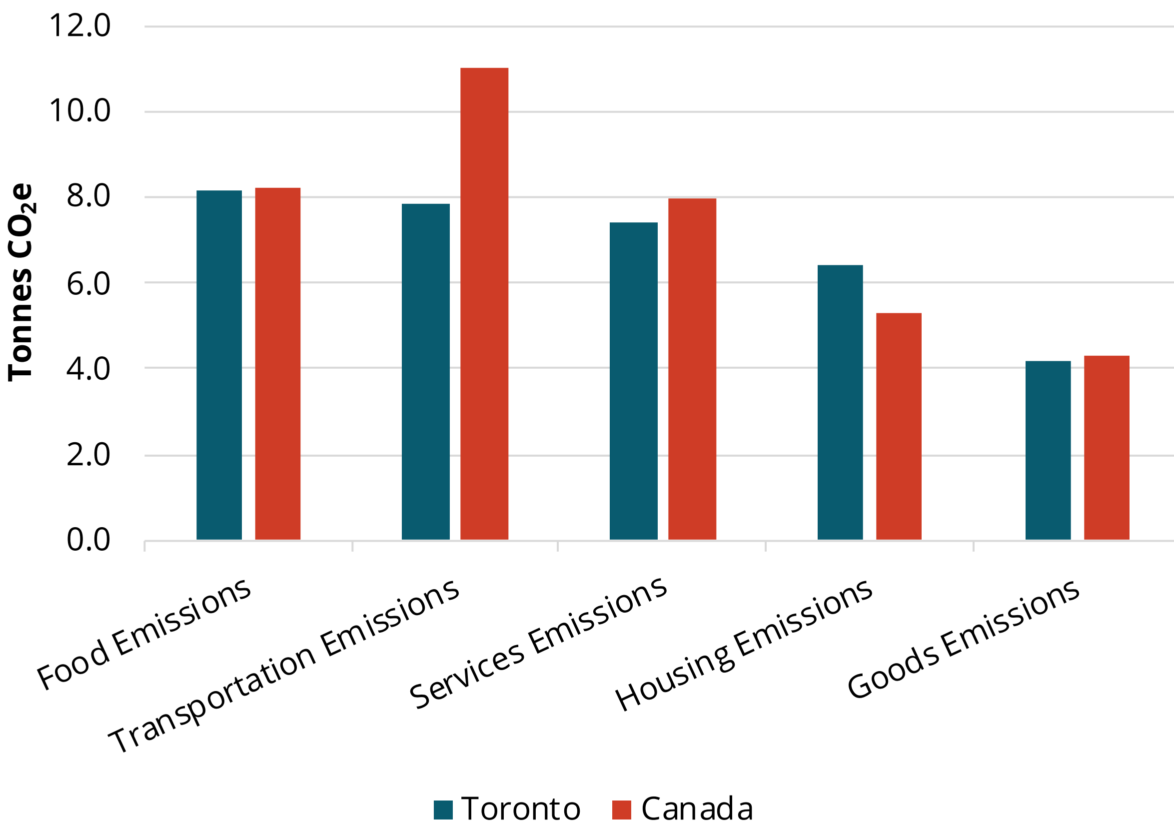
Table 3. Community-Wide Consumption-Based Emissions by Category & Sub-Category (2019)

Category & Sub-Category	Emissions ($MtCO_2e$)	Per cent of Category	Per cent of Total
Food	***9.3***		***24%***
Eating Out	2.1	22%	5%
Meats, Poultry, Fish, & Eggs	1.9	21%	5%
Other Food	1.4	15%	4%
Dairy Products	0.8	9%	2%
Alcoholic Beverages	0.7	8%	2%
Fruits & Vegetables	0.7	7%	2%
Cereals & Bakery Products	0.6	6%	1%
Transportation	***9.0***		***23%***
Gasoline	5.0	56%	13%
Vehicle Purchases	1.3	14%	3%

Air Travel	1.1	12%	3%
Other Vehicle Expenses	0.5	5%	1%
Services	***8.5***		***22%***
Healthcare	4.6	55%	12%
Misc. Services	1.2	14%	3%
Education	0.8	9%	2%
Entertainment Services	0.7	9%	2%
Insurance & Pensions	0.3	4%	1%
Housing	***7.4***		***19%***
Natural Gas	5.1	70%	13%
Shelter	0.8	11%	2%
Other Lodging	0.4	5%	1%
Electricity	0.2	2%	0%
Goods	***4.7***		***12%***
Furnishings & Appliances	1.6	33%	4%
Apparel	0.9	20%	2%
Personal Care Products	0.6	12%	1%
Housekeeping Supplies	0.5	11%	1%
Entertainment Goods	0.4	8%	1%
Misc. Goods	0.2	4%	0%

Figure 7 compares the Toronto average household emissions with the Canadian national averages. Toronto has lower emissions overall, especially from transportation. However, Toronto's emissions from housing are higher than average, primarily due to high natural gas usage throughout the city. Nearly all Toronto households heat with natural gas, driving up emissions in the housing category, while many Canadian households do not have natural gas systems at all,

Figure 7. Toronto versus Canada Average Household CBEI (by category, 2019)



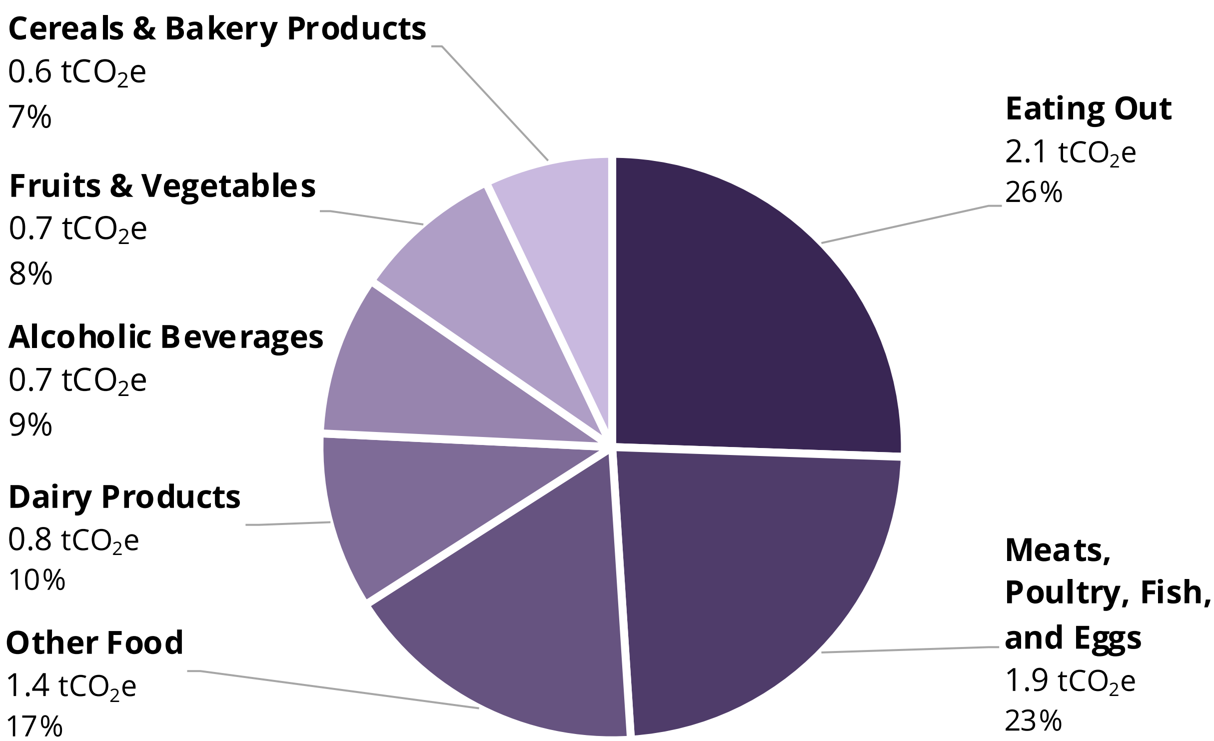
The following sections discuss each category in greater detail. Certain sub-categories are also discussed further, based on the magnitude of emissions in that category and the City's ability to influence those emissions.

> In this upcoming Key Drivers section, call-out boxes like this one provide comparisons of Toronto's consumption-based emissions inventory with its sector-based emissions inventory. These comparisons are for informational purposes.

Food

The Food category includes consumption-based emissions of all food consumed by residents of Toronto, broken into meat, dairy, fruits & vegetables, and other foods consumed at home, as well as eating out. These consumption-based emissions from food include emissions associated with the production, transport, sale, and preparation of food. This includes emissions from fertilizer use and application, livestock, operation of trucks and other equipment, building construction and operation, and fuel used in cooking (for food prepared outside the home, including eating out). The City of Toronto has adopted the Cool Food Pledge[9], committing to reduce the GHG emissions associated with food procurement for its own operations by 25 per cent by 2030, relative to a 2019 baseline year. Figure 8 provides a breakdown of these emissions across the seven sub-categories.

Figure 8. Household Food Emissions Breakdown (2019)



Food accounts for 8.2 tCO_2e, or roughly 24 per cent of average household emissions, and the single largest sub-category is eating out at 2.1 tCO_2e, or 26 per cent of total food emissions. The remaining 74 per cent of emissions include meats, poultry, fish, and eggs (23 per cent); other food, including processed foods (17 per cent), dairy products (10 per cent), alcoholic beverages (nine per cent), fruits and vegetables (eight per cent), and cereals and bakery products (seven per cent).

---

[9] https://coolfood.org/pledge/

Meat & dairy, combined, make up the largest sources of at-home food emissions for households. In Toronto, meat, poultry, fish, eggs, and dairy combined account for 2.7 tCO_2e of emissions, while fruits and vegetables, cereals, and other foods account for 2.7 tCO_2e. Eating out accounts for 2.1 tCO_2e.

Despite being only a small fraction of overall calories consumed, meat and dairy have a large impact on the typical household's emissions associated with food. This is because the emissions associated with meat consumption not only include direct methane emissions from animals, but also nitrous oxide emissions from growing the crops to feed those animals.

Further compounding these food emissions is the fact that an estimated 20 per cent of food is not consumed and goes to waste[10]. Even if food is not eaten, the emissions associated with its production are still included in the overall emissions associated with food, driving up emissions overall. While some of this loss occurs in production, storage, or transport, households are often also a significant source of food waste. According to the United Nations, Canadian households purchase more calories per capita than most other countries - nearly 3,600 calories per-person per day in 2018[11]. This includes all purchased food, consumed or otherwise.

Eating out, such as at restaurants, also contributes to a portion of food emissions. For the typical Toronto household, eating out is associated with roughly 2.1 tCO_2e per year. However, this includes not only the food consumed while eating out, but also the operational emissions from restaurants, including emissions from cooking, transportation, and construction of the building where the food is prepared. In comparison, household emissions from cooking, transportation, and construction are allocated to the transportation and housing categories. Overall, eating out likely has similar emissions per calorie as food prepared at home, when considering all similar emissions involved in food preparation.

Transportation

The transportation category includes consumption-based emissions from household gasoline usage, vehicle purchases and maintenance, and air travel. For an average household in Toronto, transportation accounts for 7.9 tCO_2e per year,

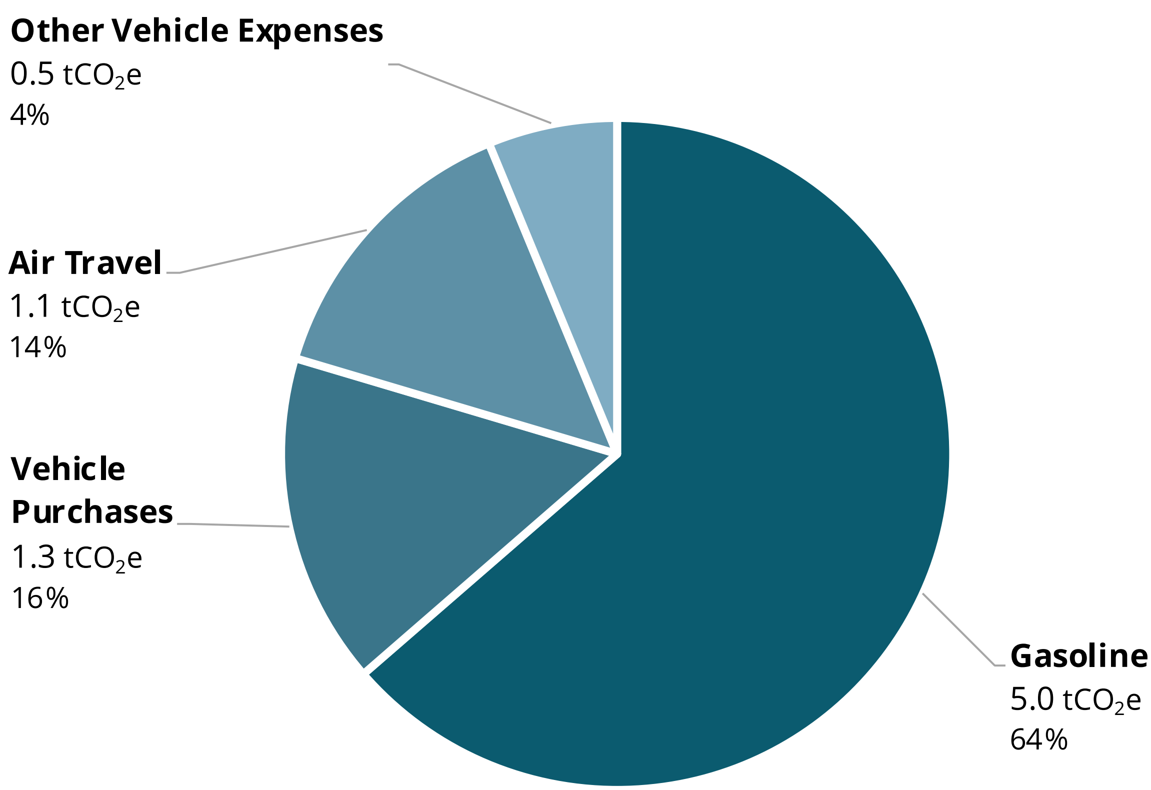
---

[10] Government of Canada, “Taking Stock: Reducing food loss and waste in Canada” https://www.canada.ca/en/environment-climate-change/services/managing-reducing-waste/food-loss-waste/taking-stock.html

[11] United Nations Our World in Data, “Food Supply” https://ourworldindata.org/food-supply

per-household (roughly 23 per cent of total household consumption-based emissions). Much of this comes from gasoline, which accounts for five tCO_2e, or 64 per cent of the total transportation emissions. The remaining 36 per cent of transportation emissions consists of vehicle purchases (16 per cent), air travel (14 per cent), and other vehicle expenses (including maintenance) (six per cent), as shown in Figure 9.

