TOWN OF HALTON HILLS

Reference Scenario Results

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Contents

Part 1: Reference Scenario 1

1. INTRODUCTION 1

2. 2016 BASELINE 2

2.1 Geographic Scope

3. REFERENCE SCENARIO ASSUMPTIONS 2

3.1 Population and Households

3.2 Climate Change

3.3 Buildings

3.5 Local Energy Generation

3.6 Transit

3.7 Transportation Mode Share

3.8 Vehicles

3.9 Municipal Fleets

3.10 Waste and Wastewater

3.11 Industry

3.12 Other

4. BASELINE SCENARIO RESULTS 7

4.1 Baseline Energy, 2016

4.2 Baseline Emissions, 2016

5. REFERENCE SCENARIO RESULTS 11

5.1 Total Energy and Emissions, 2016-2030

5.2 Energy and Emissions, 2016-2030

6. CONCLUSIONS AND NEXT STEPS 22

Part 2: Data, Methods, and Assumptions Manual 23

1. INTRODUCTION 23

2. ACCOUNTING FRAMEWORK 23

2.1 Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC)

2.2 Role of the CityInSight model: Future emissions projections

3. EMISSIONS SCOPE 26

3.3 GHG Emissions Scope

4. MODELLING 27

4.1 About CityInSight

4.3 Stocks and Flows

4.4 Sub-models

4.5 Energy and GHG Emissions Accounting

4.6 Financial Accounting

4.7 Inputs and Outputs

4.8 Spatial Disaggregation

5. MODELLING PROCESS 41

6. ADDRESSING UNCERTAINTY 42

7. DATA AND ASSUMPTIONS FOR THE TOWN OF HALTON HILLS 43

7.1 Assessment Scope

7.2 Baseline Data

7.3 Emissions Factors

7.4 Reference Scenario Assumptions Summary

7.5 Detailed Reference Scenario Assumptions

Appendix 1. Reference Scenario Results Tables 66

Glossary

Baseline Year: the starting year for energy or emissions projections.

Carbon dioxide equivalent (CO2e): a measure for describing the global warming potential of a greenhouse gas using the equivalent amount or concentration of carbon dioxide (CO2) as a reference. CO2e is commonly expressed as million metric tonnes of carbon dioxide equivalent (MtCO2e).

Cooling degree days (CDD): the number of degrees that a day's average temperature is above 18oC, requiring cooling.

District energy: Energy generation within the municipal boundary that serves more than one building.

Emissions: In this report, the term 'emissions' refers exclusively to greenhouse gas emissions, measured in metric tonnes (tCO2e), unless otherwise indicated.

Electric vehicles (EVs): an umbrella term describing a variety of vehicle types that use electricity as their primary fuel source for propulsion or as a means to improve the efficiency of a conventional internal combustion engine.

Greenhouse gases (GHG): gases that trap heat in the atmosphere by absorbing and emitting solar radiation, causing a greenhouse effect that unnaturally warms the atmosphere. The main GHGs are water vapor, carbon dioxide, methane, nitrous oxide, and ozone.

Heating Degrees Days (HDD): number of degrees that a day's average temperature is below 18oC, requiring heating.

Local electricity: Electricity produced within the municipal boundary and sold to the electricity system operator or used behind the meter.

Reference scenario: a scenario illustrating energy use and greenhouse gas emissions which aims to reflect current and planned policies and actions that are likely to be implemented.

Renewable Natural Gas (RNG): Biogas resulting from the decomposition of organic matter under anaerobic conditions that has been upgraded for use in place of fossil natural gas.

Sankey: a diagram illustrating the flow of energy through a system, from its initial sources to points of consumption.

Stationary energy and emissions: stationary energy and emissions are related to fuel combustion in residential, commercial, and industrial buildings, as well as combustion for grid-supplied electricity.

Vehicle kilometres travelled (VKT): distance traveled by vehicles within a defined region over a specified time period.

Units of Measurement:

To compare fuels on an equivalent basis, all energy is reported primarily as petajoules (PJ) or sometimes as gigajoules (GJ) (a PJ is a million GJ). Greenhouse gas emissions are primarily characterized as Kilotonnes or megatonnes of carbon dioxide equivalents (ktCO2e or MtCO2e) (a Mt is a thousand kt).

- An average house uses about 100GJ of energy in a year
- 100 liters of gasoline produces about 3.5 GJ
- A kilowatt-hour is .0036 GJ
- A terawatt-hour is 3.6 PJ
- Burning 50,000 tonnes of wood produces 1 PJ
- A typical passenger vehicle emits about 4.7 metric tons of carbon dioxide per year.*
- *Data provided by United States Environmental Protection Agency

GHG emissions	Energy
1 mtCO2 = 1,000,000 tCO2e	1 PJ = 1,000,000,000 J
1 ktCO2e = 1,000 tCO2e	1 GJ = 1,000,000 J
1 tCO2e = 1,000 kgCO2e	1 MJ = 0.001 GJ
1 kgCO2e = 1,000 gCO2e	1 TJ = 1,000 GJ
	1 PJ = 1,000,000 GJ

Part 1: Reference Scenario

1. Introduction

The Low-Carbon Transition Strategy (the 'Strategy') will chart a course for the Town of Halton Hills to reach net-zero emissions by 2030. The Strategy will be developed by evaluating future emission reduction scenarios using CityInSight, a spatial energy and emissions simulation model developed by SSG and whatIf? Technologies.

Scenario analysis projects alternate stories about how the world could unfold based on possible future pathways. Scenario planning is a technique used to inform decision-making by exploring how combinations of alternate policies, economic mechanisms, and investments could impact society and the economy.

Once we have developed a baseline energy and emissions model for the town, two emissions scenarios will be evaluated to develop the Strategy: first, a reference scenario, and then a low-carbon scenario.

The reference scenario reflects current activities and trends that generate emissions in the Town of Halton Hills, and projects what emissions could look like over time if little additional action is taken to reduce emissions. The low-carbon scenario then explores the energy and emissions implications of a suite of actions to reduce the emissions identified in the reference scenario. The low-carbon scenario will then inform the Low-Carbon Transition Strategy.

This report summarizes the technical modelling results for the baseline and reference scenario. The report is structured in two parts:

- Reference Scenario Results: this section gives a brief overview of the modelling process and key assumptions used to develop the reference scenario. It ends with a summary of the reference scenario modelling results from the baseline year (2016) to 2030.
- Data Methods and Assumptions Manual: this manual provides greater detail of the CityInSight modelling methodology and provides a comprehensive and detailed table of assumptions underlying the reference scenario.

2. 2016 Baseline

The modelling projections for both the reference and the low-carbon scenarios are built on a baseline energy and emissions model produced for the Town. The baseline model represents energy use and processes that generate emissions in the Town of Halton Hills.

Emissions come from three main sources:

- The consumption of carbon-based fuels for energy, which emit greenhouse gases during their combustion. This includes a range of activities that occur in Halton Hills, including building heating, cooling and plug loads transportation; as well as industrial processes.
- Emissions generated from decomposing organic waste and its treatment, and decomposing organic waste in wastewater treatment.
- The incidental release of emissions (methane) from the natural gas system, referred to as fugitive emissions.

The baseline is developed based on observed data in Halton Hills, including census data, energy consumption from utilities and observed transportation studies. The baseline year is 2016 because the most recent Census data is from 2016. Where more current data is available, it is used to calibrate the model projections between 2016-2019.

2.1 Geographic Scope

The GHG accounting framework in CityInSight applies the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC Protocol). The geographic boundary of the Town of Halton Hills is the inventory boundary. Further details on the modelling scope is outlined in Part 2.

3. Reference Scenario Assumptions

The reference scenario represents the Town of Halton Hills' energy and emissions projected to 2030 based on ongoing trends and planned initiatives. This scenario is made up of a suite of assumptions applied to the energy and emissions model for the Town of Halton Hills. The assumptions relate to energy and waste systems that drive emissions and include:

- Population growth
- New building construction
- Transit system expansion and its corresponding fuel type
- Personal use vehicles counts and fuel efficiency
- Waste and waste diversion rates

The activities included in the reference scenario are described below. A full list of assumptions applied in the reference scenario model are described in Part 2 of this report.

3.1 Population and Households

The population of Halton Hills is anticipated to increase by 45% by 2030, from 63,000 in 2016 to nearly 92,000, according to Town projections.[1] This captures the development at Vision Georgetown.

Employment is projected to rise by 20%, with just under 40,000 jobs in the Town by 2030 (up from 33,000 in 2016). The smaller relative employment growth projections are indicative of the fact that many residents are currently and projected to continue to commute to work in neighboring communities, including Toronto.

Population, households and employment are shown in Figure 1. A growing population and employment base translates to more homes, more commercial floor area and more vehicles—all of which influence emissions.

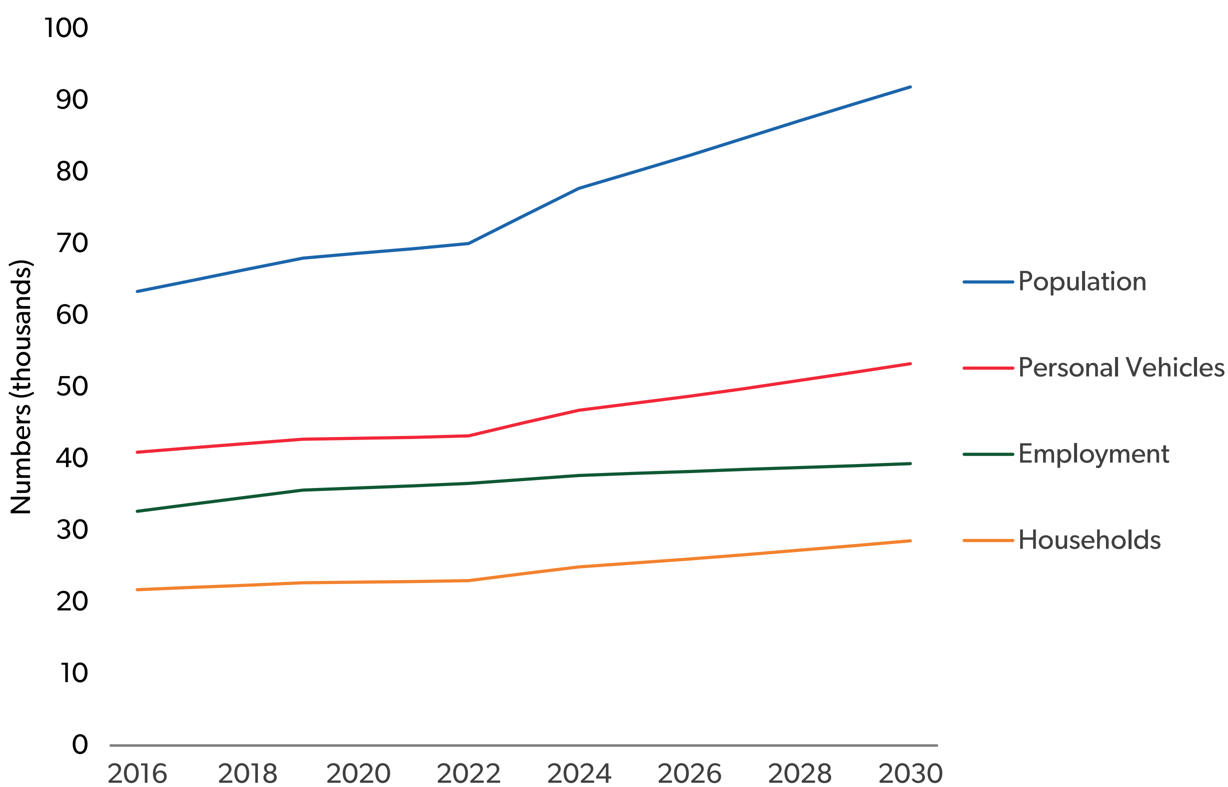

Figure 1. Projected changes in population, vehicles, employment and households, 2016-2030.

3.2 Climate Change

Halton Hills is projected to experience a decline in heating needs and an increase in cooling needs for its buildings as a result of climate change. This is reflected in heating and cooling degree days—the extent to which heating (below 18°C) and cooling (above 18°C) is required. By 2030, heating degree days are projected to decline to 3,573 (from 3,882), and cooling degree days are projected to increase to 405 (from 331).[2]

[1] Environics Analytics. (2019). Demo Stats 2019.

[2] Climate Atlas of Canada. (n.d.). RCP8.5 BCCAqv2 downscaled climate data from Pacific Climate Impacts Consortium.

3.3 Buildings

NEW CONSTRUCTION

The Halton Hills Green Development Standard (GDS) has been in place since 2014, and uses a point-based system to encourage sustainable design in new construction. Theoretically, GDS energy performance points result in buildings that are 5-20% more efficient than the 2012 Ontario Building Code (OBC).[3] An updated GDS is currently in development, and is expected to advocate for 15% better energy performance than the newest iteration of the OBC (2020).

In the reference scenario, it is assumed that between 2016 and 2030, 25% of new buildings are constructed to meet the GDS Standards applicable at the time of construction. The remaining 75% of new buildings are constructed to meet the OBC standards required at the time of construction. Since OBC 2012, it is assumed that the code is updated every five years to require improved energy performance of 10%.[4]

EXISTING BUILDINGS

The energy performance of municipal buildings is expected to improve as initiatives in the Town's Corporate Energy Plan are implemented.[5] The energy consumption by facility is anticipated to fall by 43%, averaged across 12 of the Town's facilities.

The energy performance of existing buildings is assumed to remain unchanged, for two reasons:

- There are no targeted retrofit programs for buildings in Halton Hills.
- Any gains from building renovations or heating system replacements that occur may be offset by increasing plug loads.

Across the whole non-municipal residential building stock (new and existing), this translates to about a 12.5% reduction in energy consumption by 2021, 14% reduction by 2026, and a 10% reduction by 2030. For the new non-residential building stock, there is a 10% improvement in energy performance every five years.

3.5 Local Energy Generation

Existing grid-connected renewable electricity generation is assumed to remain in operation, with contract extensions beyond their current end dates.[6] This includes 4.08 MW of rooftop solar, as well as 0.5 MW of ground mount solar PV.[7] This also includes small solar PV installations on municipal corporate buildings.

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3 Arup. (2017). Vision Georgetown Energy Master Plan.

4 Environmental Commissioner of Ontario. (2016). Conservation: Let's Get Serious 2015-2016.

5 Town of Halton Hills. (2019). 2020-2025 Corporate Energy Plan.

6 IESO. (March 2020). IESO Active Contracted Generation List (as of March 2020). Retrieved from: www.ieso.ca/Power-Data/Supply-Overview/Transmission-Connected-Generation

7 It should be noted that the Halton Hills Generating Station, a 641 MW natural gas fired electricity generating station is not included in either the baseline or the reference projection. This is because its emissions impact is captured in Ontario's grid emissions factor. For more details, see Part 2 Section 7.

3.6 Transit

The reference scenario accounts for an increase in transit trips and transit vehicle kilometres travelled (VKT) from Metrolinx's GO train Kitchener Line expansion, beginning in 2025. Transit trips will increase according to Table 1. Transit VKT is assumed to be five times higher than baseline VKT, based on the increasing frequency of transit service.

Table 1. Transit trip increase for GO Train Kitchener expansion.[8]

	2016	2025
Acton	121 daily trips	220 daily trips
Georgetown	618 daily trips	643 daily trips

While the Town is also anticipating an expansion of the local Universal Access Service, this is incorporated into personal vehicle trips because the service closely resembles taxi activities.[9]

Neither the GO expansion, nor the Universal Access Service, is assumed to be electric.

3.7 Transportation Mode Share

The reference scenario assumes that the transit and active mode shares identified in the Town's Transportation Master Plan (TMP) are achieved.[10] In addition, the GO Train expansion is assumed to exceed this transit mode share identified in the TMP. The assumed 2030 mode share is shown in Table 2.

Table 2. Reference scenario mode share in 2016 (observed) and 2030 (projected).

	2016	2030
Personal use automobiles	88.90%	83.54%
Transit	4.95%	10.77%
School bus	2.29%	2.52%
Walk	3.36%	2.74%
Bike	0.50%	0.43%

8 Metrolinx. (2019). Kitchener go expansion initial business case. Retrieved from: www.metrolinx.com/en/regionalplanning/projectevaluation/benefitscases/2019-11-14-Kitchener-Mid-Term-Service-Expansion-IBC-Update-FINAL.pdf

9 Town of Halton Hills. (2019). Transit Service Strategy. Prepared by WSP.

10 Town of Halton Hills. (2011). Transportation Master Plan.

3.8 Vehicles

A portion of personal vehicle stock in Halton Hills is assumed to be replaced with electric vehicles, starting at 0% of new vehicle sales in 2016 and up to 14% of new vehicle sales by 2030.[11] New vehicles are incorporated into the model with new population growth, as well as through replacement at the end of vehicle life. The assumption reflects the underlying increase in EV purchases.

The reference scenario assumes that commercial vehicles are not replaced with an electric counterpart.

New internal combustion engine vehicles are assumed to have the fuel economy of their manufacturing year, according to Canadian regulations.[12] Regulations schedule vehicle efficiency improvements for the upcoming decade.

3.9 Municipal Fleets

The reference scenario assumes that there will be no significant changes to municipal fleet vehicles, other than replacements at the end of vehicle life.

3.10 Waste and Wastewater

Waste generation in Halton Hills is assumed to remain constant at the baseline level of 1,250 kg/household/year.[13] The baseline waste diversion rate is 57.4%.[14] As a result of Halton Region policies, Halton Hills is expected to reach a 70% waste diversion rate by 2025. After 2025, the diversion rate stays constant at 70%. Increasing the diversion rate reduces the amount of organic waste sent to landfill.

Currently, waste is landfilled outside the Halton Hills boundary. A landfill gas capture system captures a portion of emissions produced from decomposing organic waste; once captured, some gas is flared, directly releasing carbon dioxide into the atmosphere. The remaining gas is combusted to produce electricity. There are no expected changes to how waste is treated in the reference scenario.[15]

There are two wastewater treatment plants within the Town boundary. Wastewater systems consume various fuels, and also produce emissions from the decomposition of organic waste in sewage. Wastewater emissions are projected to increase with population growth.

3.11 Industry

The model accounts for energy consumption at industrial facilities. The industrial sector is expected to grow as broader local employment grows between 2016 and 2030.

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11 Axsen, J., Wolinetz, M. (2018). Reaching 30% plug-in vehicle sales by 2030: Modeling incentive and sales mandate strategies in Canada. Transportation Research Part D: Transport and Environment, 65, 596-617.

12 SOR/2010-201. Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations. Available from: laws-lois.justice.gc.ca. Regulations Amending the Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations and other Regulations Made Under the Canadian Environmental Protection Act, 1999. Available from: pollution-waste.canada.ca

13 Halton Region. (2011). Solid Waste Management Strategy.

14 Resource Productivity and Recovery Authority. (n.d.). 2016 Residential Waste Diversion Rates by Municipal Program.

15 Waste treatment occurs outside of Halton Hills' boundaries, and is therefore a scope 3 emission. The electricity produced from the combustion of landfill gas is not included in the Town's inventory as it is under the control of Oakville Hydro. For details on scope, see Part 2 of this report.

3.12 Other

Agriculture emissions in the model relate to emissions associated with methane emissions from livestock, not energy use on farms. There are no anticipated changes to agriculture emissions in Halton Hills.

The model accounts for off-road transportation emissions, most notably from aviation. No changes are anticipated to aviation emissions.

4. Baseline Scenario Results

4.1 Baseline Energy, 2016

In 2016, 8.7 PJ of energy were consumed for activities within the Town of Halton Hills. About 81% of energy consumption is from fossil fuels.[16]

The breakdown of fuel uses varies by sector (Figure 2). Stationary energy consumption in building-related sectors (residential, commercial, municipal and industrial) covers many of the same fuels, albeit in different proportions. Natural gas is the dominant fuel consumed in residential, commercial, industrial and municipal sectors, mostly for space heating and industrial purposes. Grid electricity is also used in buildings, primarily for cooling and plug loads. A range of other fuels are also used within the Halton Hills boundary, including fuel oil, wood and propane; this is generally in rural areas without access to natural gas for heating, and in industrial processes. Energy consumption in the transportations sector is made up mostly of gasoline, and to a lesser extent diesel.

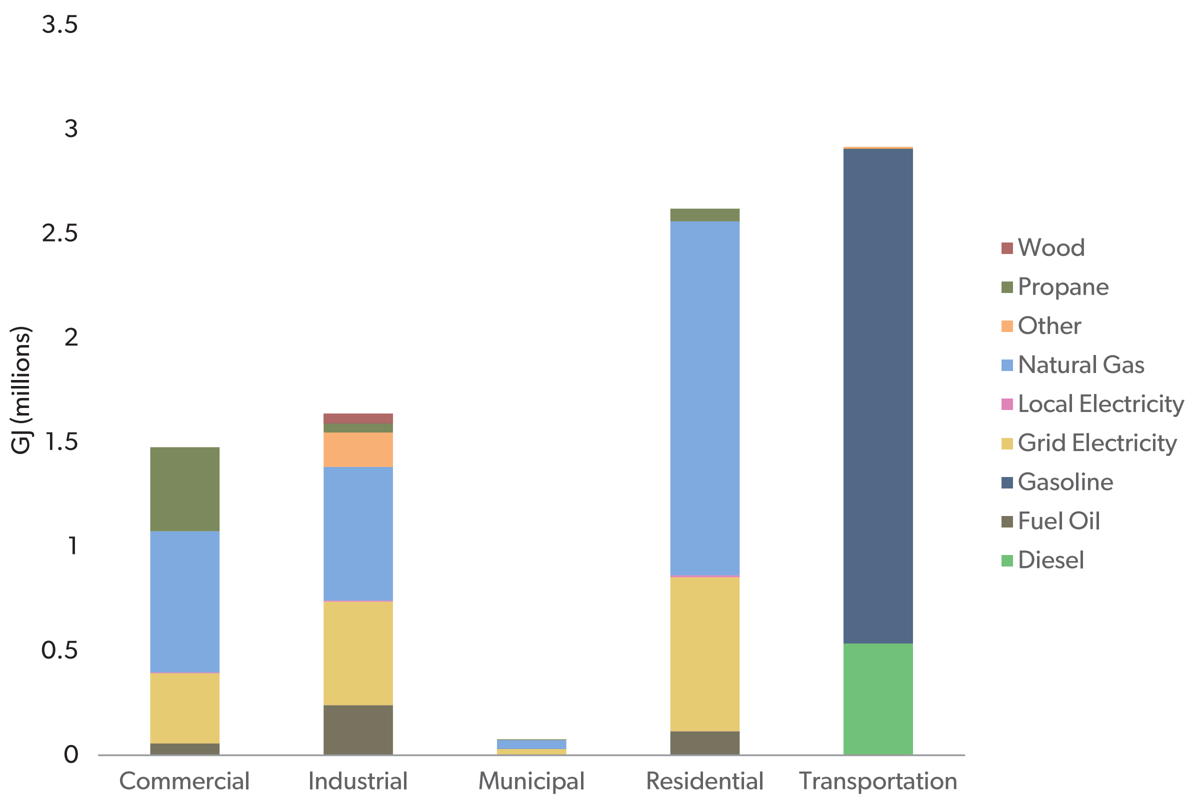

Figure 2. Energy consumption by fuel and by sector in 2016.

16 This excludes all electrical energy and the combustion of wood biomass for energy.

As shown in Figure 3, stationary energy consumption is highest in areas with dense commercial, residential or industrial activity. This includes Georgetown, followed by zones in Acton, and zones along Highway 401. For transportation energy consumption in particular, zones surrounding the core of Georgetown have the highest VKT (Figure 4). This is likely because these areas have a greater population than the more rural regions, but are not within walking or cycling distance to their end locations.

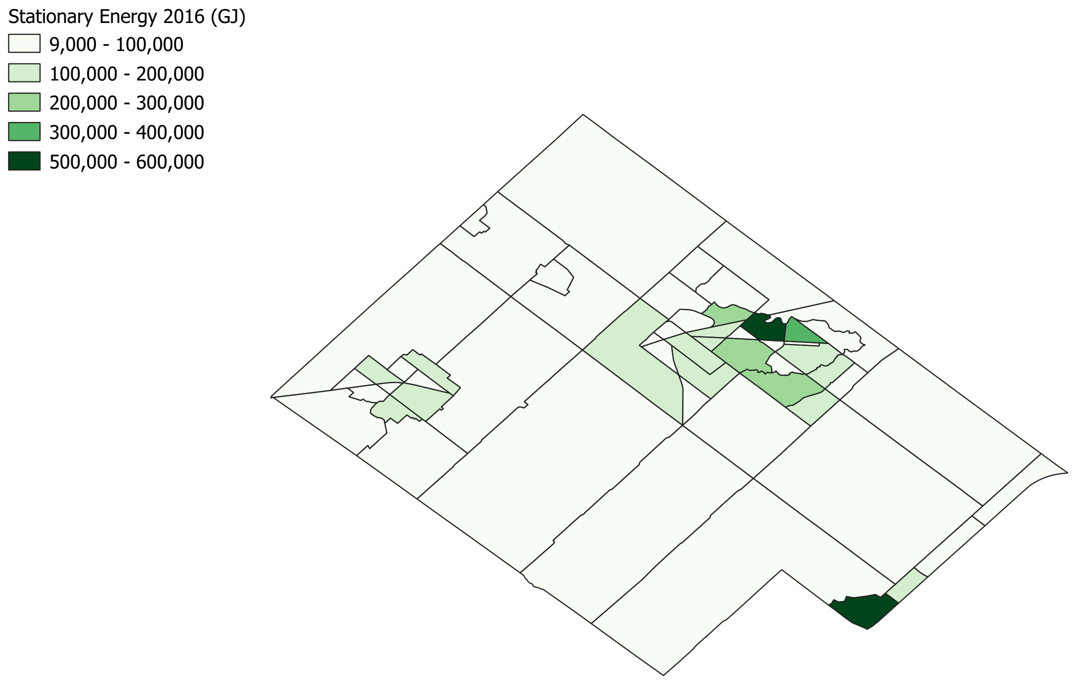

Figure 3. Stationary energy consumption by zone, 2016 (GJ).

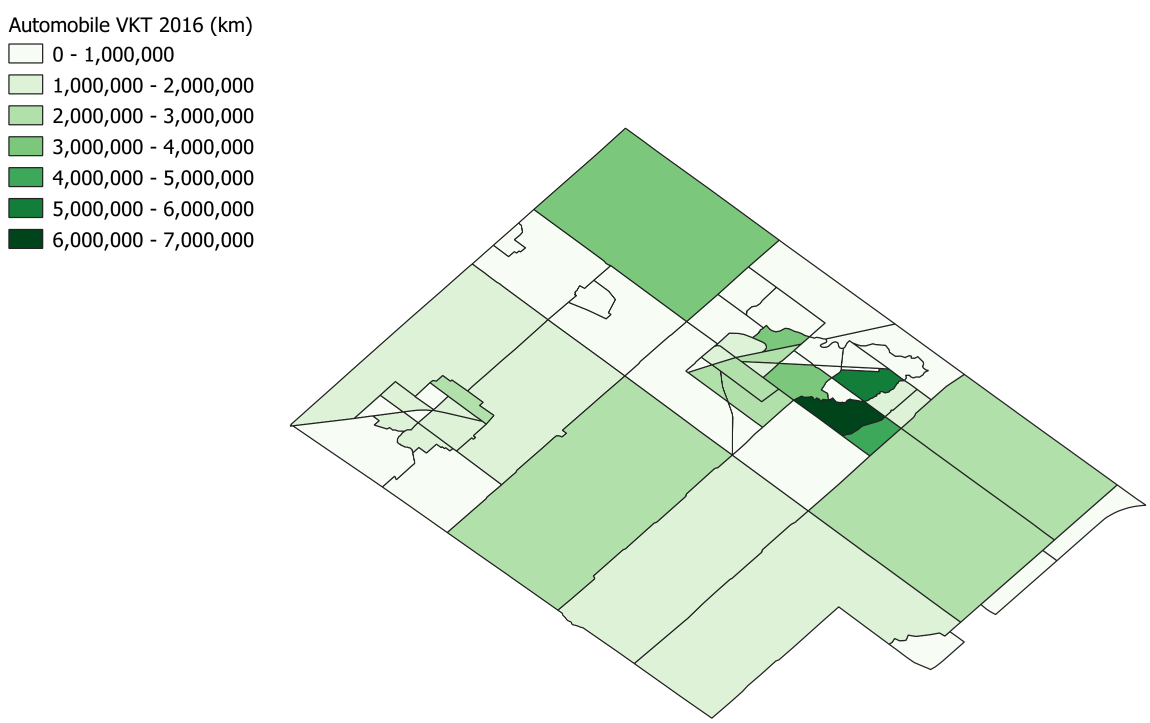

Figure 4. Personal use automobile VKT, 2016. VKT are associated with the zone where the trip originates.

4.2 Baseline Emissions, 2016

The above-noted energy activities—in addition to non-energy related emissions (i.e. waste, agricultural and fugitive emissions)—generate 541 kt CO2e of greenhouse gas emissions in 2016. This translates to about 8.6 tCO2e per person, including industrial emissions.

Per capita emissions in Halton Hills are higher than per capita emissions in the Greater Toronto and Hamilton Area as a whole (6.9 tCO2e/person), with per capita emissions in the City of Toronto at 5.5 tCO2e/person, and 7.9 tCO2e/person in the Region of Peel.[17] Compared to other municipalities in Canada with differing energy systems, Halton Hills per capita emissions are somewhere in the middle, with the City of Courtenay, BC emissions at 4.2 tCO2e/person, and emissions in the Halifax Regional Municipality are 13 tCO2e/person (this latter is high due to electricity generation from fossil fuels).

Emissions by sector are shown in Figure 5. The transportation sector is the largest energy consumer and makes up the largest share of emissions, at 41% of Halton Hills' total emissions.[18] This greater share of emissions from transportation reflects the greater emissions intensity of transportation fuels over those used in buildings—particularly grid electricity.

The second largest contributor to emissions is the residential sector (at 22% of total emissions). This is mostly from natural gas use, which is the primary source of building space and water heating in the Town of Halton Hills.

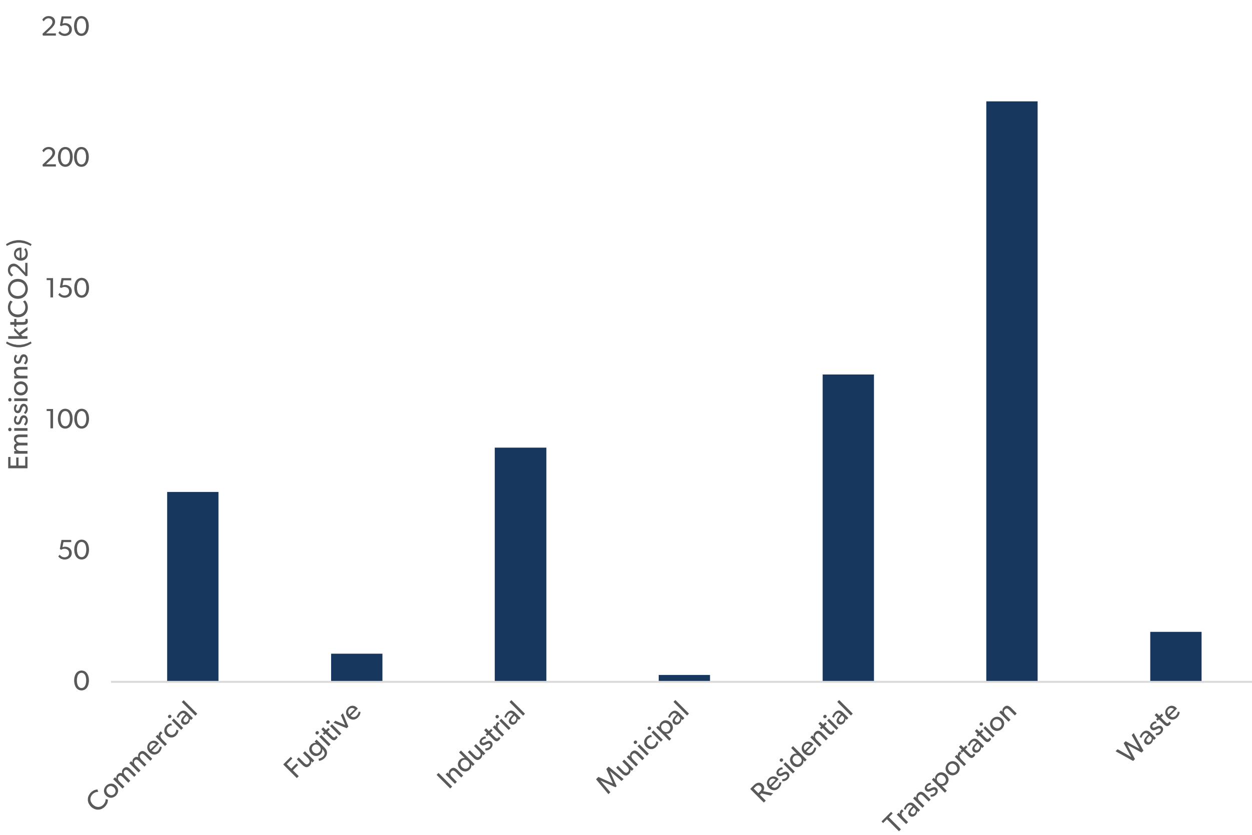

Figure 5. Town of Halton Hills emissions profile by sector in 2016.

[17] The Atmospheric Fund. (2018). Keeping Track: 2015 Carbon Emissions in the Greater Toronto and Hamilton Area. Retrieved from: taf.ca/wp-content/uploads/2018/09/TAF_GTHA_Emissions_Inventory_Report_2018-Final.pdf.

[18] This value includes both on-road and off-road transportation.

As shown in Figure 6, stationary emissions are the highest in the zone adjacent to Highway 401—an area with concentrated commercial, industrial and warehouse activities. This points to the intensity of emissions generated from industrial activities. Emissions are also generated in both the central and peripheral zones of Georgetown.

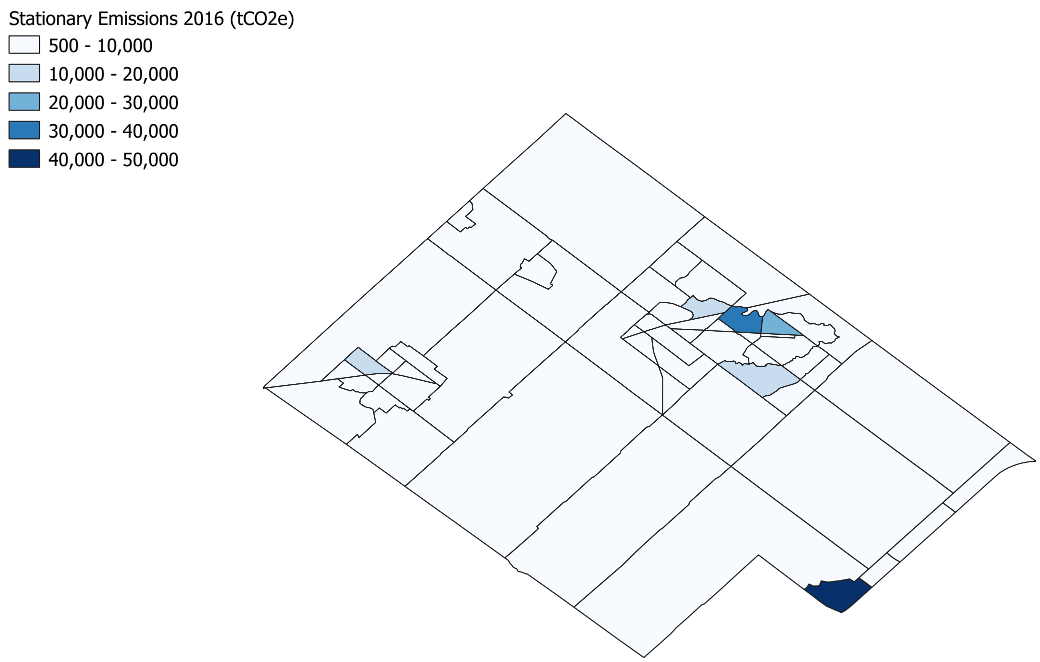

Figure 6. Stationary emissions by zone, 2016 (tCO2e).

5. Reference Scenario Results

5.1 Total Energy and Emissions, 2016-2030

In the reference scenario, total energy consumption increases by 5%, from 8.7 PJ in 2016 to 9.2 PJ in 2030.

The share of fuel consumption remains fairly constant in the Town's reference scenario. Natural gas remains the most consumed fuel in Halton Hills. There is a small decline in gasoline consumption and an increase in electricity from the uptake of electric vehicles.

Energy consumption from source to end use for the year 2016 and 2030 are shown in Figure 7 and Figure 8, respectively.[19] Notably, these diagrams also clearly show the significant energy wasted in conversion losses (in the form of waste heat) from fossil fuel combustion. In 2016, 37% of energy used in Halton hills was wasted. In 2030, this ratio is projected to decline slightly to 33%.

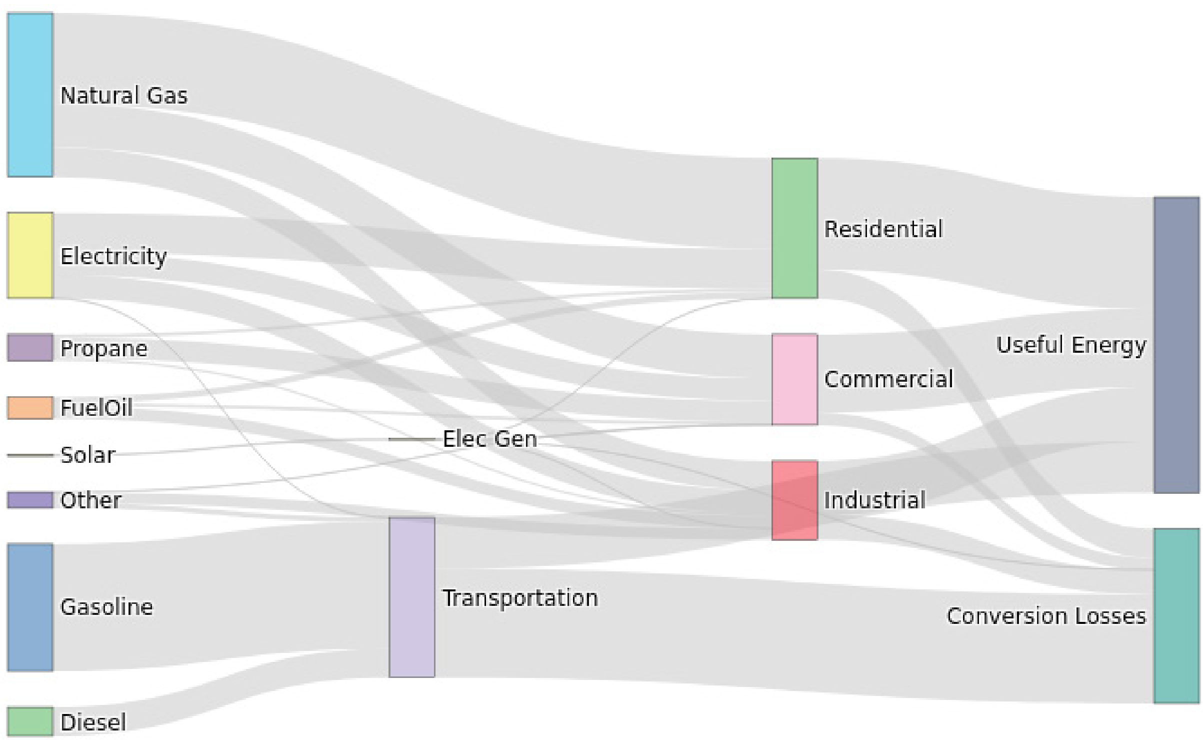

Figure 7. Energy system flows, 2016.

[19] These diagrams are known as Sankey diagrams. The height of each bar is proportional to its share of the total. See Part 2 Section 4.5 for more details on Sankey diagrams.

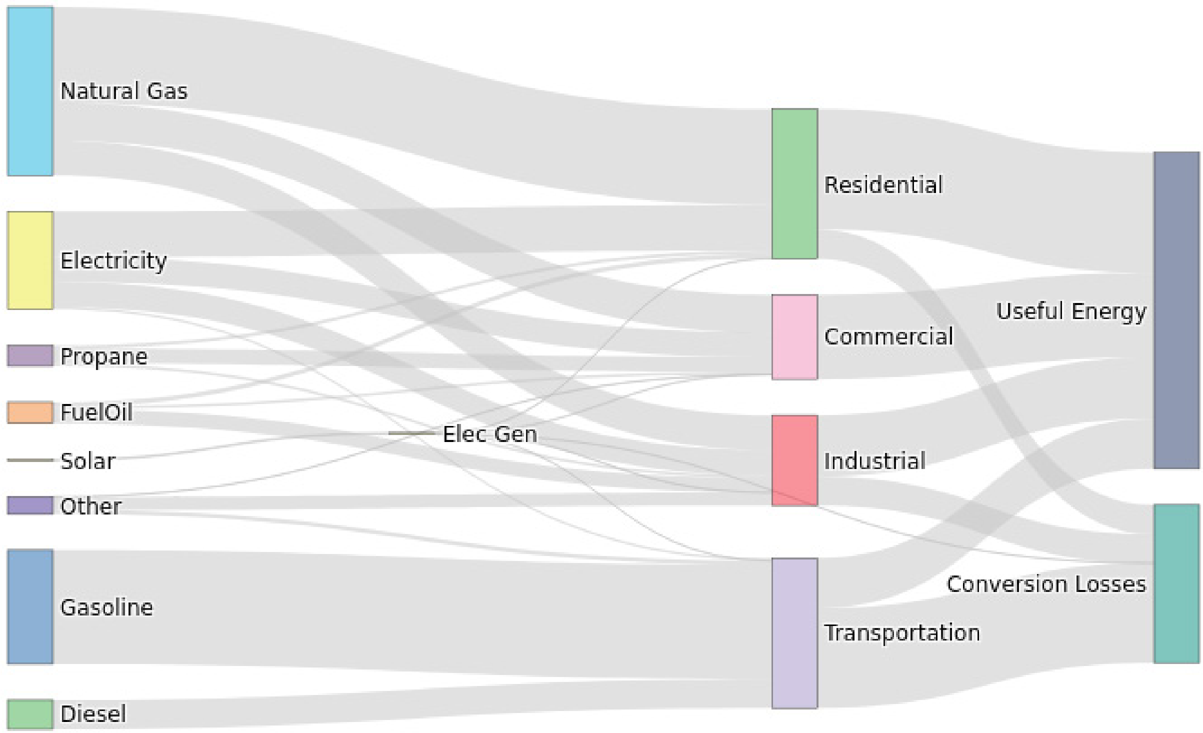

Figure 8. Energy system flows, 2030.

Although total energy consumption increases slightly through to 2030, energy consumption per capita declines by 27%, from 138 TJ per person in 2016 to 100 TJ per person in 2030 (Figure 9). This is because increasing energy consumption related to population growth is being offset by improved vehicle efficiency, reductions in vehicle mode share, and building energy performance improvements.

The resulting emissions pattern is similar, with a 6% increase, from 541 ktCO2e to 572 ktCO2e. Per capita emissions also decline from 8.5 tCO2e per person, to 6.2 tCO2e.