Figure 9. Household Transportation Emissions Breakdown (2019)



Gasoline

Gasoline consumption is the second-largest source of consumption-based emissions by Toronto residents, responsible for five tCO_2e per-household. There are two key components that drive gasoline consumption: vehicle fuel economy and the amount of driving done by Toronto residents.

The average Toronto household has about one vehicle[12] and drives an estimated 18,600 kilometres per year. Based upon data from the Traffic Emission Prediction Scheme (TEPs) model from the University of Toronto[13], the average Toronto vehicle was assumed to directly produce 216.3 gCO_2e per vehicle kilometer travelled (VKT) in 2019, equivalent to a fuel economy of roughly nine litres per 100 km[14]. When accounting for upstream lifecycle emissions from the production of gasoline, this lifecycle emissions factor was estimated at 269.7 grams of CO_2e (gCO_2e) per VKT.

Nationwide data on residential vehicle registrations and fuel economy is limited. For the purposes of comparison, Canadian average household VKT was modeled using overall Canadian vehicle availability. Based upon this modeled estimate, the average Canadian household drives roughly 30,300 kilometers per year – roughly 63 per cent more than the average Toronto household.

As of 2016, about 28 per cent of households in Toronto did not own a

Gasoline emissions are reflected in both the CBEI and SBEI.

In the 2019 CBEI, an estimated 5.7 $MtCO_2e$ are attributable to Toronto residents' gasoline usage.

In the 2019 SBEI, an estimated 5.6 $MtCO_2e$ are attributed to transportation, including gasoline and diesel use by all vehicles traveling within the geographic boundary of the city of Toronto. Of this 5.6 $MtCO_2e$, 4.5 $MtCO_2e$ was estimated to be from gasoline.

The CBEI only includes residential gasoline usage, but it includes all driving by residents, including outside of city borders. In addition, the CBEI estimates of gasoline emissions includes upstream emissions associated with oil extraction and gasoline production. Meanwhile, the SBEI includes driving by all vehicles, including commuters, tourists, and businesses, but only within city limits, and only the direct (but not upstream) emissions from burning transportation fuels.

[12] Transportation Tomorrow Survey (http://www.dmg.utoronto.ca/pdf/tts/2016/2016TTS_Summaries_GTHA.pdf)
[13] The TEPs model is used in Toronto's annual sector-based emissions inventory to estimate on-road vehicle emissions within the city of Toronto (https://teps.ca/).
[14] The average vehicle's GHG emissions intensity (gCO_2e per km travelled) is based on all vehicles (passenger, commercial vans and pickups trucks [gasoline], and light and heavy commercial trucks [diesel]) operating within the city of Toronto. The average of 216.3 gCO_2e is therefore a conservative upper-bound estimate of residents' vehicles emissions.

vehicle[15]. In contrast, only 16 per cent of Canadian households did not own a vehicle (as of 2022). Car-free households in Toronto are concentrated in the former City of Toronto, specifically Planning District 1, where as many as 52 per cent of households did not own a vehicle in 2016[15]. This area has greater levels of transit and bicycle infrastructure, and greater population and destination density, which contribute to making it easier to fulfill most daily errands without a car. In contrast, areas of Toronto further from this historic core, such as the former cities of North York, Scarborough, and Etobicoke have much lower rates of car-free households: 20, 18, and 14 per cent, respectively.

Toronto's lower rates of automobile ownership and higher rates of car-free households is in the range typically seen among major transit-rich North American cities, as shown in Table 4 below.

Table 4. Major U.S. Cities by Vehicle Ownership and Car-Free Households

City	Vehicles per-household	% of households with no vehicles
New York City	0.6	55%
Washington, DC	0.9	35%
San Francisco	1.0	32%
Philadelphia	1.1	29%
Toronto	1.0	28%
Chicago	1.1	26%
Seattle	1.3	19%
Portland	1.5	17%
Canada Average	1.4	16%
Atlanta	1.3	15%
Los Angeles	1.7	12%
Houston	1.6	9%
U.S. Average	1.8	8%
Austin	1.6	7%
Phoenix	1.8	7%

[15] Toronto Tommorrow Survey, http://www.dmg.utoronto.ca/pdf/tts/2016/2016TTS_Summaries_TTSarea.pdf

Air Travel

For some individual households, air travel is a significant portion of consumption-based emissions. However, for Toronto overall, air travel is only a small part of the city's consumption-based emissions, at an average of 1.1 tCO_2e per-household (3.2 per cent of total emissions). This varies significantly between households, largely due to income: air travel is a luxury for most households, and only the wealthiest households fly regularly.

According to data from Statista.com, as of 2017 an estimated 48 per cent of the Canadian population had not flown in the past two years, and another 31 per cent had taken only one or two flights[16]. Only 21 per cent of the population had taken three or more flights in the previous two years.

On a per-kilometer basis, air travel emissions are roughly comparable to those of driving alone in a single-occupancy vehicle. Most modern aircraft get roughly 2-3 L/100km per passenger seat[17], with fuel economy improving for longer flights. After accounting for the additional climate effects from high-altitude particulate matter, as well as lifecycle production of aviation fuels, air travel's overall emissions are roughly double what would be expected on a per gallon basis alone, making it more like driving a car getting 4.7-6.7 L/100km.

Most of the emissions from air travel result from the exceptionally long distances travelled. A round-trip flight from Toronto to London (the most popular destination from Toronto Pearson outside of North America) is 11,400 km; for two people, this means a single trip abroad would be more kilometres of air travel (22,800 km) than an entire year’s worth of typical household driving (18,600 km).

Meanwhile, very short flights (less than about 500 km) typically have extremely poor fuel economy and may not be more fuel efficient than driving alone in an average vehicle.

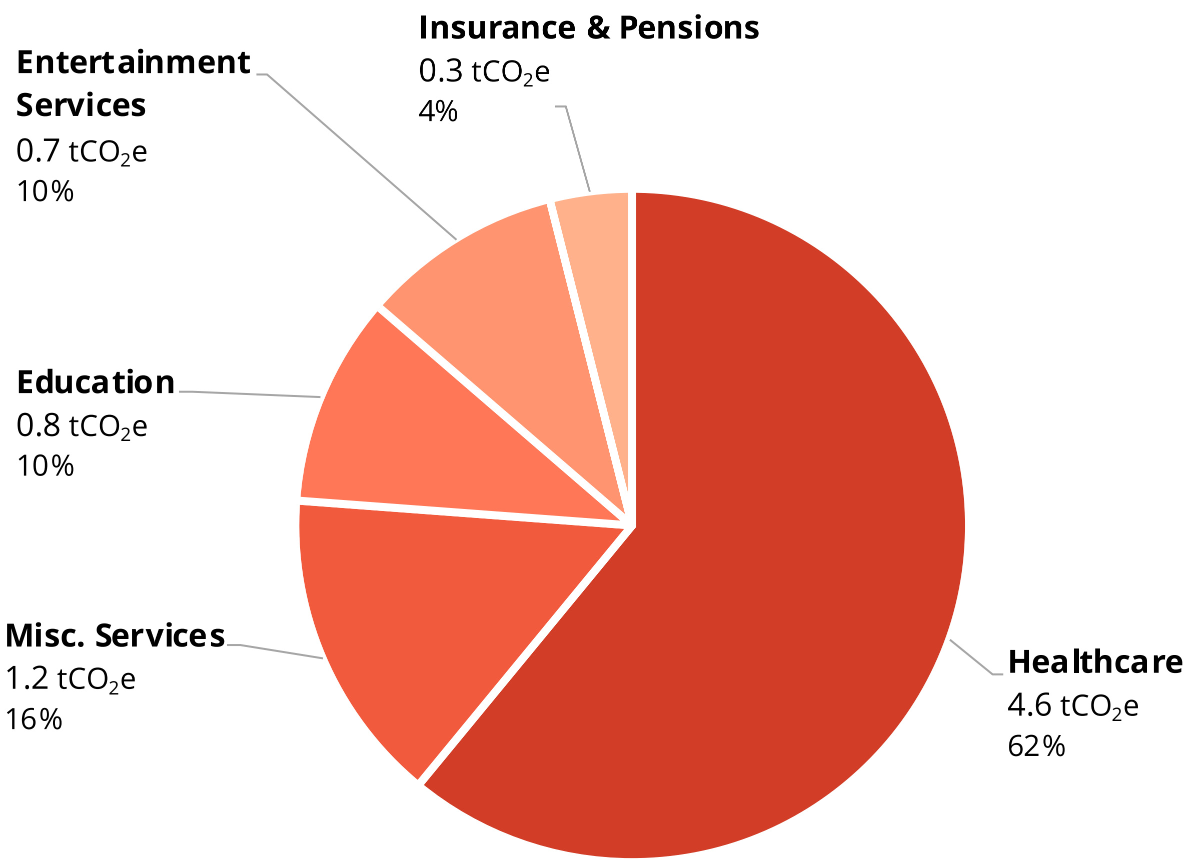
[16] Statista, Air travel in Canada in 2017, by frequency of flying: https://www.statista.com/statistics/746256/air-travel-canada-frequency-flying-2017/
[17] Wikipedia, Fuel Economy in Aircraft: https://en.wikipedia.org/wiki/Fuel_economy_in_aircraft#Regional_flights

Services

The services category includes all services used by residents, such as healthcare, entertainment, education, personal care services, financial services, and more[18].

Services account for 7.6 tCO_2e per-household, or roughly 22 per cent of total household emissions, and the single largest sub-category is healthcare at 4.6 tCO_2e, or 61 per cent of services emissions. The remaining 39 per cent of services emissions comes from miscellaneous services (15 per cent), education (10 per cent), entertainment services (10 per cent), and insurance and pensions (four per cent), as shown in Figure 10.

Figure 10. Household Services Emissions Breakdown (2019)



Healthcare dominates emissions from services primarily because it is a large economic sector. Roughly 13 per cent of Canadian GDP was allocated to healthcare

[18] See Appendix A: Methodology for more details.

in 2019[19]. In Toronto, emissions from healthcare consumption are about 13 per cent of the average household's consumption-based emissions footprint. Healthcare emissions include emissions from the construction and operation of hospitals, doctor's offices, and other medical facilities; manufacturing of pharmaceuticals and medical equipment; and more.

Other major sub-categories of emissions include entertainment services (mostly fees and admissions to museums, concerts, etc.), education, financial services such as insurance and pensions, and miscellaneous services (including personal care, household operations, and others). For other municipalities' community-wide CBEIs, these sub-categories generally account for fewer consumption-based emissions per-household because average households do not spend much on these other services. However, Toronto's higher-than-average education and income levels (compared to Canadian national averages) results in greater average spending in these categories (relative to the average Canadian household).