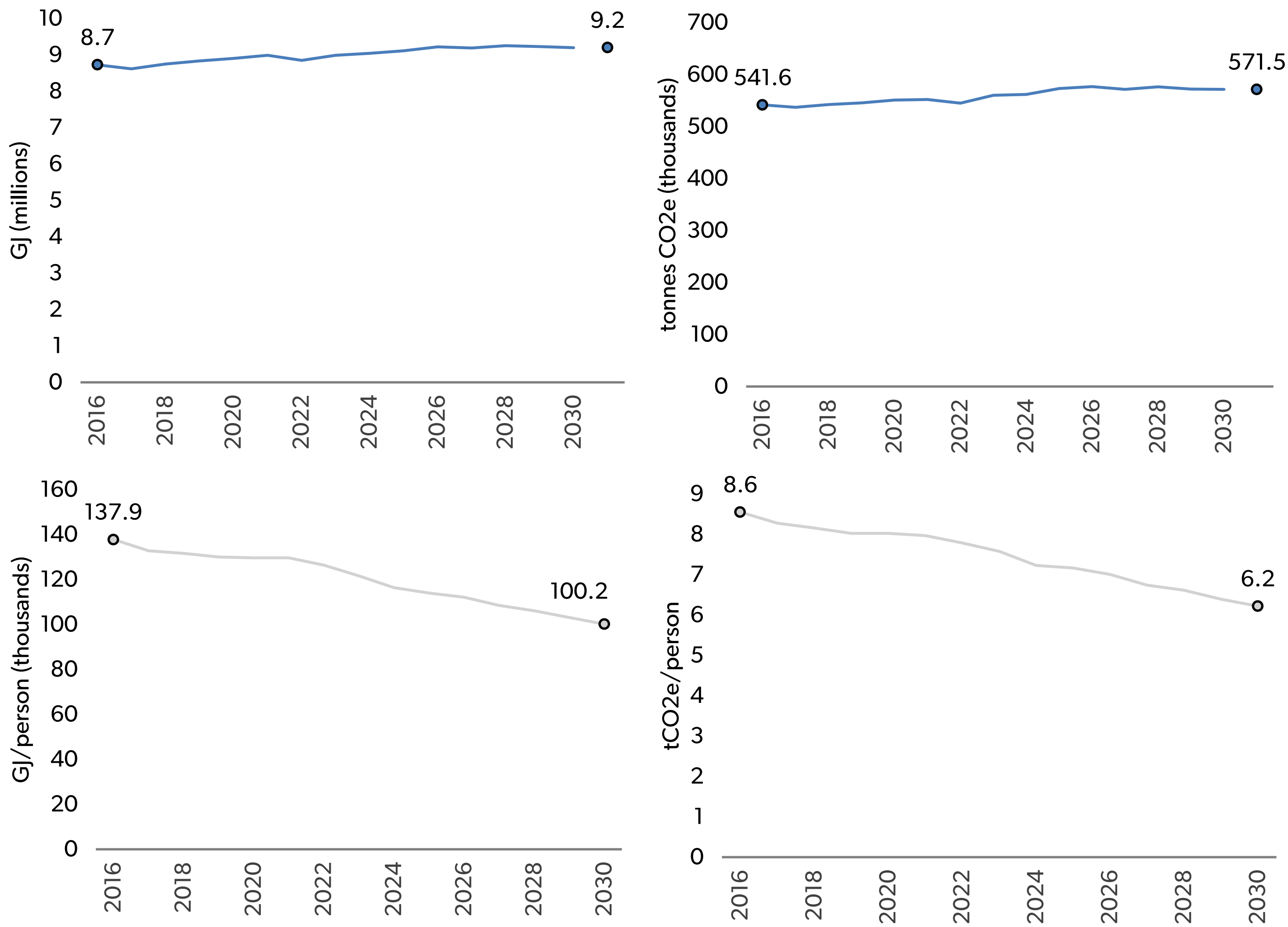

Figure 9. Total and per capita change in energy and emissions, 2016-2030.

The relative share of emissions from each sector varies only slightly from 2016 to 2030 (Figure 10). Sector trends are discussed in more detail below. This emissions growth is driven by population and employment growth projections, which outweigh any projected efficiency improvements and electrification.

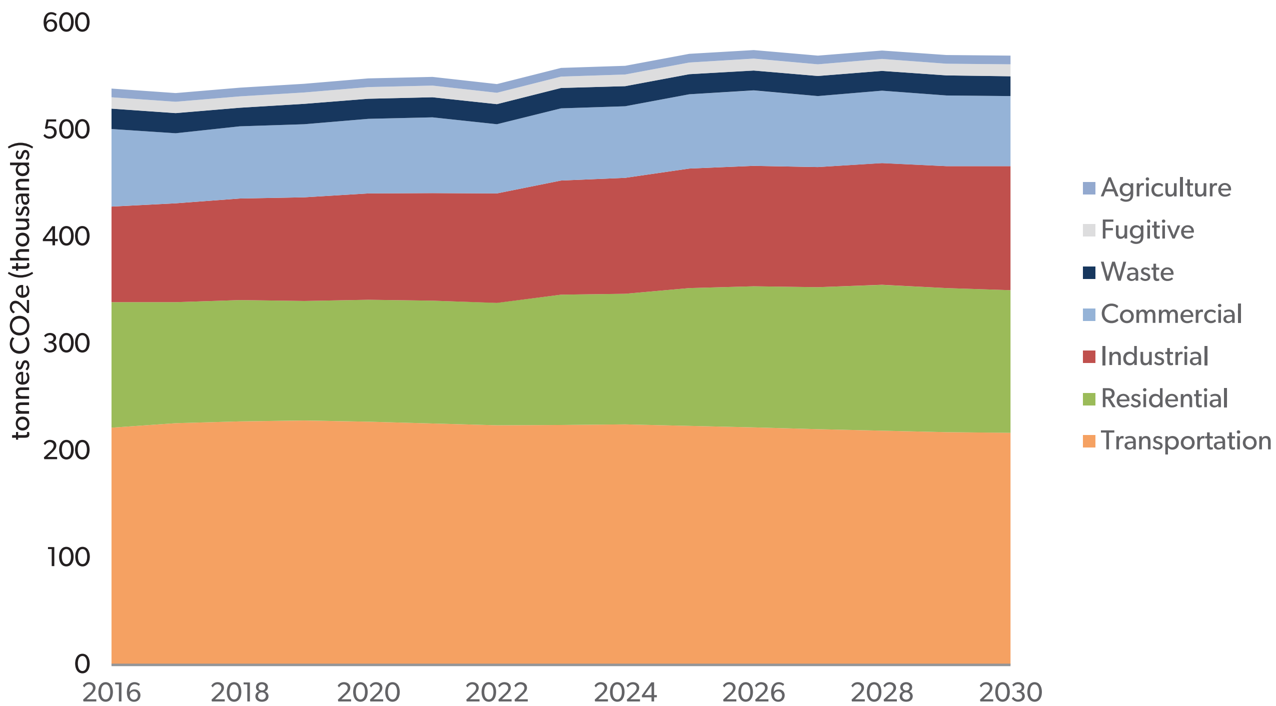

Figure 10. Emissions by sector, 2016-2030.

Similar to the baseline year, stationary emissions are highest from zones in Georgetown, adjacent to Highway 401, and to a lesser extent in Acton (Figure 11).

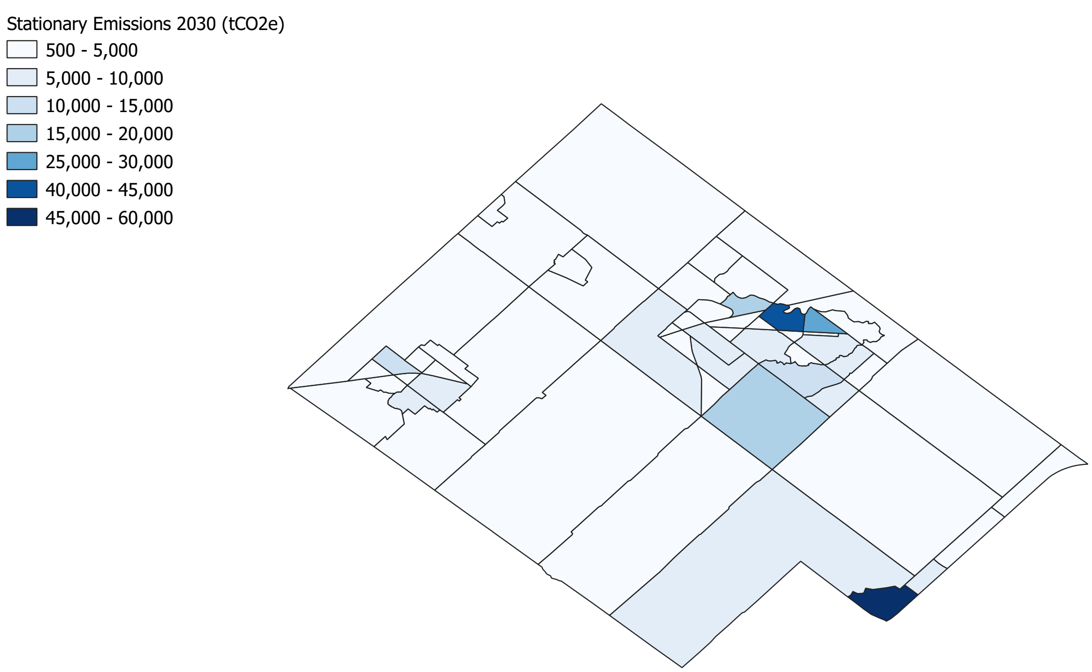

Figure 11. Stationary emissions by zone, 2030.

5.2 Energy and Emissions, 2016-2030

BUILDINGS

Space heating and industrial buildings use the most energy, in 2016 and in 2030 (Figure 12). The industrial and residential sectors see increasing energy consumption between 2016 and 2030. The fact that the commercial sector experiences a decline is indicative of the relatively small projected employment growth over the period versus population growth, combined with projected improvements in energy efficiency.

Most of the energy demand is met by natural gas, particularly in the residential sector, but electricity and fuel oil are also used in the residential, commercial and industrial sectors (Figure 13).

Municipal buildings represent the smallest square footage, and in turn use comparatively less total energy than other building sectors. Their projected decline in energy use is due to the Town corporation's energy efficiency targets.

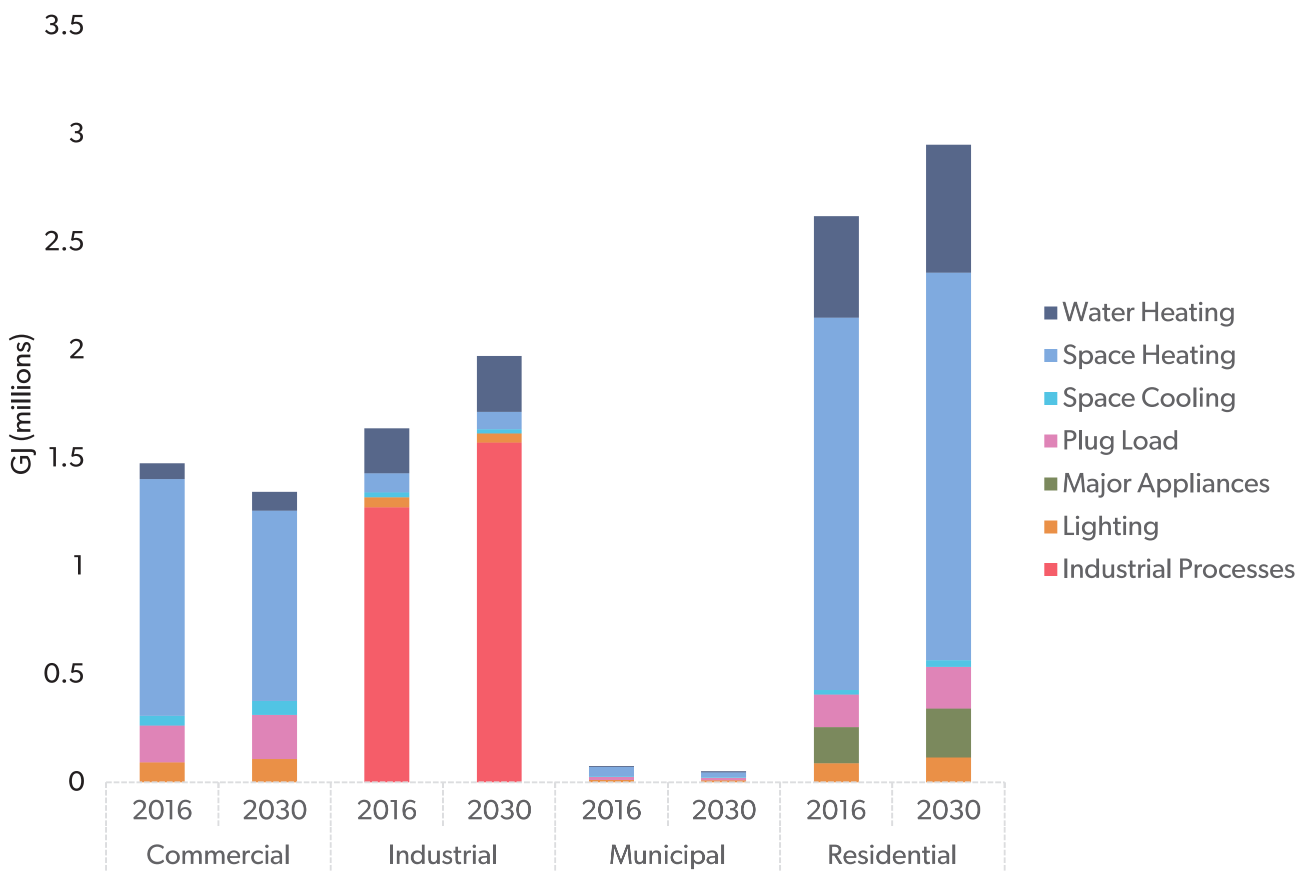

Figure 12. Energy consumption by sector and end use, 2016 and 2030.

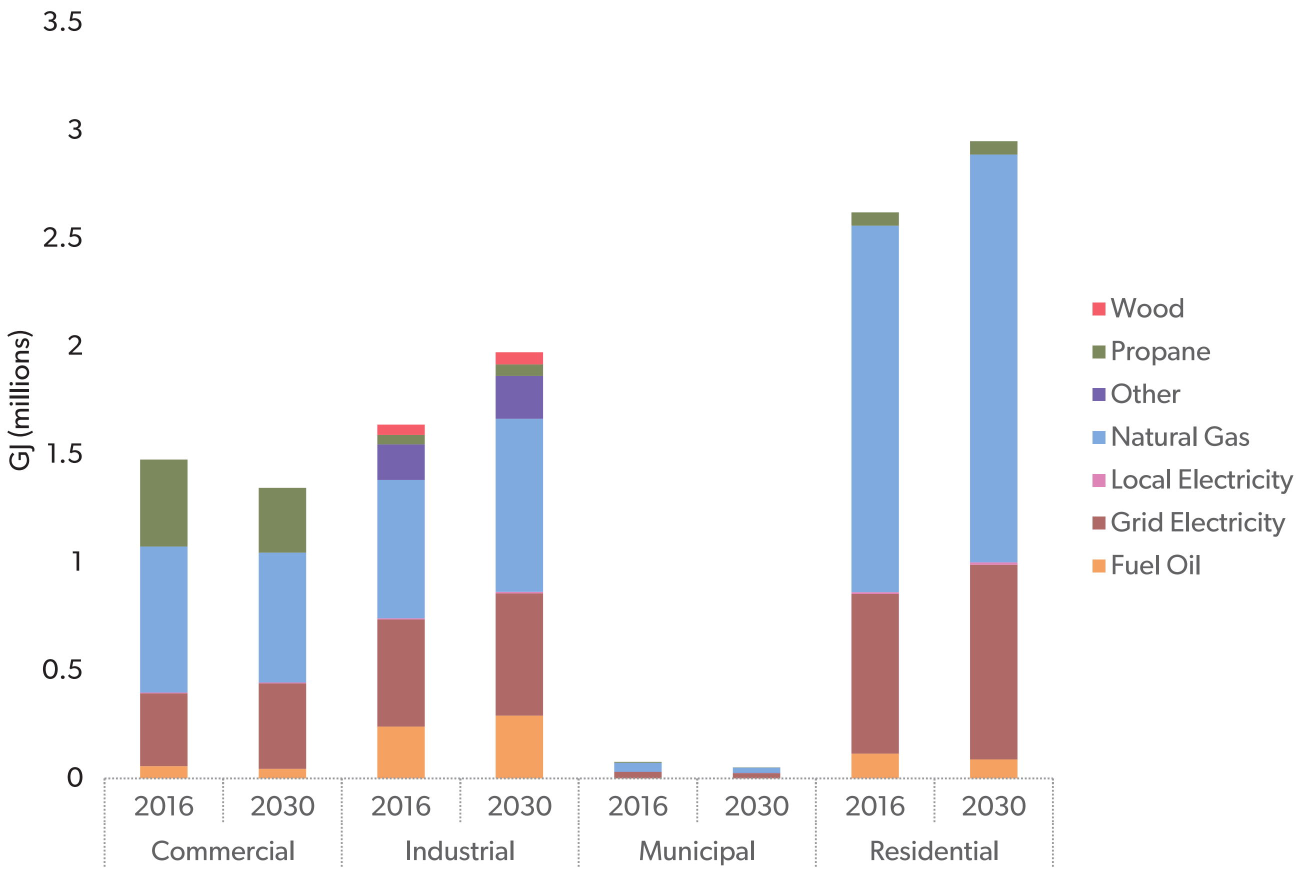

Figure 13. Energy consumption by sector and by fuel, 2016 and 2030.

This energy consumption pattern results in a similar emissions profile in both 2016 and 2030, where space heating and industrial processes are the largest contributors to emissions from buildings (Figure 14). The industrial sector sees the largest growth in emissions by 2030 (+29%), driven in part by sector growth related to employment projections, and its large reliance on carbon-intensive fuel oil. Emissions from the residential sector are also growing (+14%). Emissions from municipal buildings decline by 28%, and emissions from commercial buildings decline by 9% in the reference scenario.

Natural gas is the largest contributor to building emissions in 2016 and 2030 (Figure 15). Interestingly, although fuel oil is 14% of energy consumed in the industrial sector, it is responsible for over half of industrial building emissions. Grid-supplied electricity has a lower emissions profile than other fuels, so its relative contribution to Halton Hills' emissions profile is smaller.

Figure 14. Building emissions by sector and by end use, 2016 and 2030.

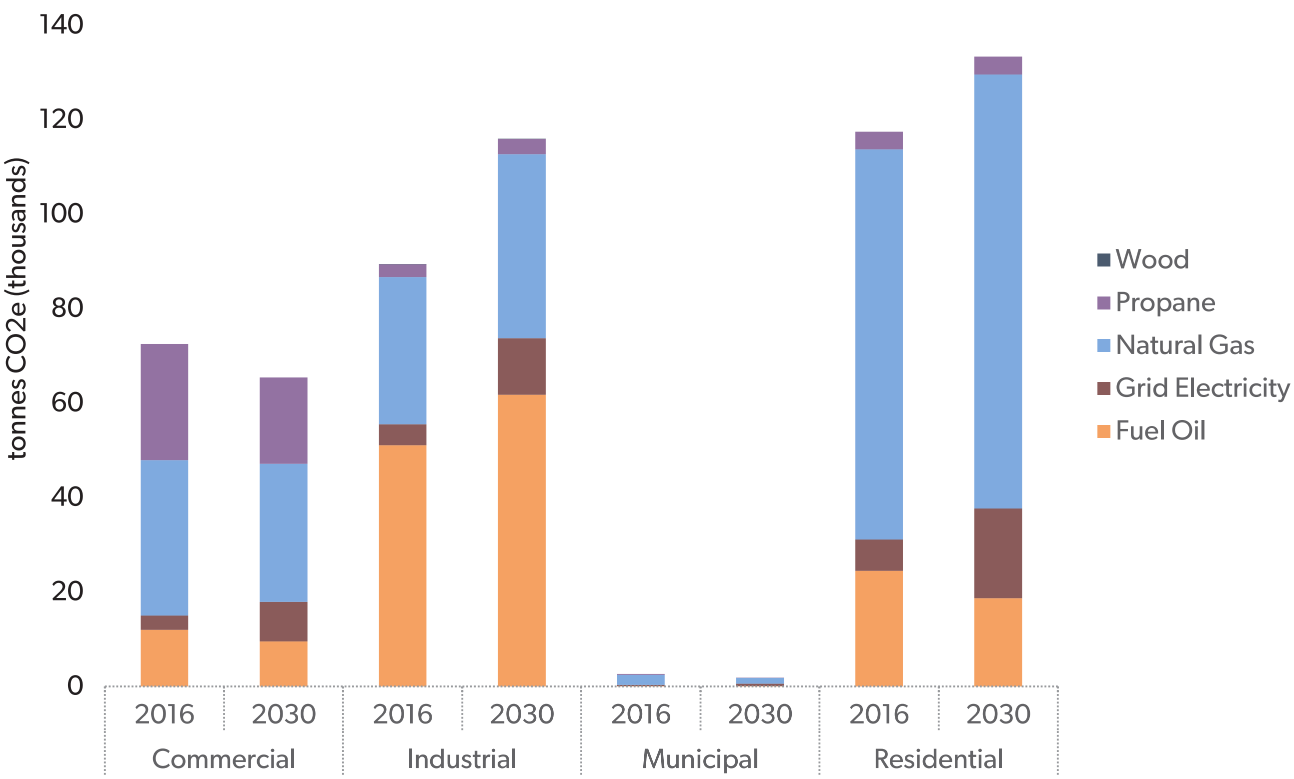

Figure 15. Building emissions by sector and by fuel, 2016 and 2030.

TRANSPORTATION

Transportation energy consumption remains dominated by personal use vehicles by the year 2030. Annual vehicles kilometres travelled (VKT) by personal use vehicles increases by nearly 0.2 billion between 2016 and 2030, increasing for trips within Halton Hills and for trips that leave or enter the Halton Hills boundary (Figure 16). Much of this growth in VKT is likely due to population increase in the Vision Georgetown development;[20] as shown in Figure 17, the Vision Georgetown zone has the highest VKT in all of Halton Hills in 2030.

This increase in automobile VKT is also accompanied by an increase in trips by other modes, most notably an increase in transit trips (Figure 18). In 2016, transit made up 5% of all trips; in 2030, transit makes up 11% of trips.

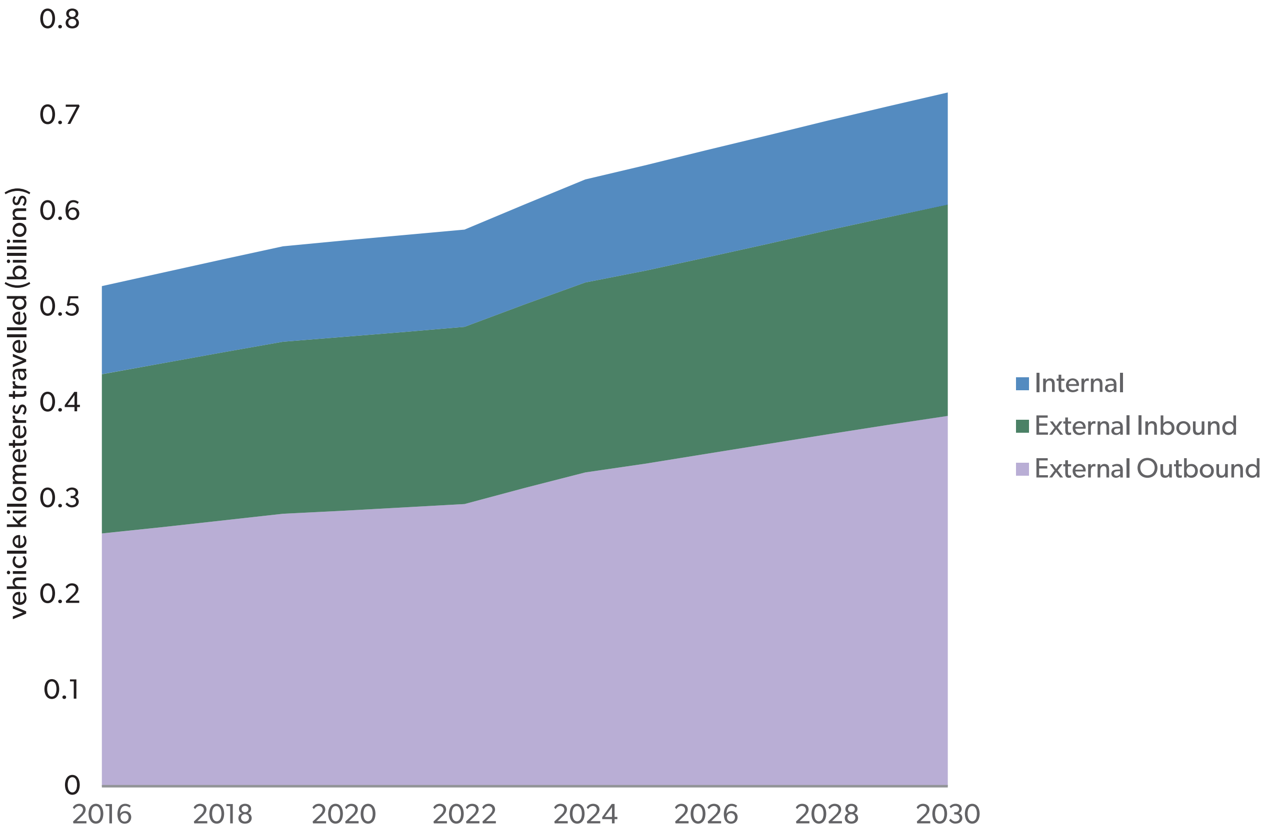

Figure 16. Personal use automobile VKT, 2016-2030.