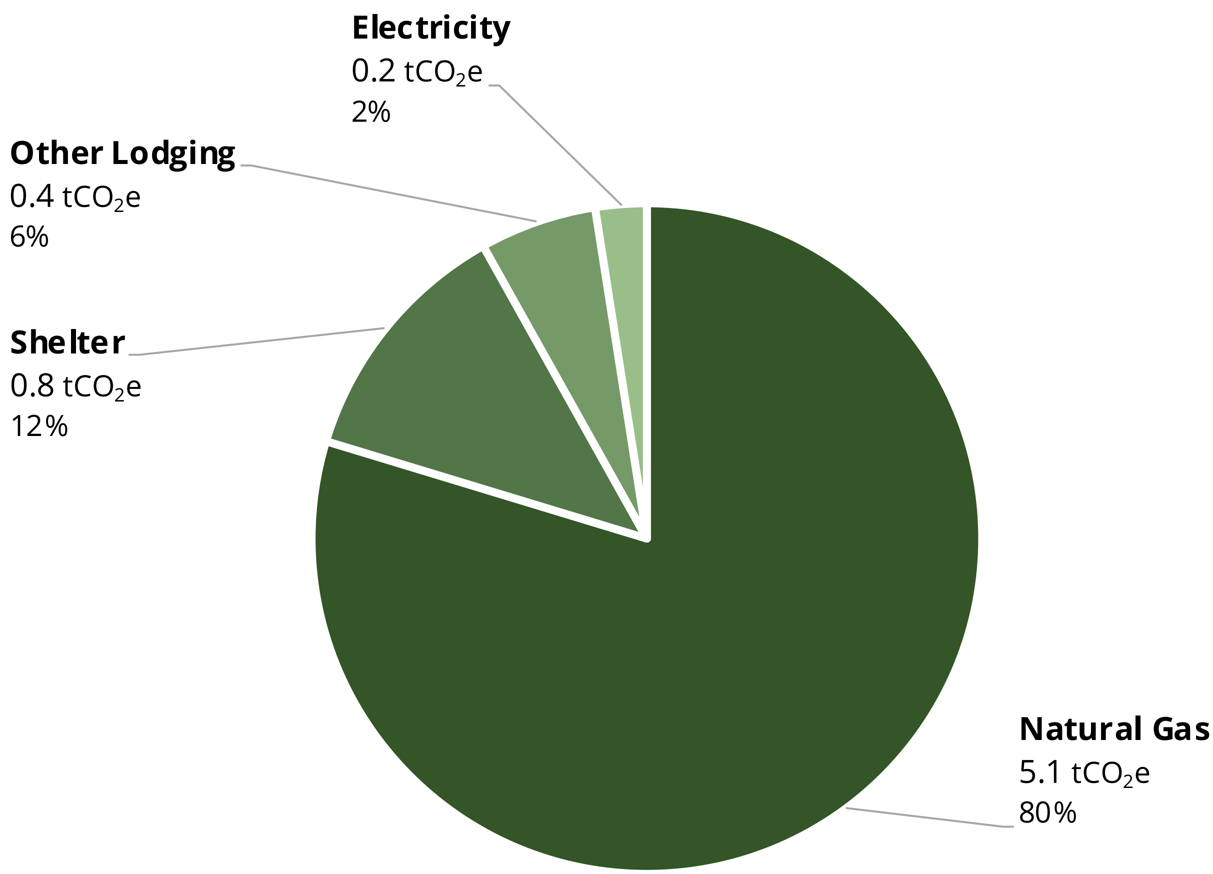
Housing

The Housing category consists of emissions associated with household natural gas and electricity use, embodied emissions in home construction and maintenance (shelter), and energy and construction of other lodging (such as hotels and motels). Figure 11 shows the breakdown of these emissions.

---

[19] Canadian Institute for Health Information, "National health expenditure trends, 2022 – Snapshot." https://www.cihi.ca/en/national-health-expenditure-trends-2022-snapshot.

Figure 11. Household Housing Emissions Breakdown (2019)



Natural gas is used in homes to provide space and water heating, clothes drying, and cooking. Electricity powers lights, electronics, and appliances. The construction and maintenance of buildings (residences and other lodging) involves emissions associated with the production of materials used in the building (steel, concrete, etc.), as well as emissions associated with transporting materials and constructing the building.

Overall, a typical Toronto household is responsible for 6.4 tCO_2e resulting from housing, roughly 19 per cent of total household consumption-based emissions, with the largest single sub-category being natural gas. Natural gas produces 5.1 tCO_2e, or 80 per cent of the total housing emissions. The remaining 24 per cent of housing emissions comes from shelter construction (12 per cent), other lodging (such as hotels & motels) (six per cent), and electricity (two per cent).

Natural Gas

Natural gas is a common fuel for home heating, water heating, clothes drying, and cooking. The primary ingredient of natural gas is methane (CH_4), a potent greenhouse gas.

An estimated 95 per cent of homes in Toronto use natural gas for heating. In 2019, natural gas use for Toronto was roughly 2,200 m^3 per-household. Nationally, the average natural gas usage in Canada for homes that heat with natural gas was close to 2,500 m^3, while the average gas usage in Ontario was 2,300 m^3. Toronto's multi-unit residential buildings (MURBs) generally have lower natural gas usage per-household than single-family homes, due to shared walls providing greater energy efficiency and smaller dwelling spaces requiring less heating.

When burned directly, the 2,200 m^3 of natural gas per-household results in roughly 4.2 tCO_2e. However, some methane is leaked into the atmosphere during the extraction, processing, and transport (piping) of natural gas into homes. While estimates of methane leakage are difficult to develop, the best available data the methane leakage rate in Ontario was 2.7 per cent, roughly double the amount reported in Canada's National Inventory Report[20]. This updated 2.7 per cent leakage rate is used for the CBEI report.

Natural gas emissions are reflected in both the CBEI and SBEI.

In the 2019 CBEI, an estimated 4.8 MT CO_2e are attributable to Toronto residents' natural gas usage.

In the 2019 SBEI, an estimated 8.9 MT CO_2e are attributed to buildings, including natural gas and electricity use by all buildings within the city. Of this 8.9 MT CO2e, 8.2 MT CO_2e was estimated to come from natural gas.

The CBEI only includes residential natural gas usage. Meanwhile, the SBEI includes natural gas use in all buildings, including homes, businesses, and government buildings within city limits.

Because one tonne of methane has the same warming impact as nearly 30 tonnes of CO_2 (when considered over a 100-year time frame), when this leakage rate is included, overall emissions from natural gas use in households are increased by

[20] The Atmospheric Fund (TAF), "Fugitive methane emissions in Ontario are double the reported rate." https://taf.ca/fugitive-methane-emissions-in-ontario-are-double-the-reported-rate/

nearly 25 per cent. Overall, household emissions from natural gas are estimated at 5.1 tCO_2e, comprising 80 per cent of total housing category emissions in the CBEI and 14 per cent of emissions overall.

Electricity

The average Toronto household was estimated to have an average electricity usage of 5,495 kWh per-household and a weighted average emissions factor of 29 gCO2e per kWh, resulting in about 0.1 tCO_2e per yr. This is substantially below the average Canadian household, which uses over 11,000 kWh per year with an emissions factor of 96.48 gCO_2e per kWh, for emissions of about one tCO_2e per yr.

Electricity emissions are reflected in both the CBEI and SBEI.

In the 2019 CBEI, an estimated 0.2 MT CO_2e are attributable to Toronto residents' electricity usage.

In the 2019 SBEI, an estimated 8.9 MT CO_2e are attributed to buildings, including natural gas and electricity use by all buildings within the city. Of this 8.9 MT CO2e, 0.7 MT CO_2e was estimated to come from electricity.

The CBEI only includes residential electricity usage. Meanwhile, the SBEI includes electricity use in all buildings, including homes, businesses, and government buildings within city limits.

Toronto's consumption-based emissions from electricity use were calculated from single-family home electricity usage and emissions factor data provided by the City of Toronto, with adjustments made to include an estimate of apartment electricity usage based upon Natural Resources Canada (NRCan) data on average Ontario single-family and apartment energy use.

Toronto's electricity usage and emissions are lower than the national average for multiple reasons. Firstly, Toronto's high rate of natural gas use for home heating means that few households use electricity for heating, resulting in lower electricity use than the Canadian average. Secondly, smaller than average homes also typically use less energy for heating, cooling, and other appliances, and apartments use still less. (Based on NRCAN data, the average single-family home in Ontario uses twice as much electricity as the average apartment.) Lastly, Toronto Hydro currently provides exceptionally clean electricity for city residents. In 2019, Ontario's electricity generation mix (including Toronto Hydro) was sourced almost entirely from zero-emission sources[21]. Nuclear made up 58.2 per cent of electricity, with hydroelectricity making up another 24 per cent, wind 8.2 per cent, solar 2.4 per cent, and bioenergy 0.5 per cent, for a total of 93.3 per cent of electricity from zero-emission sources. The remaining 6.7 per cent came from natural gas (6.1 per cent) and other non-contracted sources (0.6 per cent). Meanwhile, other parts of Canada still use coal for a portion of their electricity, resulting in higher emissions.

However, there are concerns about the future of Ontario's electricity mix. Electricity consumption in Ontario is projected to grow an estimated two per cent per year for the next two decades[22], due to increased demand from industrial, building, and transportation electrification. By 2043, Ontario is projected to need nearly 40 per cent more electricity than it currently uses. At the same time, Ontario's major nuclear power plants are in need of refurbishment, which will make significant generation capacity unavailable over the next decade.

To meet this imminent shortfall in capacity, Ontario's Ministry of Energy has directed the Independent Electricity System Operator (IESO) to procure 4,000 MW of new capacity[22]. IESO is recommending the procurement of 2,500 MW of new energy storage and renewable sources, and 1,500 MW of new gas-fired generation capacity[23]. This would represent a roughly 14 per cent increase in gas generation capacity, over the existing 10,600 MW of installed capacity (as of 2023)[22].

At the request of the Minister of Energy, IESO has released a "Pathways to Decarbonization" report analyzing outcomes and recommending strategies for Ontario to achieve zero-emission electricity by 2050[24]. This report finds that a moratorium on new natural gas generation is feasible beginning in 2027, after the current expansion is completed, and projects that under a moratorium scenario, natural gas generation capacity could be reduced to 8,000 MW by 2035, with only 5,000 MW actively used (the remaining 3,000 MW of capacity would be held in

---

[21] Ontario Electric Board, "Ontario's System-Wide Electricity Supply Mix: 2019 Data" https://www.oeb.ca/sites/default/files/2019-supply-mix-data-update.pdf

[22] Independent Electricity System Operator, "Annual Planning Outlook" https://www.ieso.ca/en/Sector-Participants/Planning-and-Forecasting/Annual-Planning-Outlook

[23] IESO News and Updates, "IESO Recommends Shift to Grid-Scale Storage in Ontario, Relying on Natural Gas Expansions to Ensure Reliability in Near-Term" https://www.ieso.ca/Corporate-IESO/Media/News-Releases/2022/10/Grid-Scale-Storage-in-Ontario-Natural-Gas-Expansions-to-Ensure-Reliability-in-Near-Term

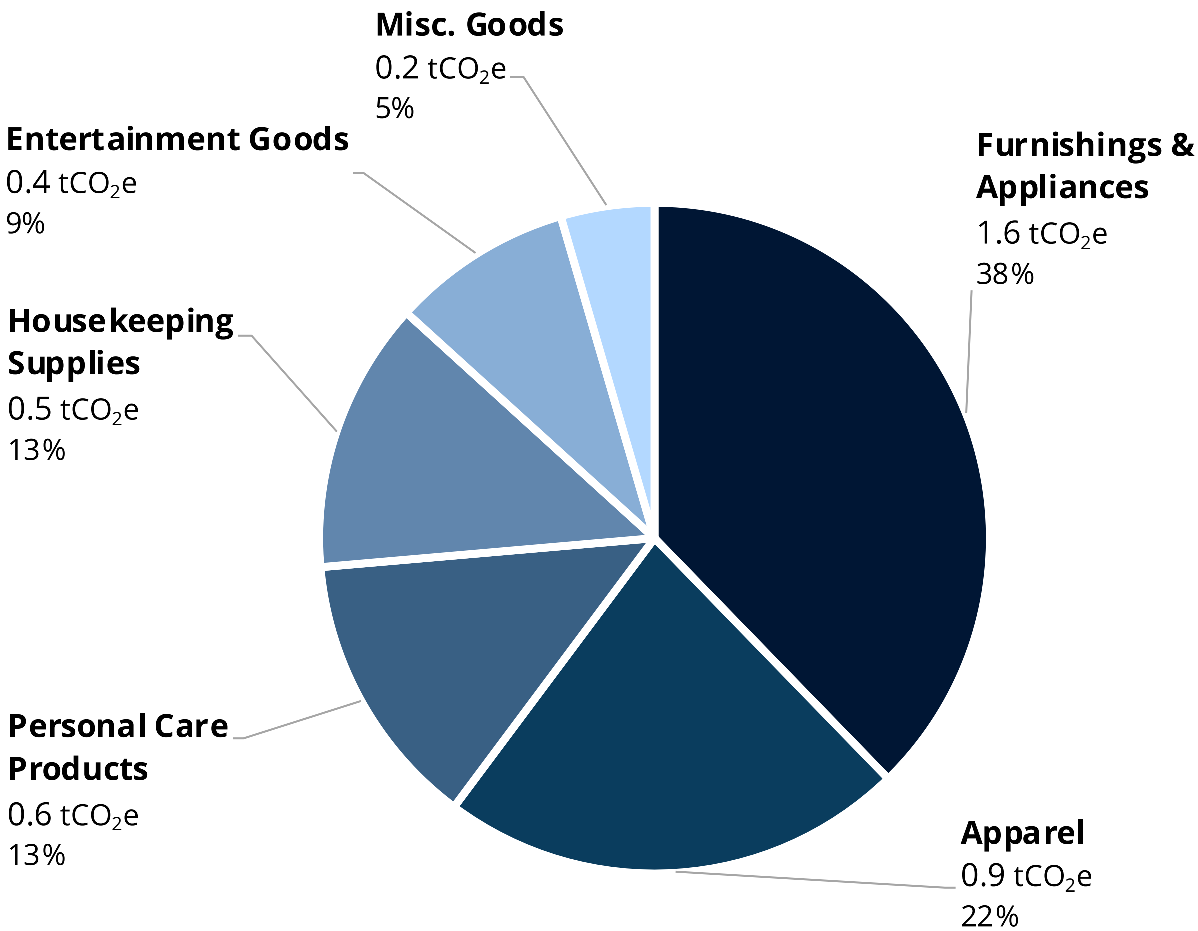
[24] IESO, "Pathways to Decarbonization" https://www.ieso.ca/en/Learn/The-Evolving-Grid/Pathways-to-Decarbonization

reserve for periods of maintenance). The report also finds that full decarbonization by 2050 is attainable through investment in additional carbon-free resources such as new nuclear, wind, solar, and hydro.