[20] VKT is allocated to the zone of trip origin.

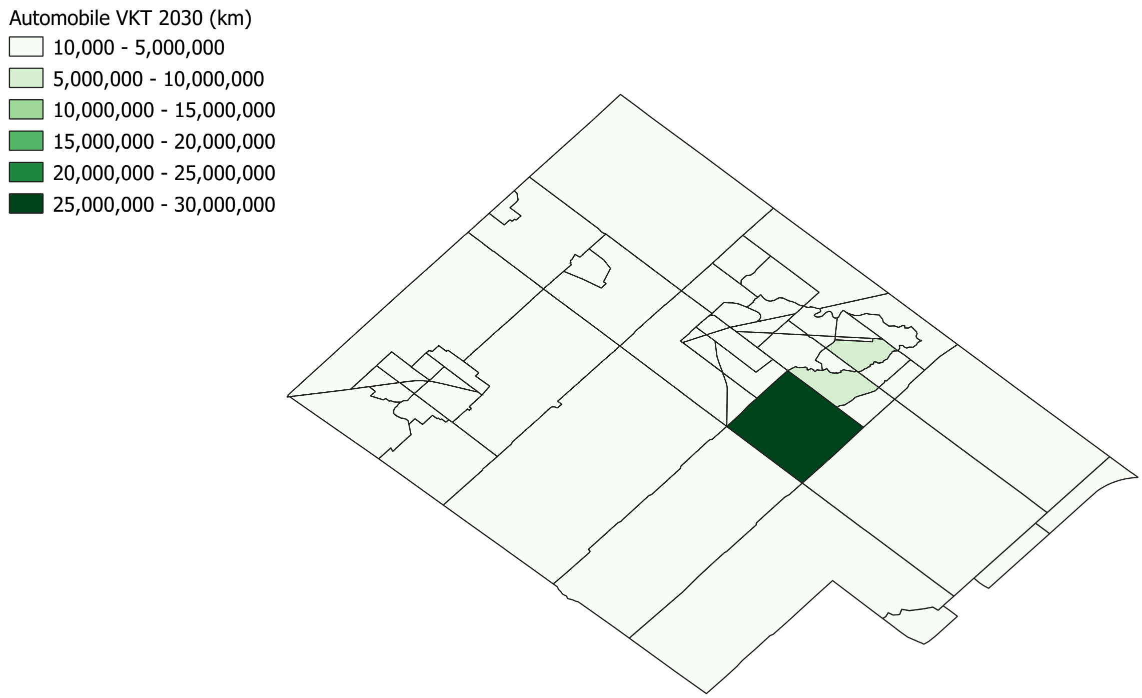

Figure 17. Map of VKT by zone, 2030.

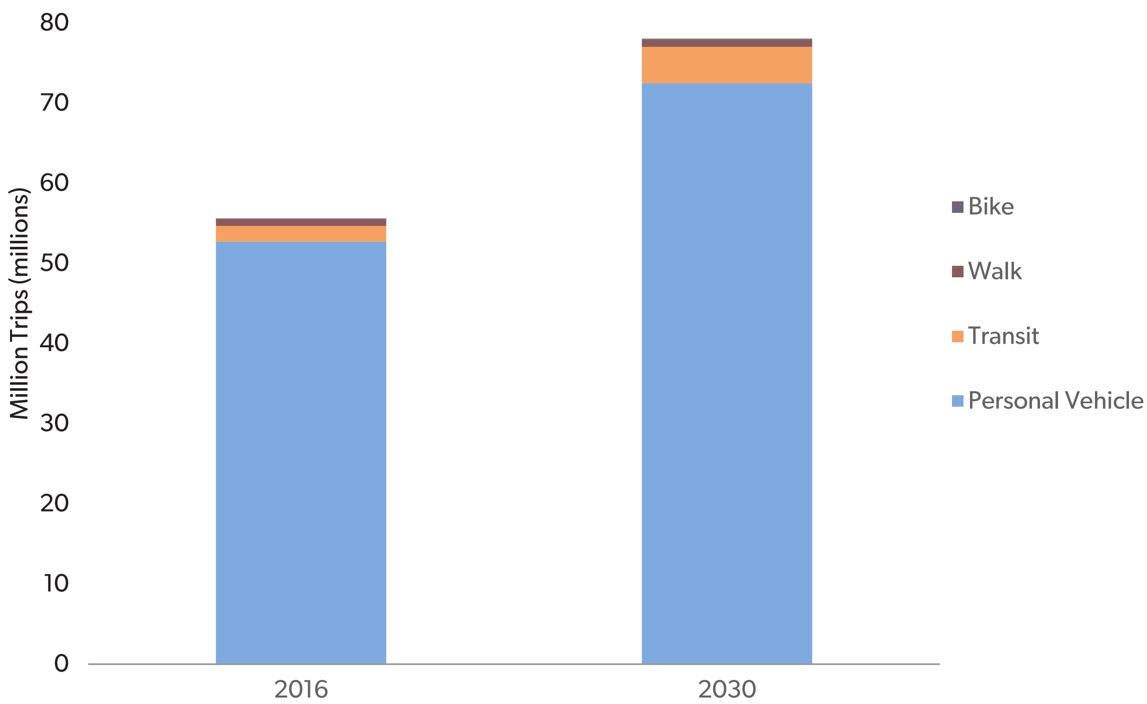

Figure 18. Number of trips by mode, 2016 and 2030.

In the baseline year, cars make up the largest segment of transportation fuel consumption, using predominantly gasoline (Figure 19). By 2030, light trucks become the largest fuel consumers in 2030, reflecting trends in increasing truck market share. In 2030, electricity is projected to represent less than 1% of fuels consumed in the car and light truck classes, and is not consumed at all in heavy truck or urban bus classes.

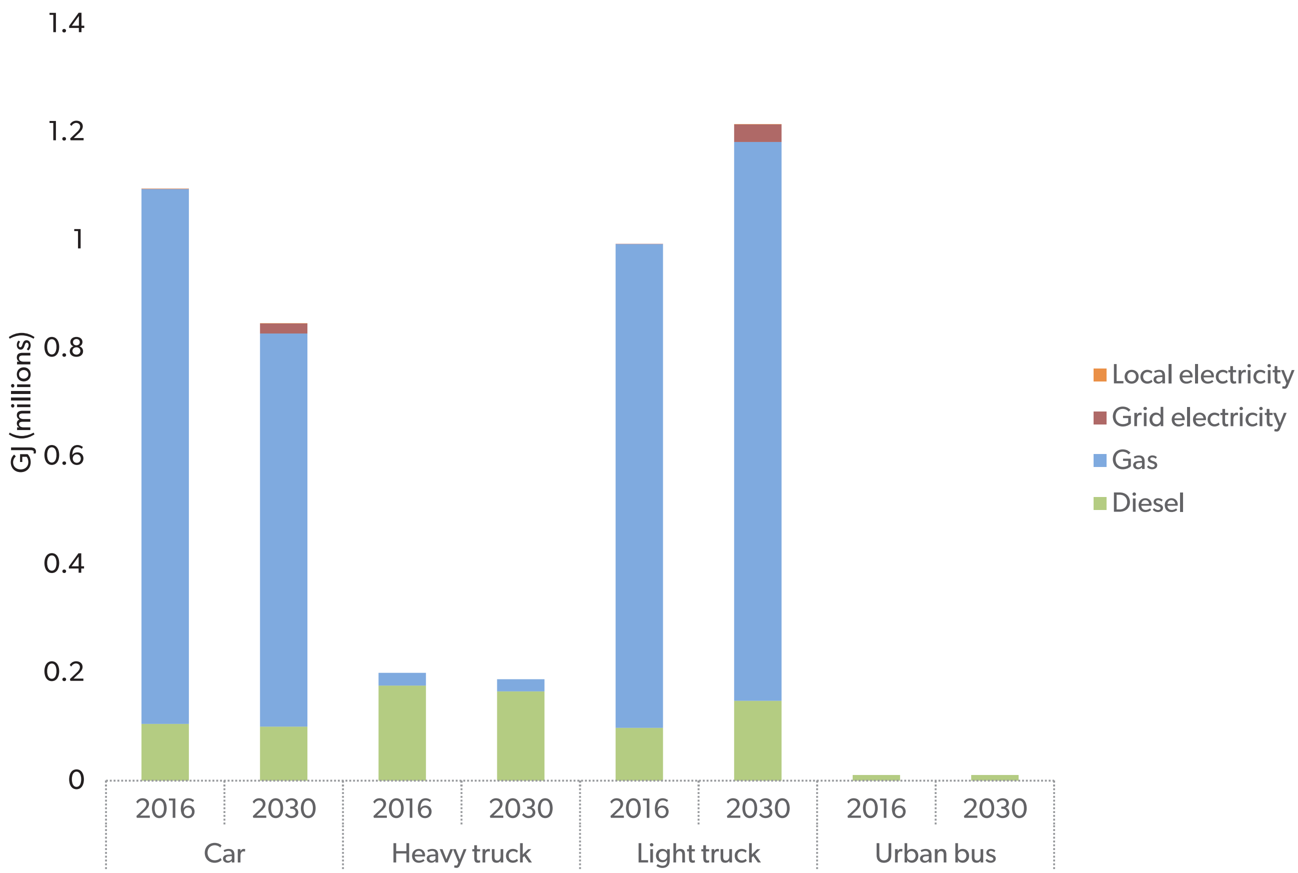

Figure 19. Energy consumption fuel vehicle class and fuel, in 2026 and 2030.

In both 2016 and 2030, emissions are predominantly from gasoline use. Emissions decline slightly by 4 ktCO2e (Figure 20). The decline is likely due to increasing use of electric vehicles for personal vehicle trips and increasing efficiency of combustion engine vehicles.

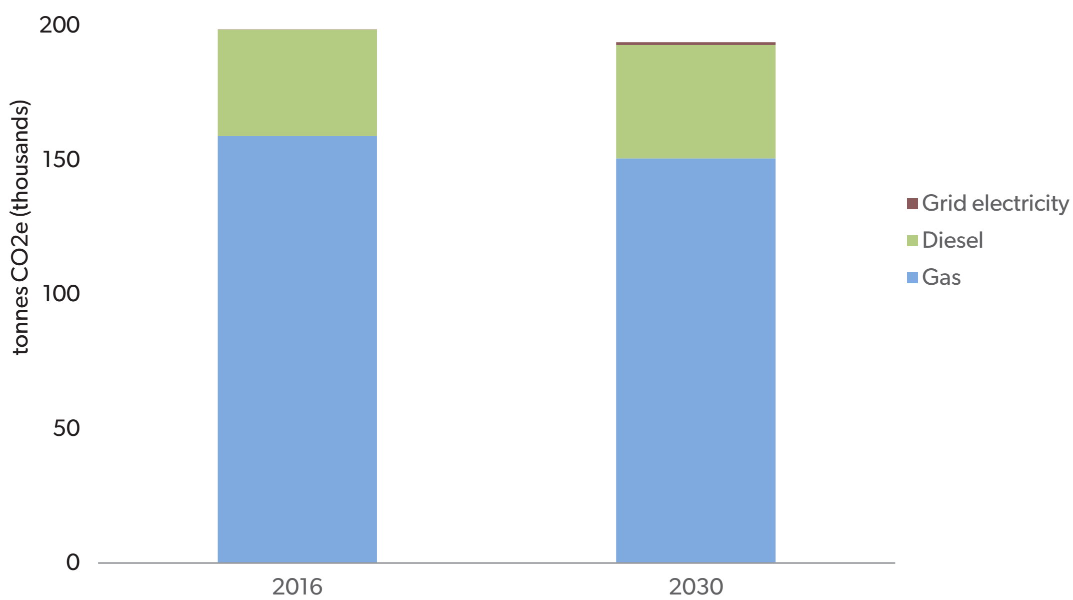

Figure 20. Transportation emissions by fuel, in 2016 and 2030.

WASTE AND WASTEWATER

Waste emissions decline slightly between 2016 and 2030 (Figure 21). This decline reflects an increasing organic waste diversion rate, which outweighs the projected increase in organic waste generation from a growing population.

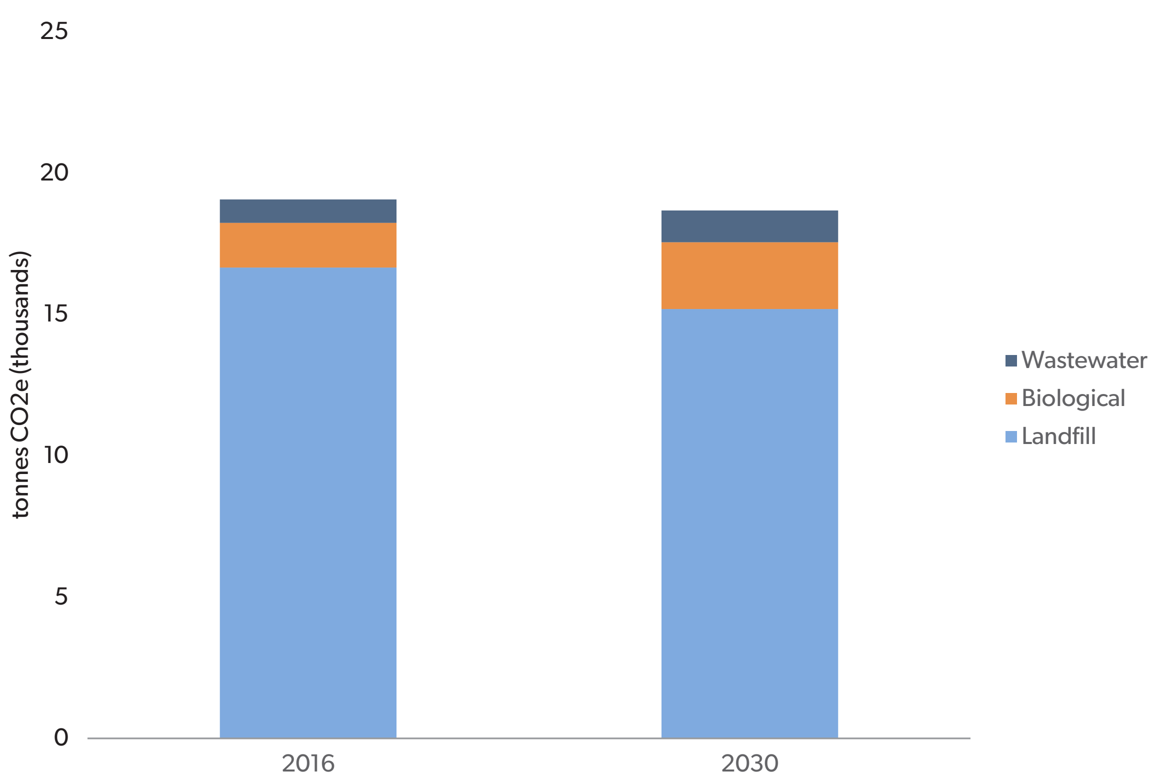

Figure 21. Waste and wastewater emissions, 2016 and 2030.

OTHER

The Reference Scenario also accounts for emissions from aviation and methane emissions from agricultural livestock. Agriculture makes up 1% of total emissions in Halton Hills; emissions from aviation make up 4% Emissions from both sources are expected to remain constant between 2016 and 2030.

6. Conclusions and Next Steps

Total emissions in the Town of Halton Hills are projected to marginally increase if no additional interventions are made. In the reference scenario, emissions from residential and industrial buildings increase, while all other sectors see small declines in emissions. Generally, total emissions increase is the result of its projected population growth, although per capita emissions do decline consistently between 2016 and 2030 from small gains in energy and waste efficiency. If no further action is taken, the Town is estimated to be 572 ktCO2e over its net-zero emissions target in the year 2030.

Ambitious action will be needed to reach its emissions reduction target. As transportation and residential buildings are the largest contributors to emissions, these sectors should be the focus of action, although emissions will need to be addressed in all sectors to achieve net zero emissions by 2030. These ambitious actions to reduce emissions will be modelled in the low-carbon scenario.

Part 2: Data, Methods, and Assumptions Manual

1. Introduction

The Data, Methods and Assumptions Manual has been created for the Town of Halton Hills to give an overview of the modeling approach and provide a summary of the data and assumptions being used as the foundation for the energy and emissions modeling. This allows for the elements of the modelling to be fully transparent. Please note that the DMA includes a description of the whole modelling process—not just the Reference Scenario.

2. Accounting Framework

2.1 Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC)

The Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) is used as the framework for reporting in CityInSight. The GPC is the result of an effort to standardize city-scale inventories by the World Resources Institute, C40 Cities Climate Leadership Group and ICLEI – Local Governments for Sustainability (ICLEI).[21]

The GPC provides a robust framework for accounting and reporting city-wide greenhouse gas emissions. It seeks to:

- Help cities develop a comprehensive and robust greenhouse gas inventory in order to support climate action planning;
- Help cities establish a base year emissions inventory, set reduction targets, and track their performance;
- Ensure consistent and transparent measurement and reporting of greenhouse gas emissions between cities, following internationally recognized greenhouse gas accounting and reporting principles;
- Enable city inventories to be aggregated at subnational and national levels;
- Demonstrate the important role that cities play in tackling climate change, and facilitate insight through benchmarking – and aggregation – of comparable data.

To date, more than 100 cities across the globe have used the GPC (current and previous versions) to measure their greenhouse gas emissions.

[21] http://www.ghgprotocol.org/city-accounting

The GPC has been adopted by the following programs and initiatives:

- The Compact of Mayors (CoM)[22] is an agreement led by city networks to undertake a transparent and supportive approach to reduce city emissions and enhance resilience to climate change. CoM cities are required to measure and report greenhouse gas emissions using the GPC. The City of Toronto is currently committed as a Compact of Mayors city.
- carbonn Climate Registry is the common, publicly available repository for the Compact of Mayors. It provides standard reporting templates to help cities report their GHG emissions using the GPC. Currently about 300 cities have reported their emissions using the carbonn Climate Registry.
- CDP runs the world's largest environmental reporting platform. More than 5,000 companies, 200 cities, and 12 states and regions use CDP's platform every year to report on their environment-related data, including GHG emissions, climate risks, water risks, and economic opportunities. CDP serves as the official reporting platform for C40 cities, the Compact of Mayors and the Compact of States and Regions. CDP supports cities in reporting their emissions using the GPC. The City of Toronto currently reports to CDP.

The GPC is based on the following principles in order to represent a fair and true account of emissions:

- **Relevance:** The reported GHG emissions shall appropriately reflect emissions occurring as a result of activities and consumption within the city boundary. The inventory will also serve the decision-making needs of the city, taking into consideration relevant local, subnational, and national regulations. Relevance applies when selecting data sources, and determining and prioritizing data collection improvements.
- **Completeness:** All emissions sources within the inventory boundary shall be accounted for. Any exclusions of sources shall be justified and explained.
- **Consistency:** Emissions calculations shall be consistent in approach, boundary, and methodology.
- **Transparency:** Activity data, emissions sources, emissions factors and accounting methodologies require adequate documentation and disclosure to enable verification.
- **Accuracy:** The calculation of GHG emissions should not systematically overstate or understate actual GHG emissions. Accuracy should be sufficient enough to give decision makers and the public reasonable assurance of the integrity of the reported information. Uncertainties in the quantification process should be reduced to the extent possible and practical.

2.2 Role of the CityInSight model: Future emissions projections

A GHG reporting protocol, such as the GPC described above, defines a standard set of categories, breakdowns, scopes, boundary treatment methods, and estimation methods. These protocols are typically geared towards reporting historical periods of observed data, designed for governments or companies to disclose the emissions impacts or progress of recent years activities. However, such protocols offer limited guidance for the development of GHG emissions projections for future years, which requires additional layers of data, inputs, and assumptions to establish a trajectory of emissions estimates. Figure 1 below shows reported versus projected GHG emissions on a conceptual timeline.[23]

22 http://www.compactofmayors.org/

23 When a model is introduced things can become more complicated, with overlapping reported and modelled time ranges. A more detailed version of this diagram is presented in the appendix.

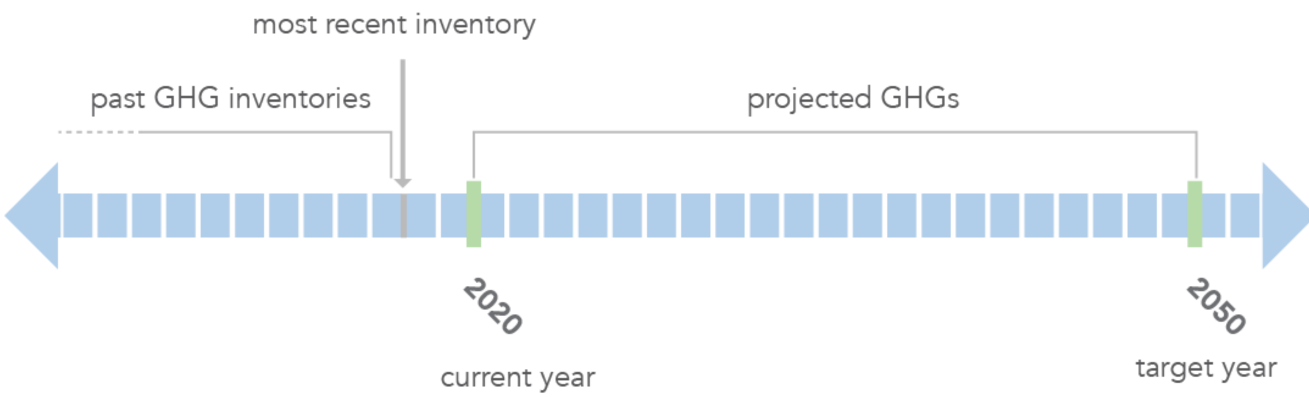

Figure 1. Conceptual timeline showing inventory reporting period and projection period.

Projecting GHG emission scenarios in support of low-carbon action planning requires:

- the consideration of various alternative city plans, policies and contextual assumptions, and
- the definition of the quantitative relationships between a city's activities, infrastructure, energy consumption, finances, and GHG emissions.
- The CityInSight model facilitates this process by capturing these relationships in a computable form, allowing them to be altered, examined, and understood.

CityInSight, initially developed in 2015, is designed so that its representation of a city's GHG emissions can be exported to the GPC reporting standard. The model is calibrated for a specific model base year (2016 in the latest update) and can effectively produce a GPC inventory report for that year, as well as for all subsequent years in its projection horizon. Figure 2 below shows the major components of CityInSight and the relationship to the GPC reporting standard.

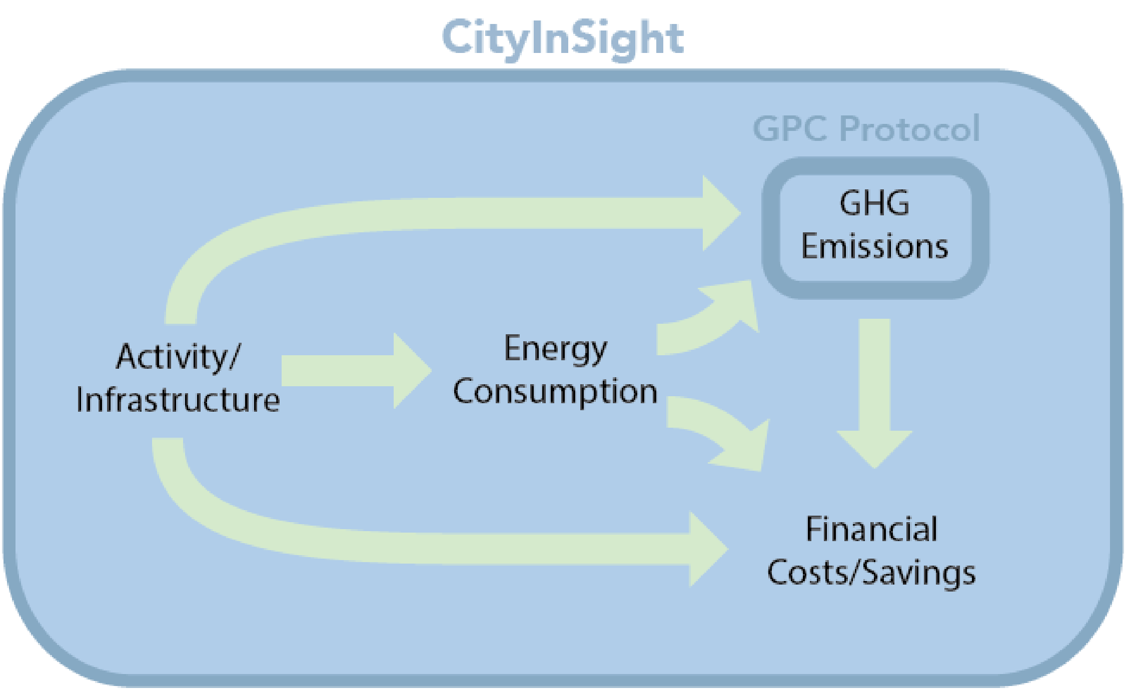

Figure 2. High-level components of CityInSight and relationship to the GPC reporting standard.

The GPC is billed as an accounting framework for city-level GHG emissions. CityInSight, as an integrated systems model, offers an extended accounting framework for community infrastructure, activity, energy, and financial flows, which is aligned with the GPC accounting framework. A description of energy accounting structure in CityInSight is provided in Section 4.

3. Emissions Scope

3.3 GHG Emissions Scope

The inventory and projects will include Scopes 1 and 2, and some aspects of Scope 3 emissions (Table 1).

Table 1. GHG emissions scopes.

Scope	Definition
1	All GHG emissions from sources located within the city boundary.
2	All GHG emissions occurring as a consequence of the use of grid-supplied electricity, heat, steam and/or cooling within the city boundary.
3	All other GHG emissions that occur outside the city boundary as a result of activities taking place within the city boundary.

The inventory addresses carbon dioxide (CO2), methane (CH4) and nitrous oxide (N20). Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF6) and nitrogen trifluoride (NF3) are not included. Emissions are expressed in CO2 equivalents per the assumptions in Table 2.

Table 2. Global Warming Potentials for selected greenhouse gases.

Greenhouse Gas	CO2 equivalents	Notes
CO2	1	
CH4	34	These have been updated in the IPCC 5th Assessment Report to include climate-carbon feedback.
N20	298	These have been updated in the IPCC 5th Assessment Report to include climate-carbon feedback.

4. Modelling

4.1 About CityInSight

CityInSight is an integrated spatially-disaggregated energy, emissions and finance model developed by Sustainability Solutions Group and whatIf? Technologies. The model enables bottom-up accounting for energy supply and demand, including renewable resources, conventional fuels, energy consuming technology stocks (e.g. vehicles, heating systems, dwellings, buildings) and all intermediate energy flows (e.g. electricity and heat).

CityInSight incorporates and adapts concepts from the system dynamics approach to complex systems analysis. Energy and GHG emissions are derived from a series of connected stock and flow models. The model accounts for physical flows (i.e. energy use, new vehicles, vehicle kilometres travelled) as determined by stocks (buildings, vehicles, heating equipment, etc.). For any given year within its time horizon, CityInSight traces the flows and transformations of energy from sources through energy currencies (e.g. gasoline, electricity) to end uses (e.g. personal vehicle use, space heating) to energy costs and to GHG emissions. The flows evolve on the basis of current and future geographic and technology decisions/assumptions (e.g. EV penetration rates). An energy balance is achieved by accounting for efficiencies, conservation rates, and trade and losses at each stage in the journey from source to end use. Characteristics of CityInSight are described in Table 3.

The model is spatially explicit. All buildings, transportation and land use data is tracked within the model through a GIS platform, and by varying degrees of spatial resolution. Where applicable, a zone type system can be applied to break up the city into smaller configurations. This enables consideration of the impact of land-use patterns and urban form on energy use and emissions production from a baseline year to future dates using GIS-based platforms. CityInSight's GIS outputs can be integrated with city mapping systems.

Table 3. Characteristics of CityInSight.

Characteristic	Rationale
Integrated	CityInSight is designed to model and account for all sectors that relate to energy and emissions at a city scale while capturing the relationships between sectors. The demand for energy services is modelled independently of the fuels and technologies that provide the energy services. This decoupling enables exploration of fuel switching scenarios. Physically feasible scenarios are established when energy demand and supply are balanced.
Scenario-based	Once calibrated with historical data, CityInSight enables the creation of dozens of scenarios to explore different possible futures. Each scenario can consist of either one or a combination of policies, actions and strategies. Historical calibration ensures that scenario projections are rooted in observed data.
Spatial	The configuration of the built environment determines the ability of people to walk and cycle, accessibility to transit, feasibility of district energy and other aspects. CityInSight therefore includes a full spatial dimension that can include as many zones - the smallest areas of geographic analysis - as are deemed appropriate. The spatial component to the model can be integrated with City GIS systems, land-use projections and transportation modelling.
GHG reporting framework	CityInSight is designed to report emissions according to the GHGProtocol for Cities (GPC) framework and principles.

Characteristic	Rationale
Economic impacts	CityInSight incorporates a full financial analysis of costs related to energy (expenditures on energy) and emissions (carbon pricing, social cost of carbon), as well as operating and capital costs for policies, strategies and actions. It allows for the generation of marginal abatement curves to illustrate the cost and/or savings of policies, strategies and actions.

4.2 Model Structure

The major components of the model (sub-models), and the first level of modelled relationships (influences), are represented in Figure 3. These sub-models are all interconnected through various energy and financial flows. Additional relationships may be modelled in CityInSight by modifying inputs and assumptions - specified directly by users, or in an automated fashion by code or scripts running 'on top of' the base model structure. Feedback relationships are also possible, such as increasing the adoption rate of non-emitting vehicles in order to meet a particular GHG emissions constraint.

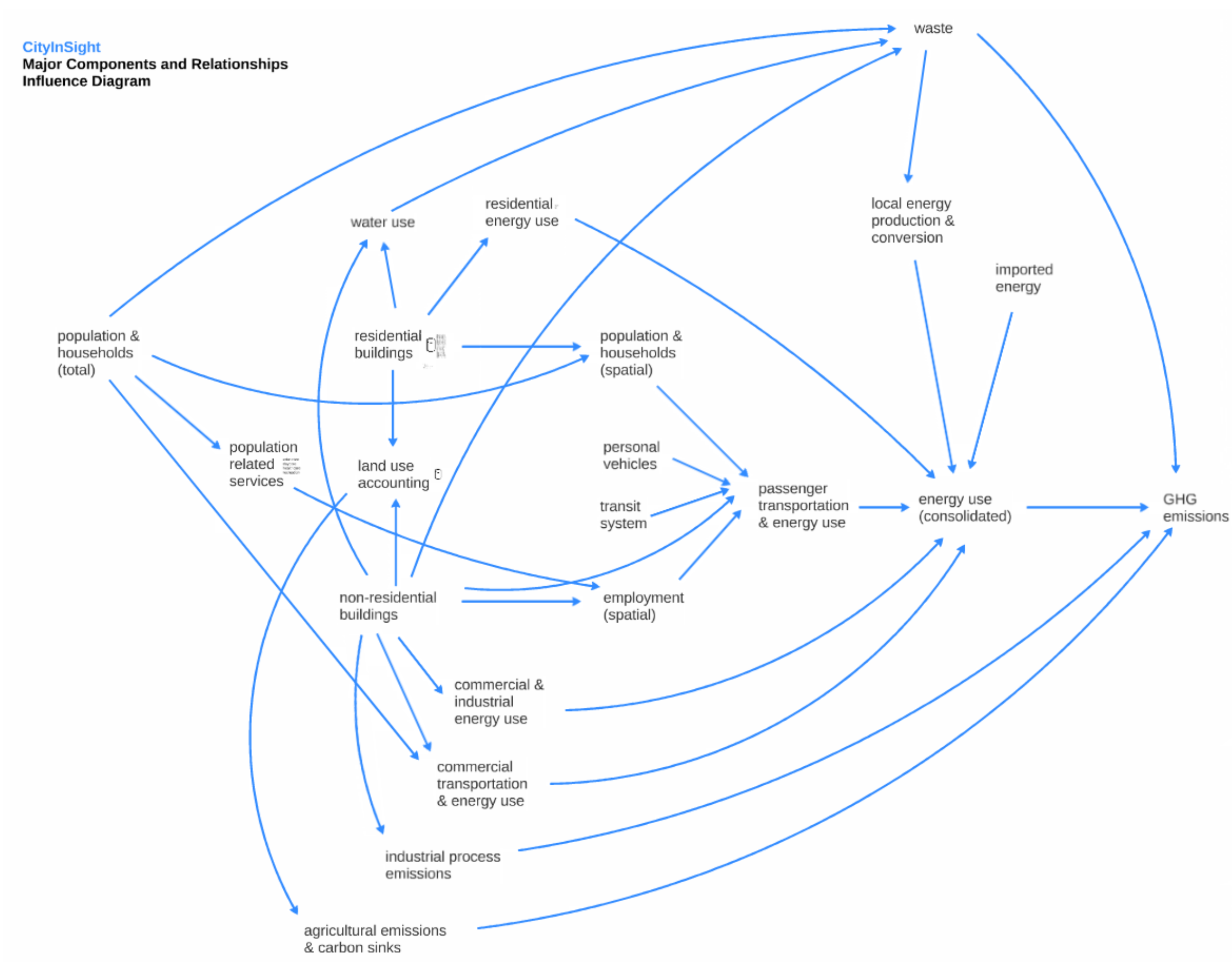

Figure 3. Representation of CityInSight's structure.

4.3 Stocks and Flows

Within each sub-model is a number of stocks and flows that represent energy and emissions processes in cities. For any given year various factors shape the picture of energy and emissions flows in a city, including: the population and the energy services it requires; commercial floorspace; energy production and trade; the deployed technologies which deliver energy services (service technologies); and the deployed technologies which transform energy sources to currencies (harvesting technologies). The model makes an explicit mathematical relationship between these factors - some contextual and some part of the energy consuming or producing infrastructure - making up the energy flow picture.

Some factors are modelled as stocks: counts of similar things, classified by various properties. For example, population is modelled as a stock of people classified by age and gender. Population change over time is projected by accounting for: the natural aging process, inflows (births, immigration) and outflows (deaths, emigration). The fleet of personal use vehicles, an example of a service technology, is modelled as a stock of vehicles classified by size, engine type and model year - with a similarly-classified fuel consumption intensity. As with population, projecting change in the vehicle stock involves aging vehicles and accounting for major inflows (new vehicle sales) and major outflows (vehicle discards). This stock-turnover approach is applied to other service technologies (e.g. furnaces, water heaters) and also harvesting technologies (e.g. electricity generating capacity).

4.4 Sub-models

The stocks and flows that make up each sub-model are described below.

POPULATION, HOUSEHOLDS AND DEMOGRAPHICS

- City-wide population is modelled using the 'standard population cohort-survival method', which tracks population by age and gender on a year-by-year basis. It accounts for various components of change: births, deaths, immigration and emigration.
- Population is allocated to households, and these are placed spatially in zones, via physical dwellings (see land-use accounting sub-model).
- The age of the population is tracked over time, which is used for analyzing demographic trends, generational differences and implications for shifting energy use patterns.
- The population sub-model influences energy consumption in various sub-models:
    - School enrollment totals (transportation)
    - Workforce totals (transportation)
    - Personal vehicle use (transportation)
    - Waste generation

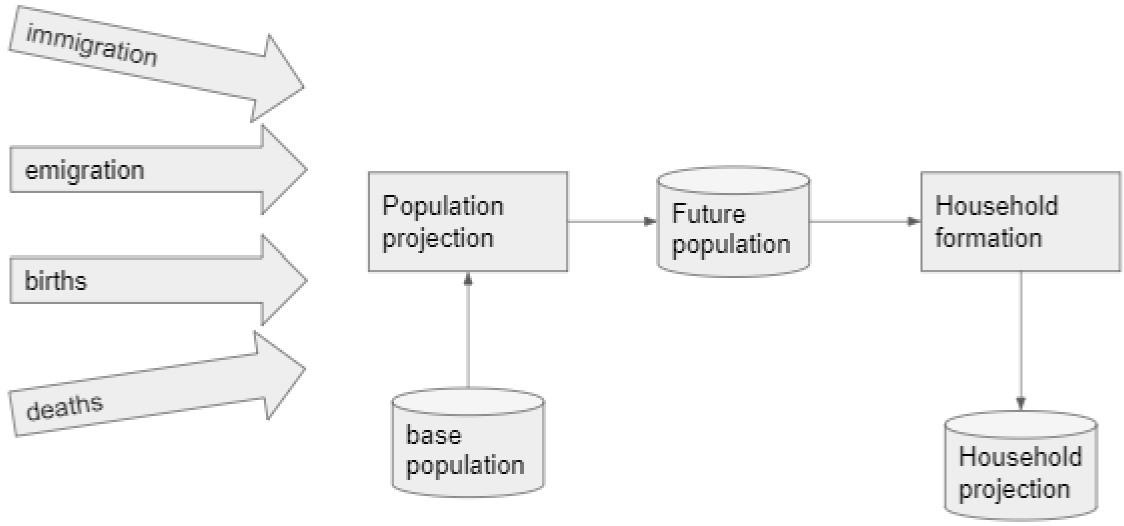

Figure 4. Representative diagram of stocks and flows in the population sub-model.

BUILDING LAND USE ACCOUNTING

Land use accounting identifies buildings in space and over time, through construction, retrofits and demolitions. In the baseline, this is often directly informed by municipal building-related geospatial data. Land use accounting consists of the follow elements:

- Quantitative spatial projections of residential dwelling units, by:
  - Type of residential structure (single detached, semi-detached, row house, apartment, etc.)
  - Development type (greenfield, intensification)
  - Population is assigned to dwelling units
- Quantitative spatial projections of non-residential buildings, by:
  - Type of non-residential structure (retail, commercial, institutional)
  - Development type (greenfield, intensification)
  - Buildings are further classified into archetypes (such as school, hospital, industrial - see).[24] This allows for the model to account for differing intensities that would occur in relation to various non-residential buildings.
- Jobs are allocated to zones via non-residential floor area, using a floor area per worker intensity.
- Land-use accounting takes 'components of change' into account, year over year:
  - New development
  - Removals / demolitions
  - Year of construction
- Land use accounting influences other aspects of the model, notably:
  - Passenger transportation: the location of residential buildings influences where home-to-work and

[24] Where possible, this data comes directly from the municipality.

home-to-school trips originate, which in turn also influences their trip length and the subsequent mode selected. Similarly, the location and identification of non-residential buildings influences the destination for many trips. For example, buildings identified as schools would be identified in home-to-school trips.

- Access to energy sources by buildings: building location influences access to energy sources, for example, a rural dwelling may not have access to natural gas or a dwelling may not be in proximity to an existing district energy system. It can also be used to identify suitable projects: for example, the location and density of dwellings is a consideration for district energy development.
- Non-residential building energy: the identification of non-residential building archetypes influences their energy consumption based on their use type. For example, a building identified as a hospital would have a higher energy use intensity than a building identified as a school.

This relationship is simplified in Figure 5.

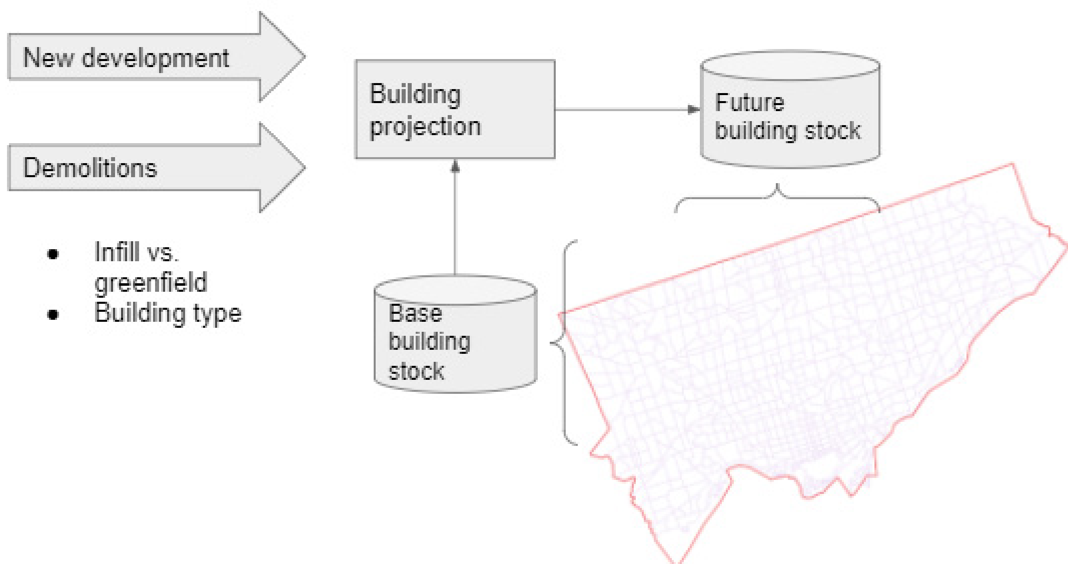

Figure 5. Diagram of land-use accounting sub-model.

Table 4. Non-residential archetypes represented in the model.

college_university	commercial_retail
school	commercial
retirement_or_nursing_home	commercial_residential
special_care_home	retail_residential
hospital	warehouse_commercial
municipal_building	warehouse
fire_station	religious_institution
penal_institution	surface_infrastructure
police_station	energy_utility
military_base_or_camp	water_pumping_or_treatment_station
transit_terminal_or_station	industrial_generic
airport	food_processing_plants
parking	textile_manufacturing_plants
hotel_motel_inn	furniture_manufacturing_plants
greenhouse	refineries_all_types
greenspace	chemical_manufacturing_plants
recreation	Printing_and_publishing_plants
community_centre	fabricated_metal_product_plants
golf_course	manufacturing_plants_miscellaneous_processing_plants
museums_art_gallery	asphalt_manufacturing_plants
retail	concrete_manufacturing_plants
vehicle_and_heavy_equiptment_service	industrial_farm
warehouse_retail	barn
restaurant	

RESIDENTIAL AND NON-RESIDENTIAL BUILDING ENERGY

Building energy consumption is closely related to the land use accounting designation it receives, based on where the building is located, its archetype, and when it was constructed. Building energy consumption calculated by:

- Total energy use intensity of the building type (including the proportion from thermal demand) is built up from energy end uses in the building. End uses include heating, lighting, auxiliary demand, etc. The energy intensity of end uses is related to the building archetype and its age.
- Then, energy use by fuel is determined based on the technologies used in each building (electricity, heating system types). From here, heating system types are assigned to building equipment stocks (heating systems, air conditioners, water heaters).
- Building energy consumption in the model also considers:
  - solar gains and internal gains from sharing walls;
  - local climate (heating and cooling degree days); and
  - energy losses in the building.
- Building equipment stocks (water heaters, air conditioners) are modelled with a stock-turnover approach that captures equipment age, retirements, and additions. In future projections, the natural replacement of stocks is often used as an opportunity to introduce new (and more efficient) technologies.

- The residential and non-residential building energy sub-model are two core components of the model. They influence and produces important model outputs:
  - Total residential energy consumption and emissions and residential energy and emissions by building type, by end use, by fuel.
  - Total non-residential energy consumption and emissions and residential energy and emissions by building type, by end use, by fuel.
  - Local/imported energy balance: how much energy will need to be imported after considering local capacity and production.

Figure 6 details the flows in the energy sub-model at the building level. This is then aggregated across all buildings within the assessment boundary.