Goods

Goods includes all physical items purchased by households (excluding items in other categories, such as food and fuel). The goods category includes items like furniture, personal electronics, clothing, personal care products, toys, and books. These goods account for 4.2 tCO_2e per-household per year, roughly 12 per cent of total emissions. Of these goods, furnishings and appliances are the single largest source, making up 1.6 tCO_2e, or 38 per cent, of consumption-based emissions from all goods. The remaining 62 per cent comes from apparel (23 per cent), personal care products (13 per cent), housekeeping supplies (13 per cent), entertainment goods (nine per cent), and other miscellaneous goods (four per cent). This breakdown is shown in Figure 12.

Figure 12. Household Goods Emissions Breakdown (2019)



Generally, goods have lower associated emissions per dollar of household spending than food and energy. Households with higher incomes tend to spend more money (as well as a greater fraction of their income) on these various goods. Homeowners also tend to spend more on home furnishings and equipment than residents that do not own their homes.

Discussion

Community-wide Consumption-Based Emissions Reduction Targets

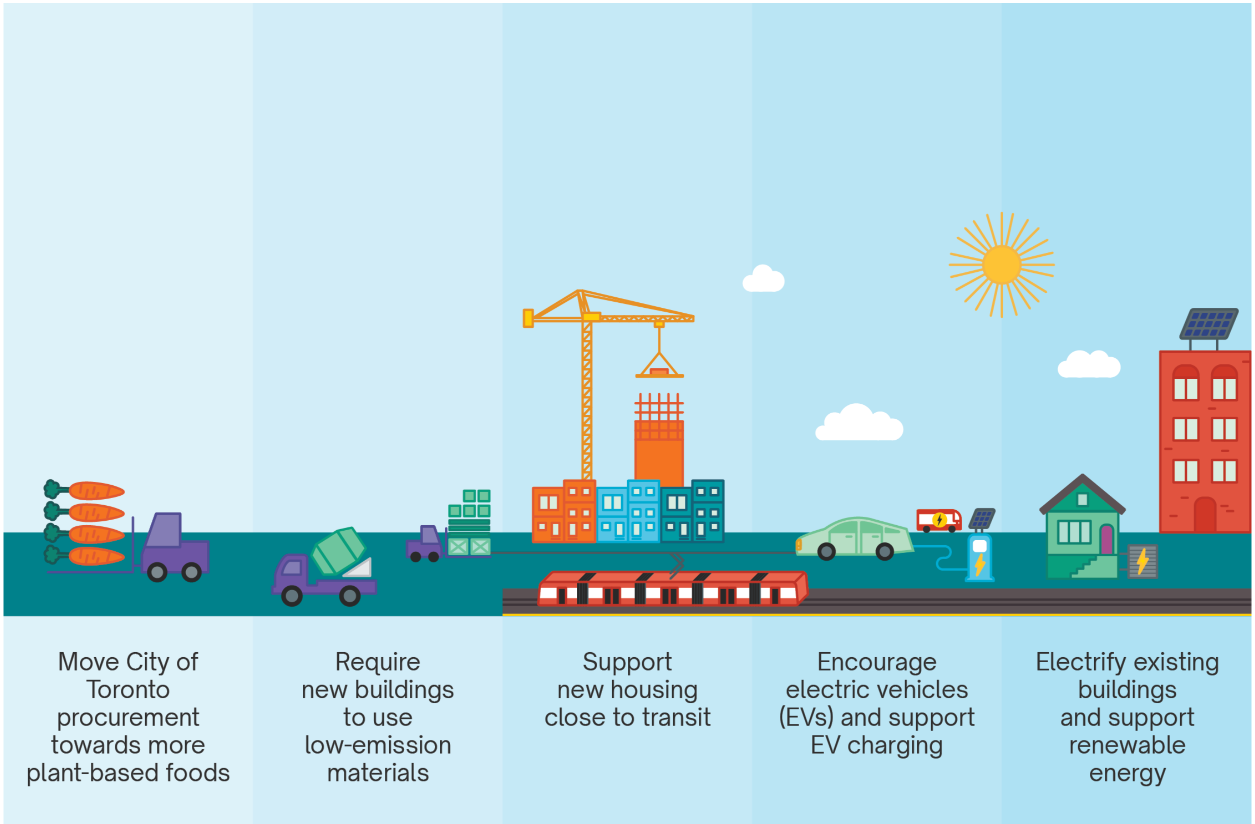
Across Toronto's community-wide consumption-based emissions inventory, transportation (specifically gasoline consumption) and natural gas usage present the greatest opportunities for the city to reduce emissions feasibly and readily from their current levels (though addressing natural gas usage will require collaboration with the Province). Eliminating emissions from natural gas and gasoline would reduce Toronto's average household consumption-based emissions by 10.1 tCO_2e, or 30 per cent overall.

Addressing emissions in these sub-categories directly aligns with existing City efforts and strategies outlined in the Council-adopted TransformTO Net Zero Strategy[25] (NZS), Net Zero Existing Buildings Strategy[26] (ExB), and Electric Vehicle Strategy[27]. The NZS sets an explicit goal of eliminating fossil fuels (especially natural gas used in homes and gasoline used in cars) by 2040. In addition, it outlines critical strategies for ensuring near zero emissions for all new buildings, expanding non-automotive alternatives, and supporting both the ExB and Electric Vehicle Strategies. The ExB specifies further actions to support transitioning existing buildings to all-electric, while the Electric Vehicle Strategy will help the city meet EV uptake targets. Figure 13 highlights some of the City's work in these and other areas.

---

[25] https://www.toronto.ca/services-payments/water-environment/environmentally-friendly-city-initiatives/transformto/
[26] https://www.toronto.ca/services-payments/water-environment/net-zero-homes-buildings/
[27] https://www.toronto.ca/wp-content/uploads/2020/02/8c46-City-of-Toronto-Electric-Vehicle-Strategy.pdf

Figure 13. City of Toronto Efforts to Support a Reduction in Consumption-Based Emissions



Ultimately, full implementation of these strategies will bring emissions in these sub-categories to zero. Electrifying all homes will eliminate natural gas emissions, while moving Toronto residents to rely on EVs or biking, transit, or walking will eliminate gasoline emissions. Working on these existing City strategies will also provide cross-category benefits, reducing emissions from most services, including the healthcare and eating out sub-categories, by varying amounts (estimated on the order of 10 to 30 per cent, based on U.S. business emissions data).

Beyond gasoline and natural gas, a few other consumption sub-categories present significant opportunities for reductions, though they are more challenging to address at the municipal level. Meat and dairy consumption (Food), air travel (Transportation), and embodied emissions from building construction (Housing) are other areas that the City could feasibly set CBE reduction targets and implement policies and programs to achieve reductions. The City is currently exploring ways to reduce emissions from meat and dairy procured by the City in line with its Cool

Food Pledge commitments, and the Toronto Green Building Standard v4[28] sets standards for reducing embodied emissions from new building construction, but the City is not currently working on other initiatives to reduce community-wide meat and dairy consumption, or address the carbon intensity of air travel.

Based on full, on-time implementation of current policies and initiatives, Toronto could readily achieve a goal of a 30 per cent reduction, relative to 2019 levels, in household-level consumption-based emissions by 2040. This would reduce emissions by 10.4 tCO_2e per-household, down to a total of 24.2 tCO_2e per-household.

An intermediate goal of a 10 per cent reduction by 2030 relative to a 2019 baseline (reducing emissions by 3.5 tCO_2e per-household, down to a total of 31.2 tCO_2e per-household). These goals can be met through Council-adopted targets for reductions in gasoline and natural gas usage by residents alone.

Alternatively, the City could adopt a more aggressive consumption-based emissions specific target, going beyond the City's current climate action plans. By setting and working towards a more ambitious target, the City could achieve greater global reductions, alongside other co-benefits. For example, meeting a higher target for emission reductions would likely require policies to reduce meat consumption and support more sustainable and local production of both food and goods, improving health and community resiliency in addition to avoiding emissions. By setting and tracking progress towards consumption-based emissions targets over time, Toronto can measure its global influence on emissions and sustainability in ways not reflected in a SBEI.

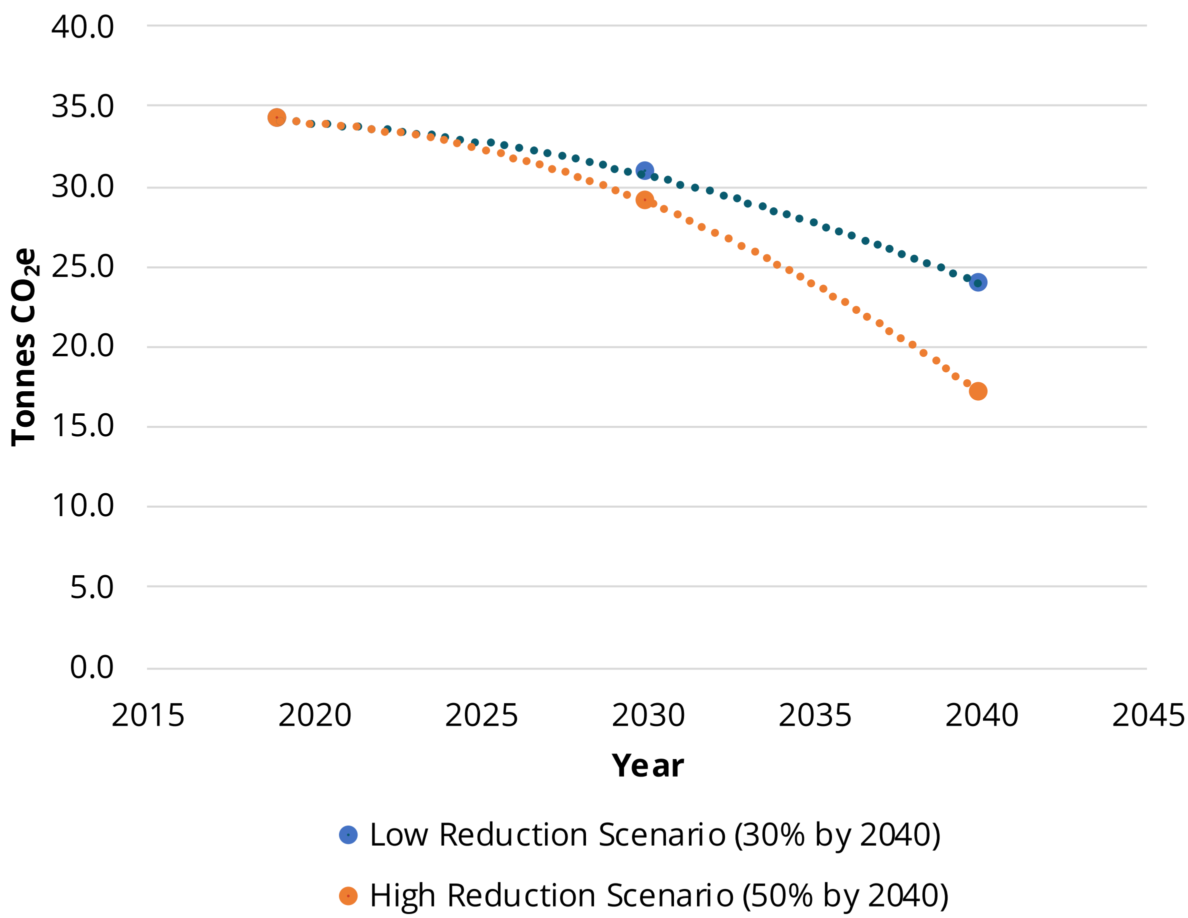
A more ambitious target for Toronto could be a goal of a 50 per cent reduction in per-household consumption-based emissions by 2040, relative to a 2019 baseline (reducing emissions by 17.3 tCO_2e per-household, down to a total of 17.3 tCO_2e per-household). This could be accompanied by an intermediate goal of a 15 per cent reduction by 2030, relative to a 2019 baseline (reducing emissions by 5.2 tCO_2e per-household, down to a total of 29.4 tCO_2e per-household).

These two potential emission reduction scenarios are compared in Figure 14, on the next page.

---

[28] https://www.toronto.ca/city-government/planning-development/official-plan-guidelines/toronto-green-standard/toronto-green-standard-version-4/

Figure 14. Potential CBEI Emission Reduction Targets



This 50 per cent reduction target could be achieved with broader economy-wide shifts and behavior changes.