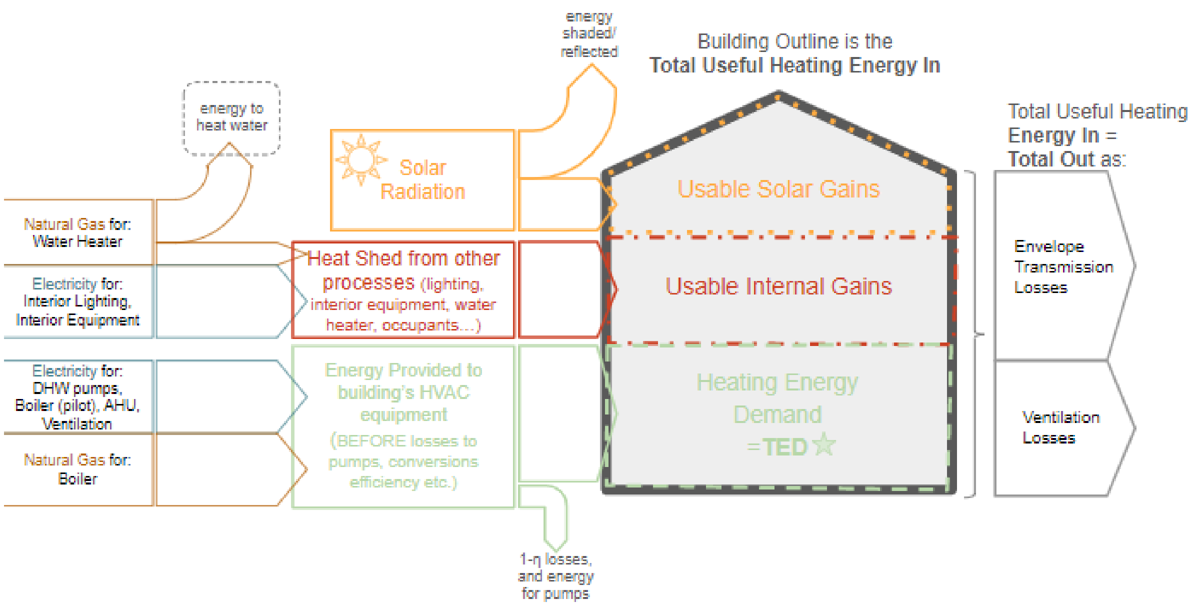

Figure 6. Building energy sub-model schematic.

TRANSPORTATION

CityInSight includes a spatially explicit passenger transportation sub-model that responds to changes in land use, transit infrastructure, vehicle technology, travel behavior changes and other factors. It has the following features:

- CityInSight uses the induced method for accounting for transportation related emissions; the induced method accounts for in-boundary tips and 50% of transboundary trips that originate or terminate within the city boundary. This shares energy and GHGs between municipalities.
- The model accounts for 'trips' in the following sequence:
  - Trip generation. Trips are divided into four types (home-work, home-school, home-other, and non-home-based), each produced and attracted by different combinations of spatial influences identified in the land-use accounting sub-model: dwellings, employment, classrooms, non-residential floorspace.
  - Trip distribution. Trips are then distributed with the number of trips specified for each zone of origin and zone of destination pair. Origin-Destination (O-D) matrix data is based on local travel surveys and transportation models.

- Mode share. For each origin-destination pair, trips are shared over walk/bike, public transit and automobile.
  - Walk / bike trips are identified based on a distance threshold: ~2km for walking, ~5-10km for biking.
  - Transit trips are allocated to trips with an origin or destination within a certain distance to a transit station.
- Vehicle distance. Vehicle kilometres travelled (VKT) are calculated based on the number of trips by mode and the distance of each trip based on a network distance matrix for the origin-destination pairs.
- VKT is also assigned to a stock of personal vehicles, based on vehicle type, fuel type, and fuel efficiency. The number of vehicles is influenced by the total number of households identified in the population sub-model. Vehicles also use a stock-turnover approach to model vehicle replacements, new sales and retirements.
- The energy use and emissions associated with personal vehicles is calculated by VKT of the stock of personal vehicles and their type, fuel and efficiency characteristics.
- Personal mobility sub-model is one of the core components of the model. It influences and produces important model outputs:
  - Total transportation energy consumption by fuel, including electricity consumption
  - Active trips and transit trips, by zone distance.

Trips accounted for in the model are displayed in Figure 7.

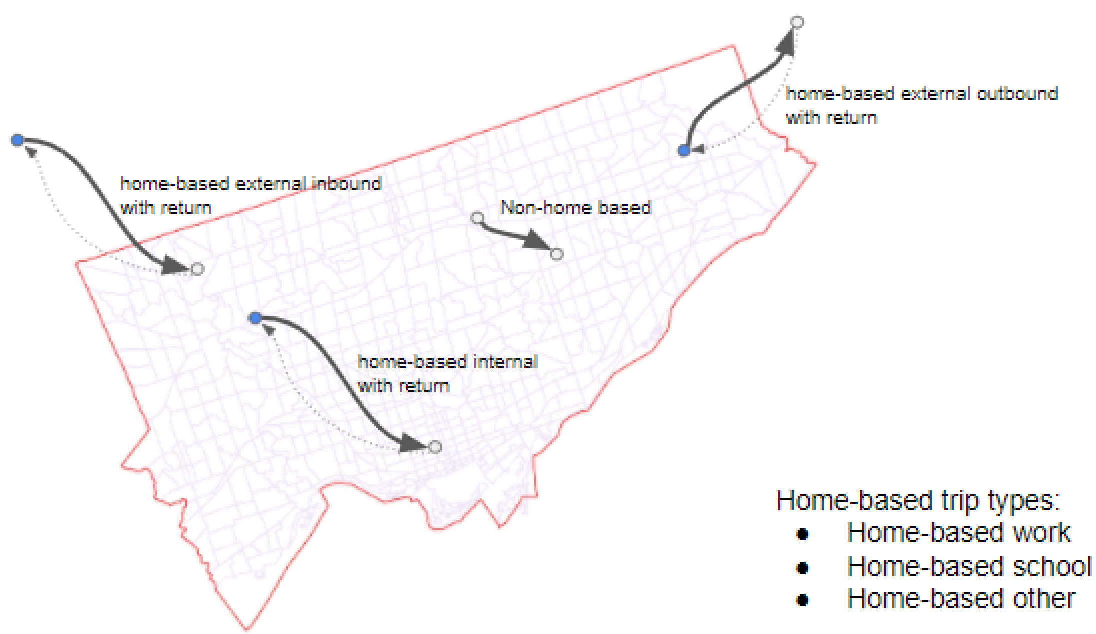

Figure 7. Trips assessed in the personal mobility sub-model.

WASTE

Households and non-residential buildings generate solid waste and wastewater, and the model traces various pathways to disposal, compost and sludge. If present in the city, the model can also capture energy recovery from incineration and biogas. Waste generation is translated to landfill emissions based on first order decay models of carbon to methane.

LOCAL ENERGY PRODUCTION

The model accounts for energy generated within city boundaries. Energy produced from local sources (e.g. solar, wind, biomass) is modelled alongside energy imported from other resources (e.g. the electricity grid and the natural gas distribution system). The model accounts for conversion efficiency. Local energy generation can be spatially defined.

FINANCIAL AND EMPLOYMENT IMPACTS

Energy related financial flows and employment impacts are captured through an additional layer of model logic. Costs are calculated as new stock is incorporated into the model, through energy flows (annual fuel costs), as well as other operating and maintenance costs. Costs are based on a suite of assumptions that are input into the model. See Section 4.6 for financial variables tracked within the model.

Employment is calculated based on non-residential building archetypes and their floor area. Employment related to investments are calculated using standard employment multipliers, often expressed as person-years of employment per million dollars of investment.

4.5 Energy and GHG Emissions Accounting

CityInSight accounts for the energy flows through the model, as shown in Figure 8.

Source fuels crossing the geographic boundary of the city are shown on the left. The four 'final demand' sectors - residential, commercial, industrial, and transportation - are shown towards the right. Some source fuels are consumed directly in the final demand sectors (e.g. natural gas used by furnaces for residential heating, gasoline used by personal vehicles for transportation). Other source fuels are converted to another energy carrier before consumption in the final demand sectors (e.g. solar energy converted to electricity via photovoltaic cells, natural gas combusted in heating plants and the resulting hot water distributed to end use buildings via district energy networks). Finally, efficiencies of the various conversion points (end uses, local energy production) are estimated to split flows into either 'useful' energy or conversion losses at the far right side of the diagram.

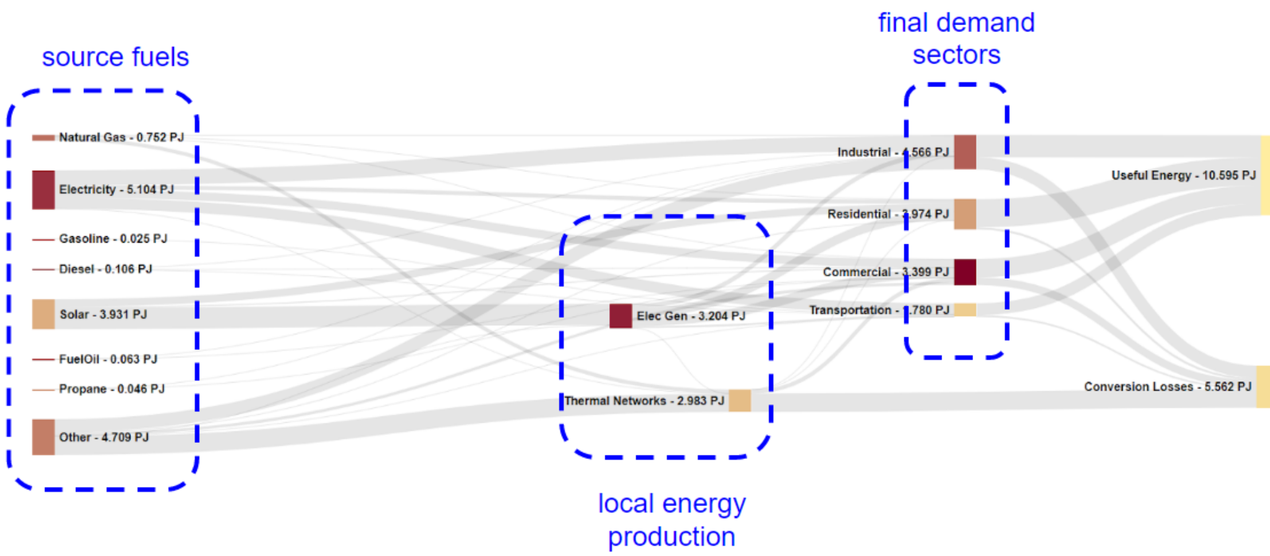

Figure 8. Energy flow Sankey diagram showing main node groups.

Figure 8 above shows the potential for ambiguity when energy is reported: which of energy flows circled are included and how do you prevent double counting? To address these ambiguities, CityInSight defines two main energy reports:

- Energy Demand, shown in Figure 9. Energy Demand includes the energy flows just before the final demand sectors (left of the dotted red line). Where the demand sectors are supplied by local energy production nodes, the cut occurs after the local energy production and before demand.
- Energy Supply, shown in Figure 10. Energy Supply includes the energy flows just after the source fuel nodes (left of the dotted red line). Where the source fuels supply local energy production nodes, the cut occurs between the source fuels and local energy production.

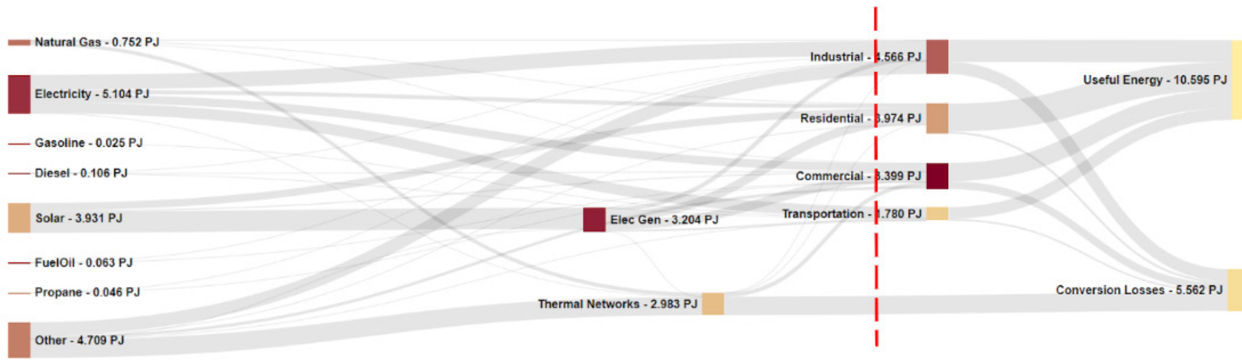

Figure 9. Energy Demand report definition.

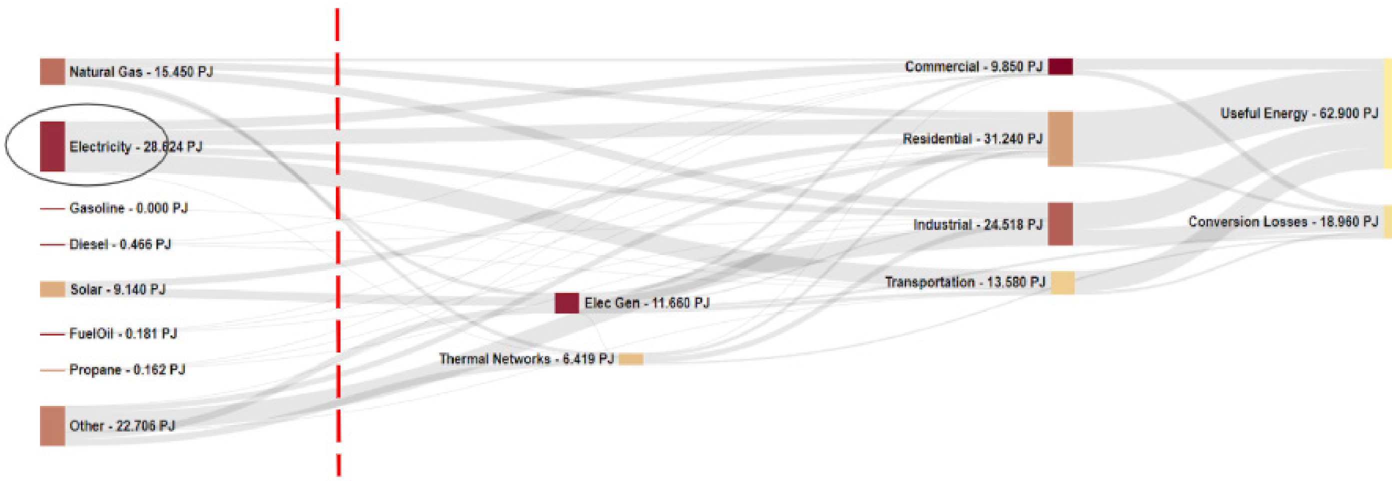

Figure 10. Energy Supply report definition.

In the integrated CityInSight energy and emissions accounting framework, GHG emissions are calculated after energy consumption is known.

4.6 Financial Accounting

The model also has a financial dimension expressed for most of its stocks and flows. Costs and savings modelling considers:

- Upfront capital expenditures: this is related to new stocks, such as new vehicles or new building equipment.
- Operating and maintenance costs: Annualized costs associated with stocks, such as vehicle maintenance.
- Energy costs: this is related to energy flows in model, accounting for fuel and electricity costs, and
- carbon pricing: Calculated by on emissions generation.

Expenditure types that are evaluated in the model are summarized in Table 5. Financial assumptions will be included in further iterations of the Halton Hills model.

Table 5. Categories of expenditures.

Category	Description
Residential buildings	Cost of dwelling construction and retrofitting; operating and maintenance costs (non-fuel).
Residential equipment	Cost of appliances and lighting, heating and cooling equipment.
Residential fuel	Energy costs for dwellings and residential transportation.
Residential emissions	Costs resulting from a carbon price on GHG emissions from dwellings and transportation.
Commercial buildings	Cost of building construction and retrofitting; operating and maintenance costs (non-fuel).
Commercial equipment	Cost of lighting, heating and cooling equipment.
Commercial vehicles	Cost of vehicle purchase; operating and maintenance costs (non-fuel).
Non-residential fuel	Energy costs for commercial buildings, industry and transport.
Non-residential emissions	Costs resulting from a carbon price on GHG emissions from commercial buildings, production and transportation.
Energy production emissions	Costs resulting from a carbon price on GHG emissions for fuel used in the generation of electricity and heating.
Energy production fuel	Cost of purchasing fuel for generating local electricity, heating or cooling.
Energy production equipment	Cost of the equipment for generating local electricity, heating or cooling.
Municipal capital	Cost of the transit system additions (no other forms of municipal capital assessed).
Municipal fuel	Cost of fuel associated with the transit system.
Municipal emissions	Costs resulting from a carbon price on GHG emissions from the transit system.
Energy production revenue	Revenue derived from the sale of locally generated electricity or heat.

Category	Description
Personal use vehicles	Cost of vehicle purchase; operating and maintenance costs (non-fuel).
Transit fleet	Costs of transit vehicle purchase.
Active transportation infrastructure.	Costs of bike lane and sidewalk construction.

FINANCIAL REPORTING PRINCIPLES

The financial analysis is guided by the following reporting principles:

- Sign convention: Costs are negative, revenue and savings are positive.
- The financial viability of investments will be measured by their net present value.
- All cash flows are assumed to occur on the last day of the year and for purposes of estimating their present value in Year 1 will be discounted back to time zero (the beginning of Year 1). This means that even the initial capital outlay in Year 1 will be discounted by a full year for purposes of present value calculations.
- We will use a discount rate of 3% in evaluating the present value of future government costs and revenues.
- Each category of stocks will have a different investment horizon
- Any price increases included in our analysis for fuel, electricity, carbon, or capital costs will be real price increases, net of inflation.
- Where a case can be made that a measure will continue to deliver savings after its economic life (e.g. after 25 years in the case of the longest-lived measures), we will capitalize the revenue forecast for the post-horizon years and add that amount to the final year of the investment horizon cash flow.
- In presenting results of the financial analysis, results will be rounded to the nearest thousand dollars, unless additional precision is meaningful.

4.7 Inputs and Outputs

The model relies on a suite of assumptions that define the various stocks and flows within the model for every time-step (year) in the model.

BASELINE

For the baseline year, many model inputs come from calibrating the model with real energy datasets. This includes real building and transportation fuel data, city data on population, housing stock and vehicle stock etc. Other assumptions come from underlying relationships between energy stocks and flows identified through research, like the fuel efficiency of personal vehicles, the efficiency of solar PV.

FUTURE PROJECTIONS

CityInSight is designed to project how the energy flow picture and emissions profile will change in the long term by modelling potential change in:

- the context (e.g. population, development patterns),
- emissions reduction actions (that influence energy demand and the composition of stocks).

Potential changes in the system are also based on a suite of input assumptions, and are frequently referred to as 'actions'. Actions are an intervention point in the model that changes the relationship between a certain stock and flow at a certain time. Action assumptions can be based on existing projections and on proposed policy design, and can be as wide ranging the stocks and flows present in the model.

Stock-turnover models enable users to directly address questions about the penetration rates of new technologies over time constrained by assumptions such as new stock, market shares and stock retirements. Examples of outputs of the projections include energy mix, mode split, vehicle kilometres of travel (VKT), total energy costs, household energy costs, GHG emissions and others. Energy, emissions, capital and operating costs are outputs for each scenario. The emission and financial impacts of alternative climate mitigation scenarios are usually presented relative to a reference or 'business as planned' scenario.

For example, an action may assume: 'Starting in 2030, all new personal vehicles are electric." This assumption would be input into the model, where, starting in 2030, every time a vehicle is at the end of its life, rather than be replaced with an internal combustion engine vehicle, it is replaced with an electric vehicle. As a result, the increase in the electric vehicle stock means greater VKT allocated to electricity and less to gasoline, thereby resulting in lower emissions.

4.8 Spatial Disaggregation

As noted above, a key feature of CityInSight is the geocoded stocks and flows that underlie the energy and emissions in the community. All buildings and transportation activities are tracked within a discrete number of geographic zones, specific to the city. This enables consideration of the impact of land-use patterns and urban form on energy use and emissions production from a baseline year to future points in the study horizon. CityInSight outputs can be integrated with city mapping and GIS systems. This is the feature that allows CityInSight to support the assessment of a variety of urban climate mitigation strategies that are out of reach of more aggregate representations of the energy system. Some examples include district energy, microgrids, combined heat and power, distributed energy, personal mobility (the number, length and mode choice of trips), local supply chains, and EV infrastructure.

For stationary energy use, the foundation for the spatial representation consists of land use, zoning and property assessment databases routinely maintained by municipal governments. These databases have been geocoded in recent years and contain detailed information about the built environment that is useful for energy analysis.

For transportation energy use and emissions, urban transportation survey data characterizes personal mobility by origin, destination, trip time, and trip purpose. This in turn supports the spatial mapping of personal transportation energy use and greenhouse gas emissions by origin or destination.

5. Modelling Process

CityInSight is designed to support the process of developing a municipal strategy for greenhouse gas mitigation. Usually the model is engaged to identify a pathway for a community to meet a greenhouse gas emissions target by a certain year, or to stay within a cumulative carbon budget over a specified period.

DATA COLLECTION, CALIBRATION AND BASELINE

A typical CityInSight engagement begins with an intensive data collection and calibration exercise in which the model is systematically populated with data on a wide range of stocks and flows in the community that affect greenhouse gas emissions. A picture literally emerges from this data that begins to identify where opportunities for climate change mitigation are likely to be found in the community being modeled. The calibration and inventory exercise helps establish a common understanding among community stakeholders about how the greenhouse gas emissions in their community are connected to the way they live, work and play. Relevant data are collected for variables that drive energy and emissions—such as characteristics of buildings and transportation technologies -- and those datasets are reconciled with observed data from utilities and other databases. The surface area of buildings is modeled in order to most accurately estimate energy performance by end-use. Each building is tracked by vintage, structure and location, and a similar process is used for transportation stocks. Additional analysis at this stage includes local energy generation, district energy and the provincial electricity grid. The primary outcome of this process is an energy and GHG inventory for the baseline year, with corresponding visualizations.

THE BASELINE AND REFERENCE PROJECTION

Once the baseline is completed, a reference projection to the target year or the horizon year of the scenario exercise is developed. The reference projection is based on a suite of input assumptions into the model that reflect the future conditions. This is often based on: existing municipal projections, for buildings and population; historical trends in stocks that can be determined during model calibration. In particular, future population and employment and allocating the population and employment to building types and space. In the process the model is calibrated against historical data, providing a technology stock as well as an historical trend for the model variables. This process ensures that the demographics are consistent, that the stocks of buildings and their energy consumption are consistent with observed data from natural gas and electricity utilities, and that the spatial/zonal system is consistent with the municipality's GIS and transportation modelling.

The projection typically includes approved developments and official plans in combination with simulation of committed energy infrastructure to be built, existing regulations and standards (for example renewable energy and fuel efficiency) and communicated policies. The projection incorporates conventional assumptions about the future development of the electrical grid, uptake of electric vehicles, building code revisions, changes in climatic conditions and other factors. The resulting projection serves as a reference line against which the impact and costs of GHG mitigation measures can be measured. Sensitivity analysis and data visualizations are used to identify the key factors and points of leverage within the reference projection.