For example, the emissions intensity of many goods and services has been declining at roughly an average one per cent per year rate[29]. By 2040, the emissions intensity of the goods, services, and eating out categories and sub-category can be expected to decline by roughly 20 per cent, which would avoid an additional eight per cent of total emissions.

---

[29] Consumption-Based Greenhouse Gas Emissions Inventory of San Francisco from 1990 to 2015, https://escholarship.org/uc/item/4k19r6z7

Meat and dairy comprise eight per cent of total emissions, and can be addressed by changing consumer choices. Meanwhile, air travel emissions (which make up three per cent) could be reduced with sustainable aviation fuel.

Many sub-categories also include embodied emissions from the construction of buildings to serve that industry (typically around 13 per cent), and emissions from transport, wholesale, and retail (typically around 5 to10 per cent), which could be reduced as well, through cleaner construction policies and broad vehicle electrification across business fleets and shipping.

Lastly, some materials (e.g., steel, concrete, and fertilizer), are currently made from very carbon-intensive processes which could be produced by low- or zero-carbon processes instead (such as green hydrogen for steel, concrete, or fertilizer, or blended content or carbon capture for concrete). Overall, a pathway to a 50 per cent reduction in emissions exists, but would require substantial and rapid changes in food choices, building energy sources and construction materials, jet fuels, and industrial processes, along with a more robust and diverse local supply network of goods and services.

Like with Toronto's ambitious net zero goals, these more ambitious targets would require successful collaboration, additional authority from, and/or action by other levels of government, the private sector, and residents. Achieving this level of reductions would require more significant programs and policies to effect greater societal change, including elements such as dramatically reducing emissions from air travel (such as through expansive use of sustainable aviation fuel), emissions associated with meat and dairy consumption, and emissions associated with construction.

Reducing household consumption-based emissions beyond 50 per cent would require still greater reductions in global emissions from the construction of buildings, production and transport of goods, and the service sector. Furthermore, due to emissions associated with nitrous oxide from fertilizer application, it may never be possible to fully achieve zero consumption-based emissions, even if all fossil fuel use is eliminated.

These community-wide consumption-based emissions targets are independent of the City's sector-based GHG emissions reduction targets. The more conservative goals – 10 per cent by 2030 and 30 per cent by 2040 – will be achieved, and exceeded, if the existing NZS initiatives are successful. As-is, the NZS strategies will affect many consumption categories – for instance, city-wide building electrification will not only reduce emissions from natural gas-fired heating of homes, but also from sub-categories such as eating out, healthcare, education, and other goods and services that are produced locally within Toronto, due to reducing emissions from natural gas used by the local businesses that provide those services to residents. Successfully switching all vehicles to zero-emission vehicles, as envisioned in the NZS, will not only avoid emissions from gasoline, but also from the transport of food and goods.

The more ambitious targets – 15 per cent by 2030 and 50 per cent by 2040 – would require additional efforts beyond the NZS. The NZS includes some actions that could support these additional efforts, including the short-term actions 15, 16, 18, 19, 20, 21, 23, 24, 29, and 30[30]; however, further actions and detail would be required. Specifically, the City would need to also work to reduce emissions from air travel, meat and dairy consumption, and new building construction (as envisioned in the Toronto Green Standard[31]), as well as work to promote greater production and consumption of local goods and services.

These targets would put Toronto at the forefront of community consumption-based emissions policy. Only a handful of other cities have adopted specific community-wide consumption-based emissions reduction targets to date:

- The City and County of San Francisco (U.S.) adopted targets to reduce community-wide consumption-based emissions by 40 per cent below 1990 levels by 2030 and 80 per cent below 1990 levels by 2050[32], goals which are equivalent to a roughly 16 per cent reduction below 2015 levels by 2030 and a 72 per cent reduction below 2015 levels by 2050[33].

---

[30] https://www.toronto.ca/legdocs/mmis/2021/ie/bgrd/backgroundfile-173757.pdf
[31] https://www.toronto.ca/city-government/planning-development/official-plan-guidelines/toronto-green-standard/toronto-green-standard-version-4/
[32] City & County of San Francisco. San Francisco Environment Code, Sec. 902 Climate Action Goals. https://codelibrary.amlegal.com/codes/san_francisco/latest/sf_environment/0-0-0-908
[33] City & County of San Francisco. "Consumption-Based Greenhouse Gas Inventory of San Francisco from 1990 to 2015." https://escholarship.org/content/qt4k19r6z7/qt4k19r6z7_noSplash_fb6cd829c9dc3869b5be1c0c2e7bf683.pdf

- London (U.K.) has adopted the target of reducing community-wide consumption-based emissions by two thirds below 2001 levels by 2030[34], equivalent to roughly a 45 per cent reduction from 2018 levels[35].
- Paris (France) has set targets to reduce consumption-based emissions by 35 per cent below 2004 levels by 2030 and achieve an 80 per cent reduction in consumption-based emissions by 2050[36,37].

It is important to note that, at least in the cases of San Francisco and London, these targets were set without technical evaluations of feasibility.

No Canadian cities have set community-wide consumption-based emissions targets that are applicable across all consumption categories. The City of Vancouver has adopted an embodied carbon reduction target for new construction[38].

The sections that follow provide additional details on actions the City of Toronto could take to achieve consumption-based emissions reductions.

Gasoline Emissions Reductions

The TransformTO NZS identifies the critical step of "Increas[ing] access to low carbon transportation options, including walking, biking, public transit and electric vehicles," with 2030 targets of achieving 75 per cent of school/work trips under 5km are walked, biked or by transit, and 30 per cent of registered vehicles in Toronto are electric. These targets are supported by short-term actions #8, 9, 10, 12, and 13,

---

[34] London Councils. "Consumption-based emissions in London have reduced but not fast enough to meet emission targets, warns new report." https://beta.londoncouncils.gov.uk/news/2021/consumption-based-emissions-london-boroughs-have-reduced-not-fast-enough-meet-emission

[35] London Councils. "Consumption-based emission profiles for London boroughs." https://www.londoncouncils.gov.uk/our-key-themes/climate-change/consumption-based-greenhouse-gas-household-emissions-profiles-london

[36] C40 Cities. "Paris Climate Action Plan: Towards a carbon neutral city and 100 per cent renewable energy." https://www.c40knowledgehub.org/s/article/Paris-Climate-Action-Plan-Towards-a-carbon-neutral-city-and-100-renewable-energy?language=en_US

[37] City of Paris. "Paris Climate Action Plan: Towards a Carbon Neutral City and 100 per cent Renewable Energies" (2018). https://cdn.locomotive.works/sites/5ab410c8a2f42204838f797e/content_entry5ae2f905a2f4220ae645f026/5af7316614ad660b652531de/files/Paris_-_Paris_Climate_Action_Plan.pdf?1526890697

[38] https://mantledev.com/insights/embodied-carbon/vancouver-reduce-embodied-emissions/

which align with moving Toronto residents away from gas-powered automobiles and towards zero-emission alternatives.

In particular, the City should prioritize the existing Electric Vehicle Strategy[39] and Cycling Network Plan[40]. The Electric Vehicle Strategy includes critical actions for expanding electric vehicle (EV) charging infrastructure and improving public awareness about EVs and EV options (including incentives).

In order to achieve Toronto's goal of net zero emissions by 2040, the City must achieve significantly accelerated EV uptake at rates well above the national average. Presently, Canada is targeting 50 per cent of new vehicles sold to be EVs by 2030 and 100 per cent by 2035. However, newly sold vehicles make up only a small fraction of total existing vehicles. Nationally across Canada, roughly two million new vehicles were sold annually between 2016-2019; with over 26 million vehicles on the road, it would take a minimum of 13 years to replace every vehicle with a new vehicle. If Toronto vehicle owners replace their vehicles at a similar rate as the Canadian national average, reaching 100 per cent of new vehicles sold as EVs by 2035 means that there will still be gas cars on the road as late as 2048, unless there is an accelerated replacement rate for existing vehicles.

Assuming normal vehicle replacement rates, achieving the Net Zero Strategy's target of 30 per cent of registered vehicles in Toronto are EVs by 2030 would require reaching 100 per cent of newly registered vehicles as EVs beginning around 2026-27 (depending on 2023-26 adoption rates). In Q3 2022, EVs made up about nine per cent of newly registered vehicles nationally[41]. Historically, Ontario has lagged national EV uptake rates in Canada[42].

As a result, full implementation of the EV Strategy is critical. However, Toronto can also increase the share of registered vehicles as EV by making it easy for people to reduce vehicle ownership. The NZS target of having 75 per cent of school/work trips under 5km are walked, biked or by transit, and the associated Cycling Network Plan,

---

[39] https://www.toronto.ca/wp-content/uploads/2020/02/8c46-City-of-Toronto-Electric-Vehicle-Strategy.pdf

[40] https://www.toronto.ca/services-payments/streets-parking-transportation/cycling-in-toronto/cycling-pedestrian-projects/cycling-network-plan/

[41] Electric Autonomy Canada, "Zero-emission vehicle market share hits record 8.7 per cent in Q3 2022: StatsCan" https://electricautonomy.ca/2023/01/24/zero-emission-vehicles-market-share/

[42] Global News, "Canada still not on track to meet electric vehicle sales target despite popularity" https://globalnews.ca/news/8776540/canada-electric-vehicle-popularity-federal-sales-target/

supports a reduction in vehicle use, and by extension, could give more residents the opportunity to reduce vehicle ownership as well.

In addition, Toronto should move forward with plans to increase density of both housing and jobs close to transit (particularly in the former City of Toronto / downtown). Neighborhood-level analyses of consumption-based emissions in the United States[43,44] shows that dense, walkable city centers and neighborhoods tend to have lower emissions than surrounding, more car-dependent lower-density neighborhoods. In particular, city centers tend to have the highest level of transit access and bike lanes, lowest rates of vehicle ownership, smaller home sizes, and more multifamily homes than surrounding neighborhoods. All of these factors serve to reduce household consumption-based emissions. In Toronto, the former City of Toronto has the lowest rates of vehicle ownership, the highest concentration of transit service, and the greatest level of amenities and services within walking distance. Building upon the existing success of the former City of Toronto is likely to be the best way to ensure that new households in the city are able to live a low-emission lifestyle.

Building more homes and destinations close to transit can help Toronto further reduce greenhouse gas emissions from transportation, avoid increased infrastructure emissions from sprawl, and protect natural habitats from greenfield development.

Natural Gas Emissions Reductions

The TransformTO NZS short-term actions #4 and 5, along with the Toronto Green Standard and Net Zero Existing Buildings Strategy, align with moving Toronto residents away from natural gas heating and appliances towards clean, all-electric buildings.

While the Toronto Green Standard will effectively address natural gas usage in new buildings, Toronto faces the challenge of ensuring hundreds of thousands of existing buildings are retrofitted to be all-electric, including homes and apartments but also offices, restaurants, hospitals, industrial and research facilities, and

[43] Jones, CM and Kammen, DM. "Spatial Distribution of U.S. Household Carbon Footprints Reveals Suburbanization Undermines Greenhouse Gas Benefits of Urban Population Density" https://pubs.acs.org/doi/abs/10.1021/es4034364
[44] The New York Times, "The Climate Impact of Your Neighborhood, Mapped" https://www.nytimes.com/interactive/2022/12/13/climate/climate-footprint-map-neighborhood.html

more[45]. The Toronto Net Zero Existing Buildings Strategy[45] (ExB) outlines a path to achieving full decarbonization of the existing building stock in Toronto. Because of the scale and complexity of the challenge of retrofitting virtually every building in the city of Toronto within the next 30 years, every step outlined in the ExB is critical. In particular, the magnitude of effort by the City and other governments around actions 4-8 in the ExB (financing and funding, integrated retrofit support, permitting and approvals processes, awareness education for building owners, and workforce development and training) will be major determinants in whether the City is able to meet its sector-based net zero targets.

Assuming the City is successful, reducing natural gas emissions will have major benefits to community-wide consumption-based emissions. Eliminating natural gas use will reduce community-wide consumption-based emissions by over 12 per cent through impacting the Housing category consumption-based emissions, and will also have additional effects on the consumption-based emissions associated with eating out, goods, and most services, including healthcare. This could potentially result in another 3 to 5 per cent in total avoided consumption-based emissions in addition to the 12 per cent reduction from reduced Housing category emissions, for a total of 15 to 17 per cent reduction.

Air Travel Emissions Reductions

Reductions in emissions from air travel emission will likely need to be driven by the use of sustainable aviation fuel (SAF), which is outside of the City's direct jurisdiction. The Canadian Council for Sustainable Aviation Fuel (C-SAF), launched in 2022 and led by Toronto Pearson International Airport, is Canada's leading organization working to accelerate the production and use of Canadian-made low-carbon and sustainable aviation fuels in Canada[46]. The City of Toronto could coordinate and collaborate with C-SAF to advance the use of SAF.