LOW-CARBON SCENARIO AND ACTION PLAN

The low-carbon scenario uses a new set of input assumptions to explore the impacts of emissions reduction actions on the emissions profile. Often this begins with developing a list of candidate measures for climate mitigation in the community, supplemented by additional measures and strategies that are identified through stakeholder engagement. For many actions, CityInSight draws on an in-house database that specifies the performance and cost of technologies and measures for greenhouse gas abatement. The low-carbon scenario is analyzed relative to the reference projection. The actions in the low-carbon scenario are together to ensure that there is no double counting and that interactive effects of the proposed measures are captured in the analysis.

6. Addressing Uncertainty

There is extensive discussion of the uncertainty in models and modelling results. The assumptions underlying a model can be from other locations or large data sets and do not reflect local conditions or behaviours, and even if they did accurately reflect local conditions, it is exceptionally difficult to predict how those conditions and behaviours will respond to broader societal changes and what those broader societal changes will be (the 'unknown unknowns').

The modelling approach identifies four strategies for managing uncertainty applicable to community energy and emissions modelling:

- Sensitivity analysis: From a methodological perspective, one of the most basic ways of studying complex models is sensitivity analysis, quantifying uncertainty in a model's output. To perform this assessment, each of the model's input parameters is described as being drawn from a statistical distribution in order to capture the uncertainty in the parameter's true value.
  - Approach: Each of the variables will be increased by 10-20% to illustrate the impact that an error of that magnitude has on the overall total.
- Calibration: One way to challenge the untested assumptions is the use of 'back-casting' to ensure the model can 'forecast' the past accurately. The model can then be calibrated to generate historical outcomes, which usually refers to 'parameter adjustments' that 'force' the model to better replicate observed data.
  - Approach: Variables for which there are two independent sources of data are calibrated in the model. For example, the model calibrates building energy use (derived from buildings data) against actual electricity data from the electricity distributor.
- Scenario analysis: Scenarios are used to demonstrate that a range of future outcomes are possible given the current conditions that no one scenario is more likely than another.
  - Approach: The model will develop a reference scenario.
- Transparency: The provision of detailed sources for all assumptions is critical to enabling policy-makers to understand the uncertainty intrinsic in a model.
  - Approach: The assumptions and inputs are presented in this document.

7. Data and Assumptions for the Town of Halton Hills

7.1 Assessment Scope

GEOGRAPHIC BOUNDARY

The geographic boundary of the modelling assessment is the municipal boundary of the Town of Halton Hills (Figure 11).

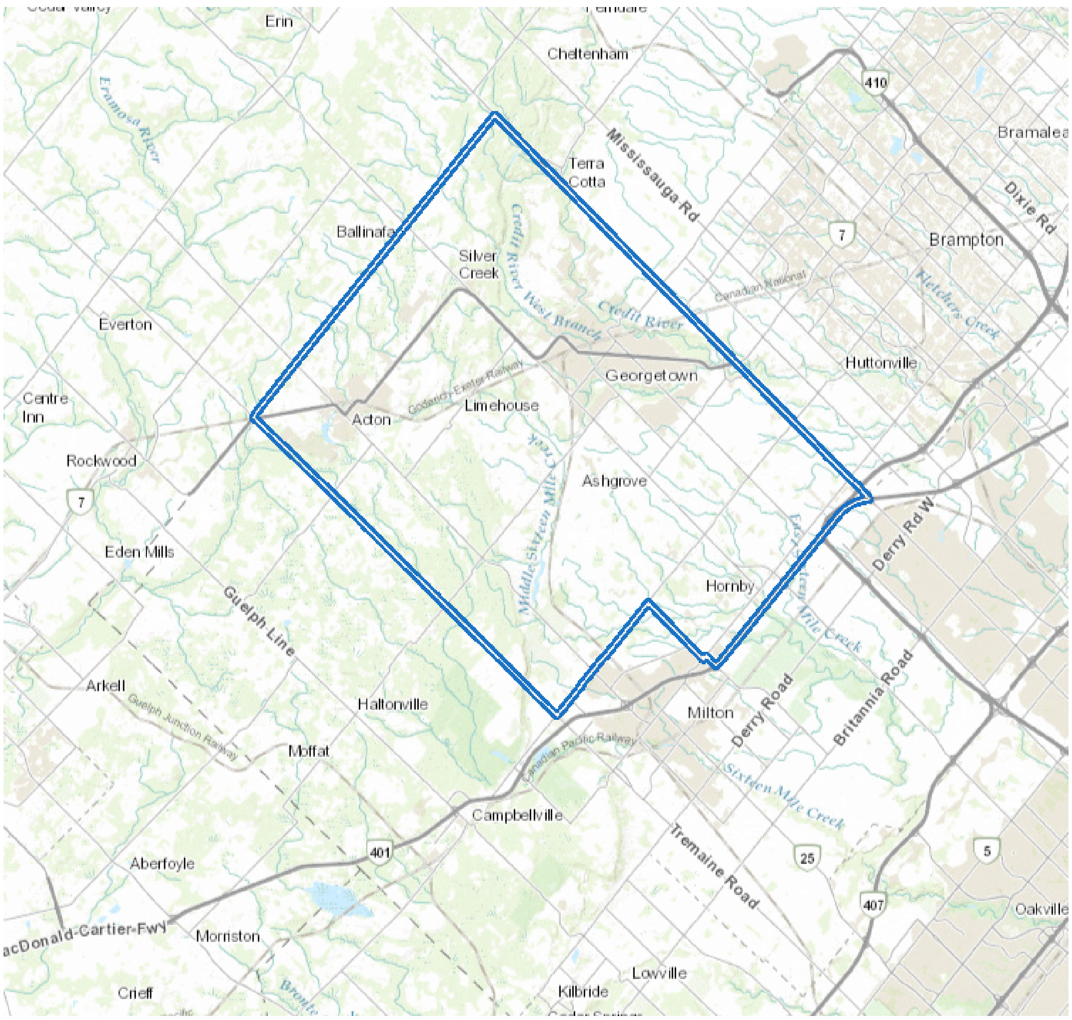

Figure 11. Assessment boundary for the Town of Halton Hills.

TIME SCOPE

- The assessment will cover the years from 2016 to 2030.
- The year 2016 will be used as the baseline year within the model. The rationale for using this as the base year is that:
- The model requires the calibration of a base year system state (initial conditions) using as much observed data as possible in order to develop an internally consistent snapshot of the city.
- A key data source for the model is census data. At the time of modelling, the last census year for which there is data available is 2016.
- Transportation Tomorrow Survey and the long-range transportation modelling conducted in the Greater Toronto Area follow the census year 2016.
- 1-year increments are modelled from the 2016 baseline year. 2016 is the first simulation period/year.
- Projections will extend to 2050, although reporting in this report is limited to the year 2030.

EMISSIONS SCOPE

The relevant emissions sources for Halton Hills and their emissions scope are detailed in Table 6. Of note is treatment of local electricity supplied to the grid: all emissions reductions from new local energy generation are accounted for locally, rather than distributed through the central electricity grid. However, central electrified generation facilities located within municipal boundaries, are only accounted for through the electricity grid emissions factor. This distinction is made because the current central electricity generation is already accounted for through the grid emissions factor. Reporting on such a facility is not required under GPC Protocol BASIC or BASIC+. New local energy generation projects are not included in electricity emissions factor projections.

Table 6. Sources included in Halton Hills model.

	Scope 1	Scope 2	Scope 3	Notes
Stationary Energy				
Residential buildings	Y	Y		
Commercial and institutional buildings and facilities	Y	Y		
Manufacturing industries and construction	Y	Y		
Energy industries	Y	Y		
Energy generation supplied to the grid	Additional renewable electricity is included beyond what is currently included in emissions factors projections			
Agriculture, forestry, and fishing activities	Y	Y		
Non-specified sources				NA
Fugitive emissions from mining, processing, storage, and transportation of coal				NA
Fugitive emissions from oil and natural gas systems	Y			
Transportation				

	Scope 1	Scope 2	Scope 3	Notes
On-road	Y	Y		
Railways	Y	Y		
Waterborne navigation				NA
Aviation			Y	
Off-road	Y	Y		
Waste				
Disposal of solid waste generated in the city			Y	
Disposal of solid waste generated outside the city				NA
Biological treatment of waste generated in the city			Y	
Biological treatment of waste generated outside the city				NA
Incineration and open burning of waste generated in the City				NA
Incineration and open burning of waste generated outside the city				NA
Wastewater generated in the city	Y		Y	
Wastewater generated outside the city				NA
Industrial processes and product use (IPPU)				
Industrial processes	Y			
Product use				NA
Agriculture, forestry and other land use (AFOLU)				
Livestock	Y			
Land	Y			
Aggregate sources and non-CO2 emissions sources on land	Y			
Other Scope 3				NA

7.2 Baseline Data

The following data was used to calibrate the model to the Town of Halton Hills and to develop its 2016 inventory baseline.

Table 7. Baseline data used to populate the Halton Hills model.

Dataset	Unit	Description	Source(s)
Demographics			
Population	# persons	Total by zone College & university student enrollment	Halton Hills Official Plan
Households / Dwellings	#	Total	Statistics Canada. 2016 Census.
Employment	# jobs (place of work)	Employment by sector/industry (NAICS) by zone	Halton Hills Official Plan
Buildings			
Parcel fabric		GIS parcel layer including attributes: - Parcel ID - Assessment roll number	From Town of Halton Hills
Building footprints		GIS: Building footprints shapefile	From Town of Halton Hills
Property assessment roll		MPAC tables: general, structure	Municipal Property Assessment Corporation Data
Residential	# dwelling units	dwellings by: - structure type - zone	From Town of Halton Hills
Non-residential	sq ft or sqm	for each building: - sector / industry - zone / GIS coordinates - year built - floorspace	Municipal Property Assessment Corporation Data
Municipal		For subset of non-residential buildings under the jurisdiction the Town of Halton Hills: - Operation Name - Operation Type - Address - Floor Area - Electricity Consumed - Natural Gas Consumed	Town of Halton Hills. Energy Conservation and Demand Management Plan. Ontario Broader Public Sector data identifies buildings and their energy intensity values but does not include floor area or energy consumption.
Land-use			
Municipal boundaries		GIS: Regional and municipal boundaries	Statistics Canada. 2016 Census

Dataset	Unit	Description	Source(s)
Policy boundaries		GIS maps of built boundary, designated greenfield, green belt / protected, etc.	Town of Halton Hills. Official Plan.
Energy infrastructure		Energy infrastructure; including district energy infrastructure, NG network, utilities, pipelines, EV charging.	Enbridge Gas. Service Network Areas. Enbridge serves Georgetown and Acton. No natural gas in most of the smaller hamlets and villages. There is a planned expansion into Ballinafad, Limehouse, and Silver Creek.
Fuel Consumption			
Natural gas	GJ preferred; m3 ok	2016-2019 (annual) total natural gas consumption. Cost ($/m3) by sector.	From Town of Halton Hills, via Enbridge Gas.
Electricity	kWh	2016-2019 (annual) otal electricity consumption. Cost ($/kWh) by sector.	Data from Halton Hills Hydro Inc
Gas and diesel sales	litres	2016-2019 (annual) total sales (L) by fuel type.	Kent Group Ltd. Gasoline and Diesel fuel data.
Grid electricity emissions factors	g/kWh	CO_2, CH_4, N_2O	CanESS model and IESO data.
Decentralized electricity generation	kWh (elec); GJ	2016-2019 (annual) total electricity generated by decentralized plant by zone by fuel/technology types; fuel use by type. Decentralized electricity capacity (MW).	IESO. (2020). Active Contracted Generation List March 2020.
District energy and network	kWh (elec); GJ	2016-2019 (annual) plant capacity and generation by fuel/technology type; fuel use by type; electricity generated from CHP; location of DE system & plant. Buildings served by DE systems: location, use type, floor area, consumption.	NA
Centralized electricity capacity	MW	2016-2019 (annual)	IESO. (2020). Active Contracted Generation List March 2020.
Centralized electricity generation	kWh	2016-2019 (annual)	IESO. (2020). Active Contracted Generation List March 2020.
Centralized electricity generation fuel use	GJ	2016-2019 (annual)	IESO. (2020). Active Contracted Generation List March 2020.

Dataset	Unit	Description	Source(s)
Energy costs			Halton Hills Hydro. Electricity. Retrieved from:https://haltonhillshydro.com/for-home/rates/electricity/ Ontario Energy Board. Historical natural gas rates. Retrieved from: https://www.oeb.ca/rates-and-your-bill/natural-gas-rates/historical-natural-gas-rates#enbridge
Residential energy consuming stocks		zone, fuel type, and stock type water heater types: conventional, solar, on demand, heat pump heat system types: oil, gas, electric, heat pump, combinations aircon types: room, central, heat pump	whatIf? Technologies. CanESS model.
Transportation			
Zones (traffic)		GIS: Traffic zone systems used for transportation modelling by the Town. Attribute of zones: greenfield or urbanized.	Town of Halton Hills.
Household travel survey		Household survey used for regional transportation modelling.	Transportation Information Steering Committee. (2018). 2016 Transportation Tomorrow Survey.
Modelled origin-destination trip matrix	person trip	24hr (not peak hour). By origin zone, destination zone, trip purpose, primary mode (auto, transit, active modes).	Transportation Information Steering Committee. (2018). 2016 Transportation Tomorrow Survey.
Distance matrix	km	Zone-to-zone road network distance matrix.	Transportation Information Steering Committee. (2018). 2016 Transportation Tomorrow Survey.
Vehicle fleet		2016 vehicle registration counts for passenger and commercial vehicles.	Transportation Information Steering Committee. (2018). 2016 Transportation Tomorrow Survey.
Corporate vehicle fleet		2016-2019 (annual) fleet count by body type (car, light truck); fuel type; technology type (internal combustion, hybrid, electric); weight class. VKT and/or fuel consumption.	Town of Halton Hills.
Local and regional (in-boundary) transit system		2016 fleet by type (subway, commuter train, bus, streetcar); VKT; energy/fuel use; vehicle fuel consumption per km.	Metrolinx. (2019). Kitchener go expansion initial business case http://www.metrolinx.com/en/regionalplanning/projectevaluation/benefitscases/2019-11-14-Kitchener-Mid-Term-Service-Expansion-IBC-Update-FINAL.pdf

Dataset	Unit	Description	Source(s)
School bus fleet		2016-2019 (annual) fleet by fuel type; VKT; fuel consumption.	
VKT	km	2016-2019 (annual) studies or estimates of regional VKT (traffic count based or other).	Transportation Information Steering Committee. (2018). 2016 Transportation Tomorrow Survey.
Rail fuel use	GJ or L	Fuel use for passenger and freight railway trips that start in or end in Town.	Statistics Canada. Table: 25-10-0029-01 (formerly CANSIM 128-0016) Provincial data will be allocated to Town on the basis of population by default
Aviation fuel use	GJ or L	Fuel use for passenger and freight aviation trips that start in or end in region.	Statistics Canada. Table: 25-10-0029-01 (formerly CANSIM 128-0016) Provincial data will be allocated to Town on the basis of population by default
Waste			
Solid waste produced	tonne / year	2016-2019 (annual) waste type and by sector	Resource Productivity and Recovery Authority. 2016 Residential Waste Diversion Rates by Municipal Program.
Waste disposal routing		2016-2019 (annual) fraction of waste generated within city handled within city boundary & handled outside of Town, by type	From Town of Halton Hills
Solid waste facilities capacity	tonne	Waste handling facilities capacity (within and outside of Town boundary), by facility type	From Town of Halton Hills
Solid waste facilities	-	% capacity used up by landfill in base year	From Town of Halton Hills
	tonne / year	2016-2019 (annual) quantities of waste taken in by handling facilities within boundary, by facility type	From Town of Halton Hills
	-	2016-2019 (annual) methane recovery fraction by handling facilities; where is recovered methane used?	From Town of Halton Hills
Diversion rates	-	2016-2019 (annual) recycling and compost diversion rates for residential and ICI waste.	Resource Productivity and Recovery Authority. 2016 Blue Box Program Marketed Tonnes.
Wastewater		2016-2019 annual wastewater volumes	Provided by the Town of Halton Hills.

Dataset	Unit	Description	Source(s)
Industry			
Industrial processes & product use		Industrial processes, production levels & emissions; by location	Government of Canada. National Pollutant Release Inventory.
Waste heat		Locations of waste heat producers, amount of waste heat	-
Agriculture			
Livestock		Heads of livestock in region by type	Government of Canada. National Pollutant Release Inventory.
Cropland	ha	Area of cropland by tillage practice for 2011 and 2016	Statistics Canada. Table: 32-10-0408-01 (formerly CANSIM 004-0205)
Forest area	ha	Area of forest for 2016	Government of Ontario. Wooded Areas. GeoHub.

7.3 Emissions Factors

Table 8. Emissions factors for fuels in Halton Hills model.

Fuel Type	Data	Source
GWP		
Greenhouse gases	Carbon dioxide (CO2), methane (CH4) and nitrous oxide (N20) are included. GWP: CO2 = 1 CH4 = 34 N2O = 298	Myhre, G. et al. (2013). Anthropogenic and Natural Radiative Forcing. Table 8.7. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
Emissions factors		
Natural gas	49 kg CO2e/GJ	Environment and Climate Change Canada. National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada. Part 2. Tables A6-1 and A6-2.
Electricity	2016: CO2: 7.47 g/kWh CH4: 0.000403 g/kWh N2O: 0.0000175 g/kWh 2051: CO2: 10.7 g/kWh CH4: 0.000952 g/kWh N2O: 0.000243 g/kWh	National Energy Board. (2016). Canada's Energy Future 2016. Government of Canada. Retrieved from https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2016pt/nrgyftrs_rprt-2016-eng.pdf IESO. (2020) Annual Planning Outlook

Fuel Type	Data	Source
Gasoline	g / L CO2: 2316 CH4: 0.32 N2O: 0.66	Environment and Climate Change Canada. National Inventory Report 1990-2015: Table A6–12 Emission Factors for Energy Mobile Combustion Sources
Diesel	g / L CO2: 2690.00 CH4: 0.07 N2O: 0.21	Environment and Climate Change Canada. National Inventory Report 1990-2015: Table A6–12 Emission Factors for Energy Mobile Combustion Sources
Fuel oil	Residential g/L CO2: 2560 CH4: 0.026 N2O: 0.006 Commercial g/L CO2: 2753 CH4: 0.026 N2O: 0.031 Industrial g/L CO2: 2753 CH4: 0.006 N2O: 0.031	Environment and Climate Change Canada. National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada. Part 2. Table A6–4 Emission Factors for Refined Petroleum Products
Wood	Residential kg/GJ CO2: 299.8 CH4: 0.72 N2O: 0.007 Commercial kg/GJ CO2: 299.8 CH4: 0.72 N2O: 0.007 Industrial kg/GJ CO2: 466.8 CH4: 0.0052 N2O: 0.0036	Environment and Climate Change Canada. National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada. Part 2. Table A6–56 Emission Factors for Biomass
Propane	g/L transport CO2: 1515.00 CH4: 0.64 N2O: 0.03 Residential CO2: 1515.000 CH4 : 0.027 N2O: 0.108 All other sectors CO2: 1515.000 CH4: 0.024 N2O: 0.108	Environment and Climate Change Canada. National Inventory Report 1990-2015: Table A6–3 Emission Factors for Natural Gas. Environment and Climate Change Canada. National Inventory Report 1990-2015: Table A6–12 Emission Factors for Energy Mobile Combustion Sources

Fuel Type	Data	Source
Waste/WW	wastewater emissions factors CH4: 0.48 kg CH4/kg BOD N2O: 3.2 g / (person * year) from advanced treatment 0.005 g /g N from wastewater discharge Landfill emissions are calculated from first order decay of degradable organic carbon deposited in landfill derived emission factor in 2016 = 0.015 kg CH4 / tonne solid waste (assuming 70% recovery of landfill methane), .05 kg CH4 / tonne solid waste not accounting for recovery	CH4 wastewater: IPCC Guidelines Vol 5 Ch 6, Tables 6.2 and 6.3, we use the MCF value for anaerobic digester N2O from advanced treatment: IPCC Guidelines Vol 5 Ch 6 Box 6.1 N2O from wastewater discharge: IPCC Guidelines Vol 5 Ch 6 Section 6.3.1.2 Landfill emissions: IPCC Guidelines Vol 5 Ch 3, Equation 3.1

ELECTRICITY EMISSIONS FACTOR

Table 9. Projected electricity emissions intensity (g/kWh).

	2017	2020	2022	2024	2026	2028	2030
CO2	33.67417	36.78	35.62	54.79	68.24	69.35	68.69
CH4	0.00689	0.01	0.01	0.01	0.02	0.02	0.02
N2O	0.001284	0	0	0	0	0	0

Source:

- IESO. (2020). Annual Planning Outlook.

7.4 Reference Scenario Assumptions Summary

Table 10 summarizes the reference scenario assumptions. Where assumptions are noted to be held constant, baseline data is carried forward annually in the projection. Detailed inputs for each assumption are outlined in Section 7.5.

Table 10. Reference scenario assumptions summary.