While the production and use of SAF is not within the City's direct authority to implement, the City can potentially play an important and valuable role in the production of SAF. Presently, one of the biggest barriers to SAF development is limited volume of feedstocks from non-edible sources. These feedstocks can come from a variety of sources, such as municipal solid waste (MSW), waste tallow

[45] https://www.toronto.ca/wp-content/uploads/2021/10/907c-Net-Zero-Existing-Buildings-Strategy-2021.pdf
[46] Canadian Council for Sustainable Aviation Fuel. https://c-saf.ca/

(animal fat) or lignocellulosic (woody) biomass[47]. As the largest city in Canada, Toronto may be in a position to become the largest provider of MSW SAF feedstock in the country. In addition, SAF faces challenges in finding suitable facility locations that have simultaneous access to feedstocks and proximity to distribution infrastructure. However, there are existing refinery facilities in Toronto (near York University, north of the former Downsview Airport), with access to rail lines that also connect to Toronto Pearson International Airport. Toronto is well poised to be the first Canadian producer of SAF if it can ensure adequate zoning and access to the municipal waste stream for private enterprise. The City might also consider local incentives for SAF production, in order to further reduce any GHG emissions associated with transporting the SAF from alternative locations further away.

Meat & Dairy Emissions Reductions

The City of Toronto has signed on to the Cool Food Pledge[48], committing to reduce emissions associated with food procurement for its own operations by 25 per cent by 2030, relative to a 2019 baseline. This 2019 baseline was an estimated 45,857 tCO_2e, or roughly 0.1 per cent of the community-wide CBEI. In addition, the City has signed on to the Good Food Cities Declaration[49], committing to support an overall increase of healthy plant-based food consumption by shifting away from unsustainable, unhealthy diets. The Good Food Cities Declaration also commits the City to reduce food loss and waste by 50 per cent, and to work with citizens, businesses, public institutions and other organizations to develop a joint strategy for implementing these measures and achieving these goals inclusively and equitably.

Under the Cool Food Pledge, the City has developed a set of initiatives to address emissions associated with food procurement. This report presents some potential options for the City to explore further to address emissions associated with food consumed by residents.

Emissions from food result from three general supply chain stages:

---

[47] Deloitte Canada. “Reaching cruising altitude – A plan for scaling sustainable aviation fuel.” https://www2.deloitte.com/content/dam/Deloitte/ca/Documents/strategy/ca-en-strategy-sustainable-aviation-pov-aoda.pdf

[48] https://coolfood.org/pledge/

[49] C40 Cities, “14 cities commit to sustainable food policies that will address the global climate emergency” https://www.c40.org/news/good-food-cities/

- fertilizer to grow plants,
- emissions from livestock, and
- emissions associated with food lost as waste.

These recommendations focus on strategies for reducing emissions associated with the consumption of animal products and reducing food waste, as plant-based foods are the least carbon-intensive options. Meat and dairy products the most carbon-intensive foods, and plant-based alternatives are more environmentally sustainable (and often healthier).

To reduce emissions from the consumption of meat, poultry, fish, eggs, and dairy, the city can prioritize policies that shift resident choices around food. Generally, there are two strategies for shifting diets: 1) educate and inform consumers on the impacts of their dietary choices, and 2) shift the social, economic, and/or behavioural environments in which consumers make their choices.

For example, strategies may include expanding education in schools and on City websites and requiring signage and labeling to help inform residents on the impacts of their food purchasing choices. Advertising campaigns to alter public perception of plant- or animal-based options, price signals on plant- or animal-based products (e.g. through taxes or subsidies), or other requirements around the placement and prominence of plant- or animal-based foods (such as in stores, restaurants, and/or public facilities that serve food) would be strategies to alter the decision-making environment for residents.

These policies can also be either positively or negatively framed, through the metaphorical "carrot or the stick" approach[50]. Generally, "carrot" policies that promote and encourage the consumption of plant-based options are more palatable and politically feasible than "stick" options that discourage or penalize consumers of animal-based options (which can also raise equity and cultural considerations).

Toronto can start by increasing familiarity, awareness, and comfort with plant-based alternatives. The City could also leverage its own procurement to require vendors that contract with the city to offer standard plant-based alternatives to all clients, expanding access to and visibility of low-emission foods.

---

[50] Collins Dictionary, https://www.collinsdictionary.com/dictionary/english/carrot-and-stick

Toronto can also prioritize public school food procurements by collaborating with the Toronto District School Board (TDSB) and the government of Ontario to support a switch to plant-based school meals. More than 211,000 Toronto students participate in student nutrition programs daily[51]. The primary objective of a plant-based school meal program would be to educate and highlight plant-based options for children. Increasing informational awareness could be easily achieved by incorporating plant-based alternatives in the TDSB's Student Nutrition Program that already provides education on healthy eating and cooking habits for students[52]. Building familiarity and comfort with plant-based foods at school can set community members up for a lifetime of healthy eating and influence the behaviors of parents and other family members.

Going beyond schools, the City could also work to follow the example set by Portugal[53], and work with other government agencies to ensure that all public facilities (such as schools, universities, hospitals, prisons, etc.) serve at least one plant-based option for every meal. While the City's Cool Food Pledge commitment and plans ensure that City procurement will prioritize plant-based options, there are other government bodies within city limits that the City can work with to move to sustainable food purchasing. The City could also work with the provincial or federal governments to advocate for a nationwide policy in all public buildings.

By the end of 2021 in Portugal, one survey found that over 70 per cent of diners at these facilities were choosing the vegetarian option[54].

Lastly, Toronto should consider expanding awareness of plant-based options by exploring options to encourage or require restaurants and grocery stores to provide clear, standardized signage for plant-based options. Presently, there is no official logo or certification system in Toronto for labeling vegetarian or vegan foods

---

[51] City of Toronto, Student Nutrition Program. https://www.toronto.ca/community-people/health-wellness-care/health-programs-advice/student-nutrition-program/

[52] City of Toronto. "Student Nutrition Program." Accessed February 16, 2023. https://www.toronto.ca/community-people/health-wellness-care/health-programs-advice/student-nutrition-program/

[53] Hunter College New York City Food Policy Center, "Vegan Menu Option Requirement, Portugal: Urban Food Policy Snapshot" https://www.nycfoodpolicy.org/vegan-menu-option-requirement-portugal-urban-food-policy-snapshot/

[54] Associação Vegetaríana Portuguesa, "Opção Vegetariana nas Cantinas Públicas" / Portuguese Vegetarian Association, "Vegetarian Option in Public Cantines": https://www.avp.org.pt/wp-content/uploads/2022/05/Estudo-Opcao-Vegetariana-Cantinas-Publicas-2022-1.pdf

in grocery stores or restaurants. Some restaurants and food businesses may use their own logos or symbols, but the lack of consistency prevents residents from becoming familiar with common plant-based options. The City could partner with local organizations such as the Toronto Vegetarian Association[55] (VegTO) or VegeCert[56] to develop a local standard logo and certification system, or seek to support the development of a national or internationally recognized standard.

Requiring standard signage and visibility can help shift behaviors[57]. To minimize the impacts to businesses, the requirement can be adopted with a long phase-in time (such as 1 to 2 years), to allow for signs and menus to be replaced with signed options on their ordinary replacement schedule, instead of requiring an additional outlay from businesses.

It is unclear whether Toronto would legally be able to require signage in grocery stores or restaurants, however. Such a requirement may need to be developed at the provincial or national level. Alternatively, Toronto could also work with industry groups such as the Retail Council of Canada[58], which sets voluntary standards for price labeling in retail establishments[59], to incorporate new labeling standards for plant-based or environmentally friendly foods (or products generally).

Further Analysis & Progress Monitoring

This report provides an initial baseline of community-wide consumption-based emissions, and outlines some potential reduction targets and strategies for achieving those goals.

However, there remains a need for additional analysis, data collection, and progress monitoring. In addition, due to the limitations of the data and CBEI methodology, the City may be better able to reduce emissions by setting targets and tracking data on specific sub-categories of emissions, rather than setting overall CBEI reduction targets.

---

[55] https://www.veg.ca/
[56] https://vegecert.com/
[57] World Resources Institute Cool Food Pledge Playbook: https://www.wri.org/research/playbook-guiding-diners-toward-plant-rich-dishes-food-service
[58] https://www.retailcouncil.org/
[59] https://www.retailcouncil.org/scanner-price-accuracy-code/

CBEI Data and Methodology Limitations

A number of data and methodology limitations restrict the ongoing usefulness of a CBEI for Toronto's future work to reduce consumption-based emissions.

Firstly, the community-wide CBEI approach for Toronto relies heavily upon U.S. datasets which may not be fully accurate or appropriate for Toronto's or Canada's economy. This CBEI uses both a consumption model based upon U.S. spending patterns, as well as emissions factors based upon the U.S. economy. Ideally, future work would use a consumption model based upon Canadian spending patterns, and emission factors based upon Canada-, Ontario-, or Toronto-specific economic and emissions data.

Even with a Canada-specific model and dataset, however, the overall methodology still relies on assumptions about consumption and behavior patterns based upon household characteristics provided through the Canadian census. Updated census data is only available every five years, with a roughly one year lag. Toronto could prepare a 2021 community-wide CBEI, but going forward, Toronto would only be able to prepare a new CBEI every five years. After a 2021 inventory, the next opportunity to prepare a community-wide CBEI would be late 2027 or early 2028, using 2026 census data.

Lastly, this approach relied on overall Toronto citywide average household characteristics only. A more detailed, neighborhood-scale analysis of consumption-based emissions, combined with household demographic and socioeconomic data, would allow for more granular understanding of which households have higher or lower levels of consumption in different sub-categories, and which communities might be impacted by policies aiming to address certain emissions. This is commonly done for CBEIs in the U.S., such as San Francisco[60], Seattle[61], and New York[62], and could be done in a future CBEI for Toronto.

---

[60] Jones, CM. "Consumption-Based Greenhouse Gas Inventory of San Francisco from 1990 to 2015," https://escholarship.org/uc/item/4k19r6z7

[61] City of Seattle Consumption-Based Emissions Inventory. https://www.seattle.gov/environment/climate-change/climate-planning/performance-monitoring#consumptionemissions

[62] New York City Household Consumption-Based Emissions Inventory. https://climate.cityofnewyork.us/wp-content/uploads/2023/04/NYC-Household-Consumption-GHG-Emissions-Inventory.pdf

Reduction Targets and Pathways

The consumption-based emissions targets outlined in this report are preliminary estimates of what the range of feasible emission reductions may look like. However, these are only early estimates – the necessary strategies for addressing each sub-category of emissions can quickly become highly technical and complex.

Due to the current limitations on data availability and in the CBEI methodology, future CBEIs may not fully reflect changes in consumption patterns or the emissions intensities of goods and services consumed, making it less useful for target-setting. These limitations may also mean that the City would only be able to prepare an updated CBEI every five years, with the release of updated national census data, unless the City uses an alternative approach to monitoring and tracking consumption-based emissions.

As an alternative to setting an overall reduction target for consumption-based emissions, the City could instead set policy- or category-specific targets, or even set targets based upon readily available, actionable data that indicates changes in consumption-based emissions without directly monitoring those emissions ("actionable data indicators" or ADI).

The Cool Food Pledge approach provides an example. Currently, the Cool Pledge sets a specific target for emissions from food procurement for internal operations, without addressing all categories of consumption. If and when the City develops policies for specific sub-categories of emissions, it can also set specific targets for the category or policy outcome, and determine appropriate metrics to track progress for that given category. This ADI approach is gaining support from C40 Cities, with forthcoming research[63] that may be able to provide additional guidance and support for Toronto upon release.

Using ADI would require preparing in-depth analysis on specific sub-categories of emissions. The City of Toronto has already prepared in-depth reports analyzing the feasibility and scale of change required to achieve reduction targets from buildings, transportation, and food procurement, which can serve as guidance. New analyses

[63] C40 Cities, "Request for Proposals: Actionable Data Indicators for Consumption-Based Emissions for London and New York City" https://www.c40.org/wp-content/uploads/2022/10/C40-RFP_-Actionable-Data-Indicators-for-Consumption-Based-Emissions.pdf

would need to be prepared for other areas, like community-wide food consumption or air travel.

Gasoline and natural gas are the top two sources of consumption-based emissions, and ADI can already be tracked to monitor progress in these sub-categories:

- The City can track progress on EV uptake through vehicle registration and survey data. The City currently receives EV and non-EV registration data annually from the provincial Ministry of Transportation (MTO). While this data is not categorized by resident vs. non-residential (e.g. business or other) registrations, most vehicles are owned by residents, and reasonable assumptions can be made about how resident EV ownership is changing based upon total EV registration data (in line with the EV Strategy and NZS EV uptake targets). However, this data could be improved if the MTO were able to provide residential registrations separately from non-residential.
- Progress on building electrification can also be measured by permitting data and utility-provided reports on natural gas usage. Using permitting data and utility reports, the City will be able to measure and track both residential and non-residential building electrification progress.

EV uptake and building electrification progress tracking alone would be sufficient to ensure the City meets a 30 per cent reduction by 2040 target. However, a more ambitious target would require additional data collection and tracking, which may prove challenging.

Some additional data that could prove helpful for refining the identified consumption-based emission reduction targets and help measure progress include:

- Data on residents' diets, such as per cent of residents who are vegan or vegetarian, or number of plant-based meals consumed;
- Restaurant and/or grocery store sales data (particularly meat);
- Airport or airline procurement of sustainable aviation fuel;
- Embodied carbon from new construction (e.g. by expanding existing permit data systems to incorporate reported embodied carbon intensities).