Category	Assumption	Source
DEMOGRAPHICS		
Population & employment		
Population	Population growth according to Town projections	Environics Analytics. (2019). Demo Stats 2019.
Employment		
BUILDINGS		
New buildings growth		
Building growth projections	Dwelling projections according to Environics data.	Environics Analytics. (2019). Demo Stats 2019.
New buildings energy performance		
Residential	25% of all new construction built to GDS. 2016-2020: 20% better than OBC 2012 2020-2026: 15% better than OBC 2020 Energy performance under code improves by 10% every five years. Once energy performance under OBC is higher than updated GDS, 100% of buildings will be constructed to OBC.	Town of Halton Hills. 2014. Green Development Standard. Assumption development as per assumptions made in Town of Halton Hills. (2018). Vision Georgetown Energy Master Plan. Post 2020 assumptions as per discussions with HH
Multi-residential		
Commercial & Institutional		
Industrial		
Existing buildings energy performance		
Residential	Existing building stock efficiency remains constant	
Multi-residential		
Commercial & Institutional		
Industrial		
Municipal	Existing municipal buildings upgraded by 2025 with improved energy perfomance	Town of Halton Hills. (2019). 2020-2025 Corporate Energy Plan.
End use		
Space heating	Fuel shares for end use unchanged; held from 2016-2050.	Canadian Energy Systems Analysis Research. Canadian Energy System Simulator. http://www.cesarnet.ca/research/caness-model .
Water heating		
Space cooling		

Category	Assumption	Source
Projected climate impacts		
Heating & cooling degree days	Heating Degree days are expected to decrease, and cooling degree days will increase.	Climateatlas.ca - BCCAqv2 downscaled climate data from Pacific Climate Impacts Consortium
ENERGY GENERATION		
Low or zero carbon energy generation (community scale)		
Rooftop Solar PV	Existing solar PV hold constant - 4.08 MW for IESO contracts New growth based on market uptake: 5% uptake by 2050 and 15% of res building energy needs (5% for apartment)	Town of Halton Hills. 2014. Green Development Standard. IESO. (2020). IESO active generation contract list (as of March 2020). Retrieved from: http://www.ieso.ca/en/Power-Data/Supply-Overview/Distribution-Connected-Generation
Ground mount solar	0.5 MW	IESO. (2020). IESO active generation contract list (as of March 2020). Retrieved from: http://www.ieso.ca/en/Power-Data/Supply-Overview/Distribution-Connected-Generation
District Energy Generation	No district energy applied. While a Natural Gas CHP Unit (<1MW) will be used to provide heat and electricity to a maximum of 2,589 units connecting to the district heating system at Vision Georgetown, this system is expected to be installed in 2035 (beyond the model end date)	Scenario 1 from Arup. (2018). Vision Georgetown Energy Master Plan.
Wind	None	IESO. (2020). IESO active generation contract list (as of March 2020). Retrieved from: http://www.ieso.ca/en/Power-Data/Supply-Overview/Distribution-Connected-Generation
Grid scale energy generation		
Centralized electricity gen	Centralized electricity generation is not included in Reference scenario reporting. There is a 641.5 MW NG generation station in the boundary of HH but its impact on emissions is captured within the Ontario grid emissions factor.	IESO. (2020). IESO active generation contract list (as of March 2020). Retrieved from: http://www.ieso.ca/en/Power-Data/Supply-Overview/Distribution-Connected-Generation
TRANSPORT		
Transit		

Category	Assumption	Source
Expanded transit	GO Kitchener line increasing two-way all-day complete by 2025. Current ridership: Acton: 121 daily trips Georgetown: 618 daily trips 2025: Acton: 220 daily trips Georgetown: 643 daily trips There is an assumed 5x increase in train VKT as a result of the project.	Metrolinx. (2019). Kitchener go expansion initial business case http://www.metrolinx.com/en/regionalplanning/projectevaluation/benefitscases/2019-11-14-Kitchener-Mid-Term-Service-Expansion-IBC-Update-FINAL.pdf Metrolinx. (2020). Full Schedules. Retrieved from: https://www.gotransit.com/static_files/gotransit/assets/pdf/TripPlanning/FullSchedules/FS20062020/Table31.pdf Town of Halton Hills. (2019). Transit Service Strategy. WSP.
Electrify transit system	No electrification on GO or Universal Access Service. Go train remains diesel.	Metrolinx. (2019). Kitchener go expansion initial business case http://www.metrolinx.com/en/regionalplanning/projectevaluation/benefitscases/2019-11-14-Kitchener-Mid-Term-Service-Expansion-IBC-Update-FINAL.pdf Town of Halton Hills. (2019). Transit Service Strategy. WSP.
Active		
Mode share	Proportional change in mode share: doubling transit mode share. By 2031, pm peak: 82% vehicle trips 4% transit 7% active 7% school bus 2006 pm peak: 84% vehicle trips 2% transit 7% active 7% school bus	Town of Halton Hills. (2011). Transportation Master Plan.
Private/personal use		
Electrify municipal fleet	No change to municipal fleets.	Town of Halton Hills. (2019). 2020-2025 Corporate Energy Plan.

Category	Assumption	Source
Vehicle electrification	Personal use: 14% new sales by 2030. Commercial: no change.	Axsen, J., Wolinetz, M. (2018). Reaching 30% plug-in vehicle sales by 2030: Modeling incentive and sales mandate strategies in Canada. Transportation Research Part D: Transport and Environment Volume 65, Pages 596-617
Vehicle fuel efficiencies / tailpipe emission standards	CAFE Fuel standards: Vehicle fuel consumption rates reflect the implementation of the U.S. Corporate Average Fuel Economy (CAFE) Fuel Standard for Light-Duty Vehicles, and Phase 1 and Phase 2 of EPA HDV Fuel Standards for Medium- and Heavy-Duty Vehicles. ------ Light duty: 2015: 200gCO2e/km 2025: 119 gCO2e/km 2030: 105gCO2e/km Heavy Duty: 20% reduction in emissions intensity by 2025, relative to 2015, 24% reduction in emissions intensity in 2030 relative to 2015	EPA. (2012). EPA and NHTSA set standards to reduce greenhouse gases and improve fuel economy for model years 2017-2025 cars and light trucks. Retrieved from https://www3.epa.gov/otaq/climate/documents/420f12050.pdf SOR/2010-201. Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations. Available from: http://laws-lois.justice.gc.ca SOR/2018-98. Regulations Amending the Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations and other Regulations Made Under the Canadian Environmental Protection Act, 1999. Available from: https://pollution-waste.canada.ca
Vehicle stock	Personal vehicle stock changes between 2016-2050. Commercial vehicle stock unchanged 2016-2050.	CANSIM and Natural Resources Canada's Demand and Policy Analysis Division.
WASTE		
Waste generation	1250 kg / household / year - no change	Halton Region. (2011). Solid Waste Management Strategy.
Waste diversion	Baseline waste diversion rate 57.4% (2010), 65% by 2016, to increase to 70% (2025). 59% was reported for 2016 to RPRA.	Halton Region. (2011). Solid Waste Management Strategy.
Waste treatment	Waste is treated outside the boundary, and partially flared, partially run through a landfill gas electricity generation. No change is waste treatment.	
Wastewater treatment	No change to wastewater treatment.	
OTHER		
Industrial efficiencies	No change.	
Agriculture	No change.	
Aviation	No change.	

7.5 Detailed Reference Scenario Assumptions

POPULATION AND EMPLOYMENT

Assumption

Environics data did not include Vision Georgetown projections. Therefore, Town-average projections were applied to zone 558 (Vision Georgetown zone).

Table 11. Population and employment input assumptions in the reference scenario.

	2016	2020	2025	2030
Population	63,333	68,668	80,005	91,868
Employment	32,712	35,973	37,996	39,363

Source

- Environics Analytics. (2019). Demo Stats 2019.

BUILDING GROWTH PROJECTIONS

Assumption

Residential dwelling unit projections come from Environics data, provided by the Town (Table 12). Environics data did not include Vision Georgetown projections. Therefore, town-average projections were applied to zone 558 (Vision Georgetown zone). Share of dwelling type in Vision Georgetown was based on the density targets in the Vision Georgetown Secondary Plan (Table 13). Commercial and industrial floor space are based on employment projections.

Table 12. Building growth assumption in the reference scenario.

	2016	2020	2025	2030
Dwelling units	21,732	22,598	26,680	30,636
Non res floor space (m2)	1,440,077	1,579,788	1,685,980	1,759,862

Table 13. Residential building type input assumption for Vision Georgetown in the reference scenario.

Density	Building Type	Share of total
Low density	Single detached	44.90%
Low density	Semi detached	-
Medium density	Row	39.50%
High density	Apt (5+ units)	-
High density	Apt (<5 units)	15.60%

Source

- Environics Analytics. (2019). Demo Stats 2019.
- Town of Halton Hills. (2018). Vision Georgetown Secondary Plan.

NEW BUILDING ENERGY PERFORMANCE

Assumption

From 2016-2020, 25% of all new buildings will be constructed to meet the Green Development Standard (GDS), reaching 20% better performance than the Ontario Building Code 2012 (OBC). 75% of buildings will be constructed to meet OBC 2012.

After 2020, 75% of new buildings will be constructed to Ontario Building Code 2020, which is estimated to be 10% better than OBC 2012. The remaining 25% of all new buildings will reach the updated GDS, which will reach 15% better energy performance than OBC 2020. The Reference scenario assumes that the OBC will require10% energy improvements every five years, but that the GDS is not updated again. Once the energy performance required under OBC is greater than that prescribed under GDS, all buildings will be constructed to OBC.

New construction efficiency improvements are summarized in Table 14.

Table 14. Schedule of efficiency improvements for new construction in the reference scenario.

	2016-2021	2022-2026	2027-2031	2032-2036	2037-2041	2042-2046
OBC energy improvement over previous version	10%	10%	10%	10%	10%	10%
Uptake	0.75	0.75	0.75	1	1	1
GDS energy performance relative to code	20%	25%	10%			
GDS uptake	0.25	0.25	0.25			

This translates to an improvement in energy performance of 12.5% across the residential building stock (new and existing) until 2021, 13.75% until 2026 and 10% until 2030 in the model. For non-residential buildings, there is a 10% improvement in energy performance every five years.

Source

- Arup. (2018). Vision Georgetown Energy Masterplan.
- Discussion with the Town of Halton Hills.
- Environmental Commissioner of Ontario. (2016). Conservation: Let's Get Serious 2015-2016.

EXISTING BUILDING ENERGY PERFORMANCE

Assumption

Municipal existing buildings are upgraded according to the Town's Corporate Energy Plan, as detailed in Table 15. Energy performance improvements are applied in the year 2025.

Table 15. Energy use intensity change at corporate buildings.

Facility	2018 Total Energy Use Intensity (kwh/sqf)	Target Total Energy Use Intensity (kwh/sqf)	Total Energy Savings Potential
Mold-Masters SportsPlex	38.26	24.06	37%
Gellert Community Centre	80.82	51.81	36%
Action Arena	29.3	22.75	22%
Robert C Austin Operations Centre	53.25	33.83	36%
District One Stations (Acton)	33.05	12.52	62%
District Two Station (Georgetown)	24.12	8.94	63%
Town Hall	22.17	15.05	32%
District Three Station - HHFD HQ	22.38	8.94	60%
Action Yard - Equipment Depot	54.99	25.89	53%
Cedarvale Community Centre	14.22	9.28	35%
Halton Hills Cultural Centre and Library	14.83	9.75	34%
Acton Library Branch	16.02	9.58	40%
Prospect Park Pavilion	12.71	7.08	44%

Existing building stock efficiency remains constant to baseline levels, as there are no comprehensive retrofit programs available. Assuming that potential efficiencies may be offset by increasing plug loads.

BUILDING ENERGY END USE

Assumption

Fuel shares for end uses remain unchanged.

Source

- Canadian Energy Systems Analysis Research. Canadian Energy System Simulator. http://www.cesarnet.ca/research/caness-model.

HEATING AND COOLING DEGREE DAYS

Assumption

Heating degree days are expected to decline, while cooling degree days are expected to increase under an RCP8.5 climate future. HDD and CDD assumptions are the median results from a series of global climate models. Table 16 shows the HDD and CCD assumptions for the Town of Halton Hills.

Table 16. HDD and CDD values used in the reference scenario.

	1950	1975	2000	2016	2025	2050
HDD	4,235	4,301	3,969	3,882	3,700	3,255
CDD	201	191	261	331	333	524

Source

- Climate Atlas of Canada. (n.d.). BCCAqv2 downscaled climate data from Pacific Climate Impacts Consortium for RCP8.5, Kitchener, Ontario. Retrieved from climatetlas.ca

LOW OR ZERO CARBON ENERGY GENERATION

Assumption

Rooftop Solar PV:

- Existing rooftop solar PV of 4.08 MW in IESO contracts are held constant. Contracts that expire are assumed to be renewed.
- New growth related to Green Development Standards, where 5% of new

Ground mount solar PV:

- Existing ground mount solar PV capacity of 0.5 MW is held constant. Contracts that expire are assumed to be renewed.

District energy generation:

- Natural gas combined heat and power unit (1MW) will be used for heat and electricity for a maximum of 2,859 units in the core of Vision Georgetown development. Assumed to be operational in 2035, and is therefore excluded from the reference scenario projection.

Wind:

- No wind generation.

Source

- Town of Halton Hills. (2014). Green Development Standard.
- IESO. (2020). IESO active generation contract list (as of March 2020). Retrieved from: http://www.ieso.ca/en/Power-Data/Supply-Overview/Distribution-Connected-Generation
- Scenario 1 from Arup. (2018). Vision Georgetown Energy Master Plan.

GRID-CONNECTED ENERGY GENERATION

Assumption

Although there is an existing 641.5 MW natural gas generating station in Halton Hills, it is not included in the reference scenario projection, because the influence of this generating station is already captured in Ontario's electricity emissions factor.

Source

- IESO. (2020). IESO Active Generation Contract List (as of March 2020). Retrieved from: http://www.ieso.ca/en/Power-Data/Supply-Overview/Distribution-Connected-Generation

TRANSIT

Assumptions

Kitchener GO Line Expansion to increase ridership in Halton Hills. The expansion is assumed to be operational in 2025, and will remain diesel trains. Trips increase as follows:

- Current ridership:
    - Acton: 121 daily trips
    - Georgetown: 618 daily trips
- 2025:
    - Acton: 220 daily trips
    - Georgetown: 643 daily trips

VKT is also expected to increase five-fold - directly proportional to the increasing service in Halton Hills.

Town of Halton Hills is also increasing its Universal Access Transit Service; however, this is modelled as personal use vehicles in the model.

Source

- Metrolinx. (2019). Kitchener GO expansion initial business case. Retrieved from: http://www.metrolinx.com/en/regionalplanning/projectevaluation/benefitscases/2019-11-14-Kitchener-Mid-Term-Service-Expansion-IBC-Update-FINAL.pdf
- Town of Halton Hills. (2019). Transit Service Strategy. Prepared by WSP.

ACTIVE TRANSPORTATION

Assumptions

Active transit mode share is expected to increase according to Table 17. GO Transit expansion is assumed to override assumptions made in the Transportation Tomorrow Survey.

Table 17. Mode share assumptions.

	2016	2020	2025	2030
Personal use automobiles	88.90%	88.65%	85.17%	83.54%
Transit	4.95%	5.04%	8.78%	10.77%
School bus	2.29%	2.40%	2.54%	2.52%
Walk	3.36%	3.41%	3.06%	2.74%
Bike	0.50%	0.50%	0.45%	0.43%

Source

- Transportation Information Steering Committee. (2018). 2016 Transportation Tomorrow Survey.
- Metrolinx. (2019). Kitchener GO expansion initial business case. Retrieved from: http://www.metrolinx.com/en/regionalplanning/projectevaluation/benefitscases/2019-11-14-Kitchener-Mid-Term-Service-Expansion-IBC-Update-FINAL.pdf

PERSONAL AND COMMERCIAL-USE VEHICLES

Assumptions

Municipal fleets:

- Municipal fleets remain constant at 213 vehicles, and are not electrified.

Electrification of personal vehicles:

- EVs make up 14% of new sales by 2030; share hold constant from 2030 to 2050. Proportion of EVs in total vehicle share are shown in Table 18.

Table 18. Personal use vehicle stock input assumptions in the reference scenario.

	2016	2020	2025	2030
Car (gasoline)	1,404	1,484	1,720	1,679
Car (hybrid)	1	1	1	1
Car (diesel)	25	28	33	33
Car (plug-in hybrid)		12	32	52
Car (electric)	0	53	173	296
Light truck (gasoline)	1,145	1,477	1,855	1,925
Light truck (hybrid)	0	1	1	1
Light truck (diesel)	6	99	127	135
Light truck (plug-in hybrid)		15	40	65
Light truck (electric)	0	55	195	356
Total	2,581	3,222	4,178	4,544

Electrification of commercial vehicles:

- Commercial vehicles are not electrified.

Vehicle fuel efficiency:

- Vehicle fuel efficiency improves according to CAFE standards, enshrined in Canadian legislation through SOR-2010-201 and SOR/2018-98.
- Light duty vehicles:
- 2015: 200gCO2e/km
- 2025: 119gCO2e/km
- 2030: 105g/CO2e/km
- Heavy Duty Vehicles: 20% reduction in emissions intensity by 2025, relative to 2015, 24% reduction in emissions intensity in 2030, relative to 2025.

Source

- Town of Halton Hills. (2019). 2020-2025 Corporate Energy Plan.
- Axsen, J., Wolinetz, M. (2018). Reaching 30% plug-in vehicle sales by 2030: Modeling incentive and sales mandate strategies in Canada. Transport and Environment, 65, 596-617.
- SOR/2010-201. Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations. Retrieved from: http://laws-lois.justice.gc.ca
- SOR/2018-98. Regulations Amending the Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations and other Regulations Made Under the Canadian Environmental Protection Act, 1999. Retrieved from: https://pollution-waste.canada.ca

WASTE

Assumptions

Waste generation is assumed to remain constant at 1250 kg / household / year. Waste diversion is assumed to be 65% in 2016, up to 70% in 2025. Waste is assumed to be treated in a Landfill gas capture and utilization system. This results in emissions from flaring and from a 2.3 MW landfill gas facility. The facility is operated in partnership with Halton Region and Oakville Hydro, so the electricity generated from the plant is not included in the Halton Hills inventory. This results in total waste generation and diversion patterns in Table 19.

Table 19. Waste generation and diversion input assumptions in the reference scenario (tonnes).

	2016	2020	2025	2030
WASTE DESTINED TO LANDFILL				
Compostable waste	3,398	3,577	3,932	4,491
Paper waste	2,339	-	-	-
Plastic and metal	7,885	8,522	9,102	9,741
Other	8,860	8,148	6,258	6,846
Food and beverage	5,343	5,199	4,354	4,527
Textile	-	-	-	-
Wood	4,356	4,779	5,100	5,323
Pulp and paper	-	-	-	-
Petroleum products	-	-	-	-
Rubbers	-	-	-	-
Construction and demolition	1,399	1,535	1,638	1,710
WASTE DIVERSION				
Compostable waste	-	-	-	-
Paper waste	18,926	23,267	25,341	27,086
Plastic and metal	329	464	698	751
Other	4,771	6,713	10,367	11,457
Food and beverage	2,078	2,942	4,334	4,541
Textile	-	-	-	-
Wood	-	-	-	-
Pulp and paper	-	-	-	-
Petroleum products	807	885	945	986
Rubbers	684	750	801	836
Construction and demolition	-	-	-	-
WASTE TO BIO TREATMENT				
	7,026	7,734	9,175	10,479

There are two wastewater treatment plants within the Town of Halton Hills. No major changes to the wastewater system are expected, but wastewater volumes are expected to increase with growing population. Local wastewater treatment data is currently unavailable - wastewater data from regional estimates currently used as a placeholder, scaled for population differences.

Source

- Halton Region. (2011). Solid Waste Management Strategy.
- Resource Productivity and Recovery Authority. (2017). 2016 Residential Waste Diversion Rates by Municipal Program.

OTHER

Assumptions

- There are no assumed changes to industrial process efficiencies.
- Agricultural emissions from livestock remain unchanged.
- Aviation emissions remain unchanged.

Appendix 1. Reference Scenario Results Summary Tables

Table A1. Energy by Sector (GJ)

	2016	2020	2025	2030
Commercial	1,476,411	1,440,281	1,388,258	1,344,725
Industrial	1,638,083	1,789,417	1,905,524	1,973,338
Municipal	76,002	76,059	52,030	51,033
Residential	2,620,330	2,589,712	2,813,246	2,950,580
Transportation	2,915,961	3,004,607	2,955,053	2,878,418
Total	8,726,787	8,900,075	9,114,111	9,198,094

Table A2. Energy consumption by fuel (GJ)

	2016	2020	2025	2030
Diesel	537,183	557,756	570,748	572,641
Fuel Oil	411,864	413,287	416,490	423,379
Gasoline	2,369,554	2,433,653	2,352,831	2,244,737
Grid Electricity	1,600,887	1,681,688	1,807,762	1,935,874
Local Electricity	18,058	24,283	24,283	24,283
Natural Gas	3,056,567	3,053,001	3,231,353	3,316,131
Other	174,093	190,962	202,240	209,195
Propane	511,397	493,571	453,389	414,861
Wood	47,184	51,874	55,015	56,992
Total	8,726,787	8,900,075	9,114,111	9,198,094

Table A3. Energy by end-use (GJ)

	2016	2020	2025	2030
Industrial Processes	1,272,836	1,403,594	1,506,879	1,572,543
Lighting	237,376	248,221	261,678	273,315
Major Appliances	166,659	171,833	201,535	226,214
Plug Load	336,418	354,789	384,416	409,859
Space Cooling	91,204	98,477	100,895	118,202
Space Heating	2,949,373	2,811,533	2,817,899	2,776,835
Transportation	2,915,961	3,004,607	2,955,053	2,878,418
Water Heating	756,960	807,021	885,757	942,707
Total	8,726,787	8,900,075	9,114,111	9,198,094

Table A4. Energy by sector and fuel (GJ)

	year	Diesel	Fuel Oil	Gasoline	Grid Electricity	Local Electricity	Natural Gas	Other	Propane	Wood
Commercial	2016	-	56,241	-	337,291	3,805	675,977	-	403,097	-
	2030	-	44,924	-	394,559	4,949	601,654	-	298,639	-
Industrial	2016	-	240,054	-	496,189	5,597	640,168	164,906	43,986	47,184
	2030	-	290,279	-	566,040	7,100	801,158	199,186	52,583	56,992
Municipal	2016	-	340	-	29,222	330	42,979	-	3,132	-
	2030	-	287	-	23,823	299	24,898	-	1,726	-
Residential	2016	-	115,229	-	738,149	8,326	1,697,442	-	61,183	-
	2030	-	87,889	-	901,053	11,303	1,888,422	-	61,914	-
Transport	2016	537,183	-	2,369,554	37	0	-	9,187	-	-
	2030	572,641	-	2,244,737	50,399	632	-	10,009	-	-

Table A5. Emissions by sector (tCO2e)

	2016	2020	2025	2030
Agriculture	8,083	8,083	8,083	8,083
Commercial	72,546	69,783	69,350	65,432
Fugitive	10,723	10,719	10,935	11,038
Industrial	89,448	99,480	111,940	116,008
Municipal	2,617	2,598	1,964	1,881
Residential	117,451	113,866	128,781	133,376
Transportation	221,704	227,487	223,474	217,032
Waste	19,064	18,928	18,764	18,667
Total	541,638	550,944	573,292	571,517

Table A6. Emissions by fuel (tCO2e)

	2016	2020	2025	2030
Diesel	39,613	41,094	42,041	42,180
Fuel Oil	87,628	87,938	88,622	90,088
Gasoline	158,853	163,115	157,740	150,551
Grid Electricity	14,323	18,974	38,786	40,817
Jet Fuel	23,238	23,238	23,238	23,238
Natural Gas	148,762	148,588	157,268	161,393
Non Energy	37,870	37,730	37,783	37,788
Propane	31,278	30,188	27,730	25,374
Wood	73	80	84	87
Total	541,638	550,944	573,292	571,517

SSG *whatIf?*