Conclusion & Next Steps: Community-wide Consumption-based Emissions

Toronto's per-household consumption-based emissions are roughly 34 tonnes of CO_2e annually, slightly below the Canadian average of 37 tCO_2e per-household. Toronto's largest categories of consumption-based emissions are food, transportation, and services. The City can target reductions in gasoline use in residents' vehicles, natural gas use for home heating, and residents' meat and dairy consumption. In addition, the City can expect to achieve emission reductions (in both consumption- and sector-based emissions inventories) across multiple other consumption categories from policies that target both residential and commercial / industrial buildings that provide goods and services to local residents.

By prioritizing implementation of the existing TransformTO NZS, including policies and initiatives around electric vehicles (such as Toronto's EV Strategy), the citywide Cycling Network Plan, the Toronto Green Standard, and the Existing Buildings Strategy, the City can achieve the largest and most feasible consumption-based emission reductions of 30 per cent from the 2019 baseline of 34 tonnes per year. In addition, if the City were to adopt policies to encourage and support residents in choosing plant-based food options in lieu of meat & dairy, and work to promote local production of sustainable aviation fuel, it could realize consumption-based emission reductions of as high as 50 per cent.

Ambitious reduction targets of 15 per cent by 2030 and 50 per cent by 2050 for household consumption-based emissions would be well-aligned with existing sector-based emissions reduction and climate action goals and will ensure the City takes a leadership role in addressing GHG emissions that occur inside and outside city borders. However, given the limitations of the CBEI methodology and data, the City should not expect to use frequent inventory updates to monitor progress. Instead, the City should set targets specific to individual sub-categories, and track readily available data that can be used to evaluate progress in reducing consumption-based emissions in those specific areas.

Appendix A – Community-wide Consumption-based Emissions Inventory Methodology

General Overview

The community CBEI is not a direct measurement of individual households' consumption or behavior. Instead, a model (a series of complex calculations) is used to estimate consumption of goods and services and associated emissions. This approach uses a combination of real-world consumption or emissions data where available along with predictions based upon demographic, regional, and national averages.

Preparing a complete CBEI involves multiple models. The standard EcoDataLab CBEI methodology uses three models: a vehicle miles travelled (VMT) model, a household energy model, and a consumption model. The consumption model is built of separate sub-models for each sub-category of consumption, excluding gasoline and household energy use. Each model and sub-model follows the same general formula, described below.

1) Select a survey

First, a nationwide survey, conducted by the U.S. federal government, that focuses on an important element of the inventory is selected. The U.S. models are built using the Consumer Expenditures Survey (CEX)[64], the National Household Travel Survey (NHTS)[65], and the Residential Energy Consumption Survey (RECS)[66].

These surveys are used to build the full suite of models for the CBEI. CEX provides data used to model all sub-categories of consumption except for gasoline and home energy use. NHTS provides data for the vehicle miles travelled model, which translates into gasoline usage. RECS provides data for the home energy use models including electricity, natural gas, and other heating fuels.

2) Identify key household characteristics

Next, household characteristics are identified which are both included in the survey and for which nationwide data from the U.S. census and other data sources are

---

[64] https://www.bls.gov/cex/
[65] https://nhts.ornl.gov/
[66] https://www.eia.gov/consumption/residential/

available. These data include variables like household size, income, vehicle ownership, etc. Geography, climate, and other relevant data are also included where applicable. For a complete list of variables in each model, see Model Input Variables below.

3) Build a predictive model

With the nationwide survey and selected household and geographic characteristics, a computer program is run to identify how strongly each of those household characteristics correlate with the survey results. This technique is called multiple linear regression, and is a type of machine learning. The computer sees many input data (the household and geographic characteristics) and learns how to predict what the outcome will be (the survey result). The computer then provides an equation that takes each of those household and geographic characteristics and produces an estimated result.

A single linear regression might take this form:

$$y = mx + b$$

where y is the survey result (dependent variable), x is the household and geographic characteristics (independent variable), m is the computer's predicted correlation between x and y (slope), and b is a fixed value that adjusts for any underlying base discrepancy between x and y when x is equal to 0 (intercept).

In multiple linear regression, the equation takes on a more complex form:

$$y = m_1x_1 + m_2x_2 + m_3x_3 + \ldots + b$$

where in this case, each x (x_1, x_2, x_3, etc.) is a different household or geographic characteristic, with its own unique correlation (m_1, m_2, m_3, etc.), that together add up to produce the overall result. The number of x variables depends on the sub-model and available data. Almost all sub-models use at least six variables (...x_6), with some using a dozen or more to reach the most accurate prediction possible.

In addition, many of the values considered do not scale linearly. Instead, the models often look more like this:

$$ln(y) = m_1x_1 + m_2*ln(x_2) + m_3x_3 + ... + b$$

where the survey result might actually be scaled as a natural log (ln) variable, and some of the household and geographic characteristics are also calculated using its natural log (or sometimes both its ordinary and natural log values). This generally occurs in cases where there are nonlinear effects from household characteristics, and smaller values have different implications than larger values. For example, a household of two is typically two adults, whereas a household of three typically includes a child, which can significantly change consumption patterns. Similarly, consumption patterns based on income change significantly once basic needs are met and "luxury goods" start being consumed.

4) Run the model using local data

After these multivariate logistic regression models are built (see above), local data is then collected to be used in the model. These data consist mostly of census and climate data, from federal sources including the U.S. Census Bureau, the National Oceanic and Atmospheric Administration (NOAA), but also include things like energy prices, inflation rates, fuel economy, and emission factors from sources including the Energy Information Agency (EIA), the Bureau of Labor Statistics (BLS), the Department of Energy (DOE), and the Environmental Protection Agency (EPA). Those values are transformed to fit the required inputs to the model, and then the model is run with that local data as the independent (x) variables in the model.

Running these models produces dollars of household expenditures for most sub-categories of consumption, except for the VMT and household energy models, which produce estimated miles travelled by private automobile and energy usage (in kWh of electricity, therms of natural gas, and BTU of other heating fuels).

5) Calculate emissions

After calculating consumption using the models, emissions are calculated. Most consumption emissions are calculated using the U.S. EPA's U.S. Environmentally Extended Input-Output Model (USEEIO)[67], which bridges the gap between

---

[67] https://www.epa.gov/land-research/us-environmentally-extended-input-output-useeio-models

consumption (dollars) and emissions (grams of CO_2e). The USEEIO model includes data on emissions by sector and supply chain stage, allowing for differentiation between emissions associated with production, transport, wholesale, and retail, for all U.S. emissions (emissions occurring outside the U.S. are not included). To account for emissions associated with fixed capital investments (e.g. buildings & infrastructure construction, excluding residential construction), all sub-category emission factors are increased by roughly 13 per cent, in line with the overall economy-wide share of emissions attributable to fixed capital. (Research is underway to better allocate fixed capital emissions to the associated sub-category)

In the standard U.S. approach, electricity emissions are calculated using EPA's Emissions and Generation Resource Integrated Database (eGrid) emission factors, detailed at the zip code level and then scaled to any geography. For all other direct consumption of fuels (natural gas / methane, gasoline, etc.), the latest Intergovernmental Panel on Climate Change (IPCC) estimates of global warming potential (GWP)[68] and best available academic literature are used to estimate life-cycle emissions. (IPCC GWP values are commonly used across the majority of emissions reporting protocols, such as the Global Protocol for Community-Scale GHG Inventories[69] and the Local Government Operations Protocol[70]). This includes fugitive emissions (e.g. undesired leaks of greenhouse gases) and non-CO_2 GHG emissions, as well as any additional climate forcing effects from other emissions (such as particulate matter or contrails).

When working with local jurisdictions, these national or grid average emission factors are replaced with the best available local data.

6) Make final adjustments to consumption estimates

While the multiple linear regression model help to estimate consumption, the model does not perfectly resemble reality. These discrepancies are adjusted by comparing the model's predicted results with real-world data wherever available, and scaling the model outputs accordingly where real-world data isn't available.

To achieve this, the model results are compared with the actual results for the

---

[68] IPCC AR6 Chapter 7: Supplementary Material. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter_07_Supplementary_Material.pdf
[69] https://ghgprotocol.org/greenhouse-gas-protocol-accounting-reporting-standard-cities
[70] https://ww2.arb.ca.gov/local-government-operations-protocol-greenhouse-gas-assessments

most granular level of data available. This can be national-level data (in the case of surveys), state- or province-level data (in the case of transportation), or locality-level data (in the case of energy or water consumption). For cases where real-world data is available at the geographic scale of interest, the real-world data is used instead; otherwise, the model is run at the same geographic level at which data is available and use that to create a scaling factor, which is used to correct the locally modeled data. For example, modeled state-level energy use is compared with real state-level energy data, and then used to generate a scaling factor to adjust each census tract's modeled energy use. This scaling correction is usually on the order of 10 per cent.

City of Toronto Assumptions and Adjustments

Many of the underlying principles and assumptions of the U.S. CBEI model have been retained in preparing the City of Toronto's community-wide CBEI. However, multiple adjustments have also been made to adapt the standard approach outlined above for use in Canada and for the City of Toronto.

Steps 1 through 3 outlined above, used to prepare the underlying models, remained largely constant. The community-wide CBEI was developed using the assumption that Toronto residents have the same consumption patterns that Americans would, if Americans lived in Toronto. As a result, we could use the pre-existing U.S. model formulas without adjustment. However, one adjustment was made to the VMT model, to remove two variables that consider how race in the U.S. correlates with different levels of household VMT. In addition, because Toronto already had household energy data available, the U.S. energy models were not used for energy.

For data collection, city-wide and nation-wide data from the Canadian census was collected from StatCan for 2016[71] and 2021[72]. Linear interpolation was used to estimate household characteristics for 2019, and vehicle ownership data was retrieved from the Transportation Tomorrow Survey[73].

---

[71] StatCan, 2016 Census Profile. https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/index.cfm?Lang=E

[72] StatCan, 2021 Census Profile. https://www12.statcan.gc.ca/census-recensement/2021/dp-pd/prof/index.cfm?Lang=E

[73] Transportation Tomorrow Survey 2016. http://www.transportationtomorrow.on.ca/

Prior to running the model, household incomes were converted into USD using Bank of Canada exchange rate data for 2019[74]. After producing the model results, VMT was converted into vehicle kilometers travelled (VKT) and combined with TEPS model data from the University of Toronto to estimate overall fuel consumption. A lifecycle emissions scaling factor of 20 per cent was also applied to account for upstream emissions from the production of gasoline.

USD-based model outputs of consumption were normalized based on 2019 U.S. household expenditure survey data and combined with U.S. EEIO emission factors to produce overall consumption emissions.

For household energy use, electricity and natural gas usage data was provided by the City of Toronto. Electricity consumption for multifamily housing units was estimated using NRCan data for Ontario households by housing type to scale existing Toronto data on single-family households.

Toronto city staff estimated that 95 per cent of households use natural gas for heating using the following approach:

Rate of natural gas use for heating systems in Toronto residential buildings

Municipal Property Assessment Corporation (MPAC) data for Toronto[75] describes the heating system used in each building in the city. As of December 2022[76], approximately 95 per cent of residential buildings in Toronto used heating types of forced air, hot water, or gravity hot air. The City of Toronto assumes these three heating types utilize natural gas as their primary fuel source.

To reach this estimate, City staff analyzed the latest available MPAC Electronic Assessment Information (EAI) file entitled "EAI-1900-structure," which contains these fields:

- STRUCTURE - Str Code: This field denotes the structure type. Classes 300 through 399 are residential structures.

---

[74] Bank of Canada, Annual Exchange Rates. https://www.bankofcanada.ca/rates/exchange/annual-average-exchange-rates/

[75] The City of Toronto extracts Electronic Assessment Information (EAI) files from MPAC on a quarterly basis. The file "EAI-1900-structure" contains data on the structure type and heating system used in each structure (building). Further details are available from MPAC: https://mpac.ca/sites/default/files/docs/pdf/mpdf/EAIFileSpecificationsALL.pdf

[76] MPAC EAI dataset extracted December 12, 2022.

- STRUCTURE - Heating: This field denotes the heating system used in the structure. Classes include:
  - FA: Forced air
  - HW: Hot water
  - EL: Electric
  - GR: Gravity hot air
  - PL: Pipeless hot air
  - RD: Radiant electric
  - OT: Other - steam, solar
  - NO: No central heat

The dataset was filtered to count the number of structures with Str Code values between 300 and 399[77] and Heating classes FA, HW, or GR[78]. Of the total 812,322 residentials structures in the EAI dataset, 95 per cent of structures (771,196 structures) were labeled with a natural gas-powered heating system.

This figure was corroborated through City staff communication (March 2023) with Enbridge, Toronto's natural gas utility, who estimate that between 95 and 98 per cent of single family homes in Toronto currently rely on natural gas-powered heating systems.

Further, this figure of 95 per cent aligns well with the estimated share of residential homes in Toronto that use natural gas-powered heating systems that was applied in developing Toronto's Net Zero Strategy. That analysis assumed, as of 2016, 93.2 per cent of residential buildings utilized natural gas-powered heating[79].

Model Input Variables

The standard U.S. consumption models use the following six variables: household size, average income, vehicle ownership, home ownership, share of household

---

[77] See Appendix 8 for detailed descriptions of Str Code values 300-399: https://mpac.ca/sites/default/files/docs/pdf/mpdf/EAIFileSpecificationsALL.pdf

[78] City staff assume hot water heating systems are 100 per cent natural gas-powered, and assume gravity hot air heating systems have been converted to natural gas-powered heating systems since the MPAC dataset was collected.

[79] See Toronto's greenhouse gas technical modelling results dashboard, "Building End Use" category, "BAP - Residential Building End Uses by System" table, "Furnace Gas" System "2016 Share" value: https://cis-community.ssg.coop/toronto/bld-end-use

respondents with a bachelor's degree or higher (educational attainment), and number of rooms (home size).

The Canadian-adjusted vehicle miles travelled model uses household size, average income, vehicle ownership, home ownership, and educational attainment, along with commute time to work, drive alone to work, number of homes per square mile, number of employed people per square mile, employed people per-household, family status, children per-household, youth per-household, adults per-household, and Census region.

The standard U.S. home energy models use household size, average income, home ownership, and home size as well as detached home status, heating and cooling degree days, statewide average price of electricity, statewide average price of natural gas, and census division. However, these U.S. home energy models were not used in the Toronto CBEI, due to the availability of local data.

Technical Details

The Consumer Expenditures Survey (CEX) is the only annual national survey of household consumption in the United States. Within the CEX, there are a total of 95 categories and sub-categories of expenditures for everything U.S. households consume, including detailed breakdowns of food, utilities, home construction, transportation, household goods and services.

The CEX is used as the initial basis for our consumption models across all categories of expenditures. Because the smaller sub-categories have more uncertainty and error associated with them, EcoDataLab's models are generally developed based upon topline means levels across the CEX dataset[80]. After running the models at the local level, local consumption estimates are normalized to national data by using a scaling factor based upon the ratio of national modeled results to real-world national survey results, across each category of consumption. CEX categories are then mapped to Personal Consumption Expenditures (PCE)[81]

[80] The CEX dataset includes multiple "tiers" of consumption, where smaller tiers roll up into larger tiers. For example, meat, dairy, fruits, and vegetables roll up into "Food at home", which combines with "Food away from home" to roll up into "Food". EcoDataLab's models are generally based on higher-level aggregates of consumption, and not more detailed breakdowns that are available in the data.

[81] https://www.bea.gov/data/personal-consumption-expenditures-price-index

developed by the Bureau of Economic Analysis (BEA)[82]. Each PCE maps to one or more sectors of the U.S. economy, and each sector has associated full supply chain emissions available through the U.S. EPA's USEEIO model. BEA's PCE Bridge Tables for 2012[83] allow for assigning emissions to cradle-to-gate, transportation to market, and trade stages. Custom emission factors (grams CO_2e per dollar of expenditure) are then created based on the detailed mapping of sectors, PCE and CEX categories. This converts average U.S. household expenditures to total U.S. emissions, broken down by each CEX category and in total.

These custom emission factors are then increased to account for embodied emissions in fixed capital investments (buildings and infrastructure). Emissions from fixed capital are attributed to each sector based upon that sector's economic weight. This results in a new, final emission factor (grams CO_2e per dollar of CE expenditure) that accounts for all lifecycle emissions associated with that category of expenditure.

However, these lifecycle emission factors based upon USEEIO data are only available for the year 2012. To calculate emissions in other years, they are adjusted backwards and forwards in time as needed using an average decarbonization rate (assumed one per cent[84]). Prior to calculating emissions, all modeled and real-world household expenditures are also normalized to 2012 U.S. dollars using the category-specific Consumer Price Index (CPI)[85] for each category.

While the CBEI models started with the CEX, greater accuracy in calculating emissions can be achieved by using other household surveys for specific sub-categories: namely, by using the National Household Travel Survey (NHTS) to model household vehicle miles travelled (VMT), and by using the Residential Energy Consumption Survey (RECS) to model household energy usage. These models are the most robust models that could be constructed using recent and relevant data, and in many cases are a very strong fit. For instance, at the U.S. state level, EcoDataLab's electricity and natural gas models have a goodness of fit R^2 value of about 0.87 and 0.72, meaning they explain about 87 per cent and 72 per cent of the

---

[82] https://www.bea.gov/
[83] https://apps.bea.gov/industry/xls/underlying-estimates/PCEBridge_2007_2012_DET.xlsx
[84] CoolClimate Network, Consumption-Based Greenhouse Gas Emissions Inventory of San Francisco from 1990 to 2015, https://escholarship.org/uc/item/4k19r6z7
[85] U.S. Bureau of Labor Statistics, Consumer Price Index for All Urban Consumers. https://www.bls.gov/news.release/cpi.t01.htm

variation in household energy use, for their respective categories of energy. When comparing with specific city- and county-level data, these modeled results are typically within about 10 per cent of the real-world data, providing sufficient accuracy for historical back-casting and local tract-level estimates of variation.

In preparing consumption-based emissions inventories, CEX-based modeled estimates of expenditures on gasoline, electricity, natural gas, and other fuels are replaced with results from these other sub-models. With these models, direct and indirect (well-to-pump) emission factors are applied for both fossil fuels and electricity consumed directly by households.

Gasoline emissions are normally based on U.S. national average vehicle fuel economy data[86] from the Department of Transportation, but in this case they were based on City of Toronto-provided data on citywide average vehicle fuel economy (indirect emissions were estimated based upon prior academic research). Electricity emission factors are usually based on U.S. EPA eGrid region emission factors[87] at the zip code level, and scaled to other geographies based on population, unless local emission factors are available (as is the case with Toronto).

Because of the combination of local characteristics to inform regression modeling and scaling based on real-world national data to capture general trends, this methodology allows for consistently tracking changes in the quantity of household consumption over time, and to estimate the impact of consumption on emissions using best-available sources.

As reported in the Consumption-Based Greenhouse Gas Emissions Inventory of San Francisco from 1990 to 2015[88], this consumption-based approach accounts for essentially all GHG emissions in the U.S. economy but allocated to households and government. Figure 7 in that report shows that the CBEI correlates very closely to the sector-based inventory (within 10 per cent). One limitation of this approach is that imports are assumed to be produced with the same carbon intensity as domestic production. Possible future work could incorporate a multi-regional input

---

[86] https://www.bts.gov/content/average-fuel-efficiency-us-light-duty-vehicles
[87] https://www.epa.gov/egrid/download-data
[88] CoolClimate Network, Consumption-Based Greenhouse Gas Emissions Inventory of San Francisco from 1990 to 2015, https://escholarship.org/uc/item/4k19r6z7

output model (MRIO) (such as Eora[89], Exiobase3[90], or OCED ICIO[91]) to account for the carbon intensity of imports. MRIO models incorporate data on the exchange of goods and services between different countries, allowing for adjustments to emission factors based upon global trade patterns and emission intensities of production in different countries.

Limitations

Unlike other CBEI approaches, which scale national emissions based upon single variables like income or population, this model approach allows for some ability to assess the effect of policy and to track changes over time. The current approach offers this improved tracking by including more policy-relevant variables, including home size, household size, home ownership, education, income, population density, and vehicle ownership.

However, local changes in policy, behavior, infrastructure, and technology which might affect consumption or emissions in ways beyond the model variables are not included in the current approach. If a local policy changed consumption patterns independently of household characteristics, or the carbon intensity of products or services consumed locally, these changes would not be tracked with the current methodology. Additional data could supplement the approach in future studies.

The current approach does not include an estimate of total error. Ideally, each estimate of consumption and emissions would include uncertainty bounds and analysis of error. Potential sources of error include reporting error in household survey day, sampling error, model error, categorization error, and other errors typically associated with input-output models (in this case, the USEEIO). In addition, in adapting the U.S. model for Canada, there may also be other unaccounted for differences in consumption behaviors and allocation of household spending to various consumption categories. Some of these errors are quantified (for instance, household characteristics in census data have error ranges provided); these error ranges could be included in the model outputs with additional research.

The carbon intensity of imported goods is also assumed to be the same as domestically-produced goods. The current model is unable to track the countries of

---

[89] https://worldmrio.com/
[90] https://www.exiobase.eu/
[91] https://www.oecd.org/sti/ind/inter-country-input-output-tables.htm

origin of emissions associated with local consumption. This assumption may affect individual products, such as computers, but is unlikely to have a large impact overall since the United States has a large, fairly carbon-intensive production system, with considerable electricity production from coal, similar to many exporting countries. Canada's emissions profile is generally similar to the U.S., though not identical. Future studies could incorporate a multi-regional input output model to provide better data on the effect of international supply chains on consumption-based emissions, or a Canada-specific environmentally-extended input-output model.

Lastly, it is also assumed that price corresponds with "value added" economic activity. If residents of an area purchase higher priced goods, then the methodology will linearly scale emissions up with prices. This scaling is appropriate if higher prices are the result of additional economic activity, such as importing products from abroad, but is problematic when prices are artificially raised, such as for branding purposes. Conversely, less costly products will result in lower emissions in the model. Generally, it is assumed that price differences average out over thousands of households.

Appendix B: Opportunities for Individual Action

Examples of Individual Actions to Reduce Gasoline Consumption

Some Toronto households already have low to no emissions from automobile usage. Based on the 2016 Toronto Tomorrow Survey, roughly 28 per cent of Toronto households do not own a vehicle[92]. In 2019, only about 51 per cent of workers drove to work[93]. In contrast, a Statista survey found that only 16 per cent of Canadian households did not own a vehicle[94], and StatCan data suggests about 75 per cent of Canadian households drive to work[93]. However, this still leaves most households with automobiles and a substantial fraction driving to work.

Given Toronto's built environment and transit service, many households can likely further reduce automobile usage from greater use of public transit, including both TTC services and regional GO trains, as well as biking. The City of Toronto has also recently adopted a Complete Streets Plan, aiming to expand safe & protected bike lanes throughout the city to further support alternative transit.

For households that aim to reduce their emissions from automobiles but cannot avoid driving, switching their primary commute vehicle to an electric vehicle is a common strategy. Depending on location and use case, some households can purchase one or more electric assist bicycles (e-bikes) to substitute for an automobile. E-bikes are bicycles that include an electric motor to assist pedaling, and can go up to 32 kph. Some models include large cargo carriers capable of carrying kids, groceries, or even furniture. Bike Share Toronto offers 24/7 access to bikes throughout the city[95].

Between bikeshare, public transit, and the availability of car-sharing, rentals, or taxis (including Uber and Lyft), some households can achieve significant reductions in automobile usage, or even eliminate their automobile use altogether.

---

[92] 2016 Toronto Tomorrow Survey, http://www.dmg.utoronto.ca/pdf/tts/2016/2016TTS_Summaries_TTSarea.pdf

[93] Estimate based on interpolation of StatCan data for Toronto between 2016 (https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/index.cfm?Lang=E) and 2021 (https://www12.statcan.gc.ca/census-recensement/2021/dp-pd/prof/index.cfm?Lang=E)

[94] Statista.com Car Ownership in Canada, https://www.statista.com/forecasts/998479/car-ownership-in-canada

[95] Bike Share Toronto, https://bikesharetoronto.com/.

Examples of Individual Actions for Reducing Natural Gas Use

Typically, the most effective ways for households to reduce their natural gas usage is to replace gas furnaces and water heaters with heat pumps, clothes dryers with electric alternatives, and gas cookstoves with induction cooktops. The City of Toronto has already established initiatives to support building decarbonization and enable households to move to clean, zero-emission appliances[96].

Even with financial support, these replacement appliances and associated home electrical upgrades can be expensive, so energy efficiency improvements in the interim can also help reduce natural gas usage.

Examples of Individual Actions for Reducing Food Emissions

Households that aim to reduce emissions from food have two primary strategies they can use. First, avoiding food waste and only buying as much food as the household needs is one of the easiest - and most cost-effective - ways to avoid food emissions. Second, replacing meat and dairy with plant-based substitutes can lead to further large emissions reductions. Buying organic and locally grown food does not typically have much impact on emissions but can provide other social and economic benefits.

Examples of Individual Actions for Reducing Electricity Emissions

Some common strategies for households to reduce their electricity emissions include energy efficiency improvements and/or switching to 100 per cent carbon-free or renewable electricity.

Ontario's electric grid is already 93 per cent carbon-free electricity. With growing electricity demand and maintenance scheduled for the province's main nuclear power plants, there is expected to be an increase in the use of fossil fuels for generating electricity over the next few years. Ultimately, however, IESO has prepared strategies to enable a zero-emission power grid by 2050. In the interim, however, there may remain some emissions from electricity, which individual residents could offset with separate renewable energy procurement, or on-site generation (e.g. rooftop solar).

---

[96] City of Toronto, Environmental Grants & Incentives. https://www.toronto.ca/services-payments/water-environment/environmental-grants-incentives/

To improve energy efficiency, households can improve insulation and weatherization, replace old lightbulbs with LEDs and ensure new appliances are EnergySTAR-certified, and use a smart thermostat to ensure heating and air conditioning only run when needed.