APPENDIX F: Data, Methods, and Assumptions Manual

July 2021

Purpose of this Document

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, as well as lays a foundation for replication and updates of future modelling efforts that the Town of Halton Hills may wish to embark upon.

Contents

Glossary

Base 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 18°C, 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 18°C, 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.

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 ($ktCO_2e$ or $MtCO_2e$) (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

Accounting Framework

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).[1]

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.

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

- The Compact of Mayors (CoM)[2] 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.

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[1] www.ghgprotocol.org/city-accounting.

[2] www.compactofmayors.org/.

- 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.

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.[3]

[3] 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.

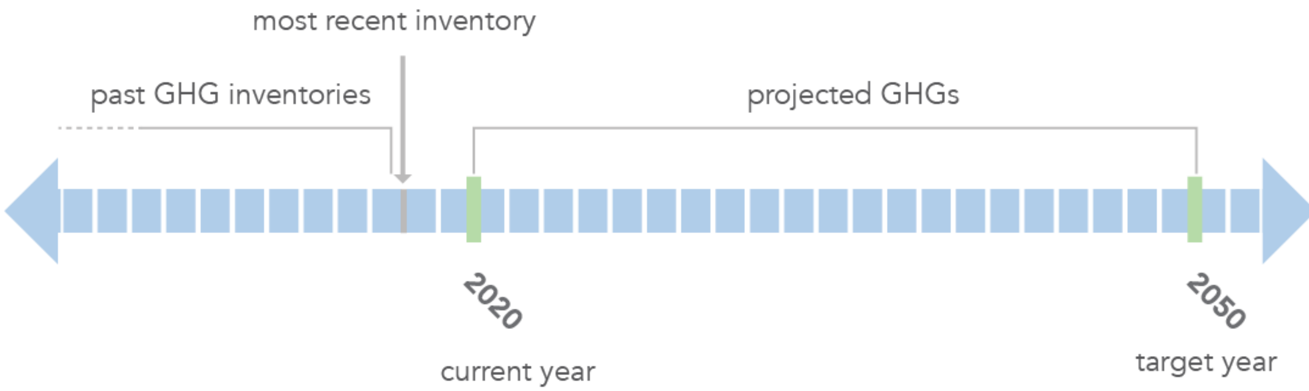

Figure 1. Conceptual timeline showing inventory reporting period and projection period.

Projecting GHG emission scenarios in support of net-zero action planning requires:

1. the consideration of various alternative city plans, policies and contextual assumptions, and
2. 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.

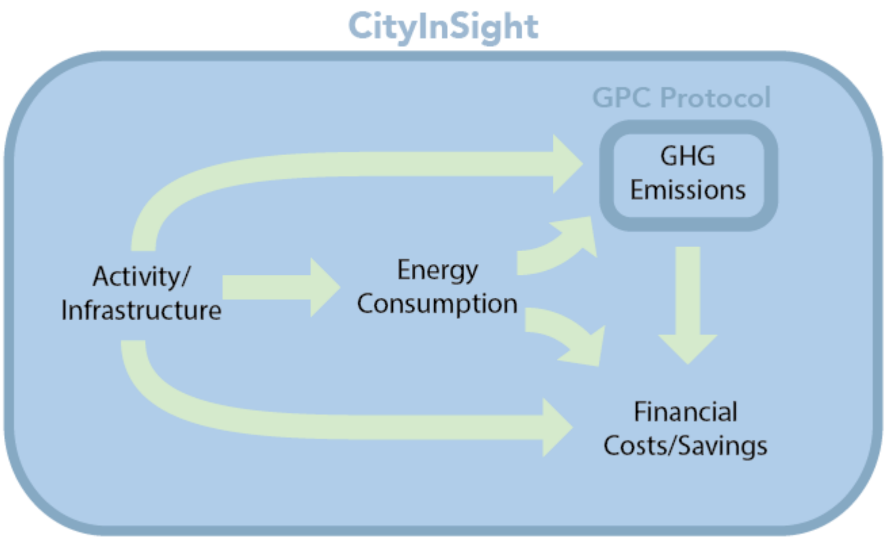

Figure 2. High-level components of CityInSight and relationship to the GPC reporting standard.

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 the energy accounting structure in CityInSight is provided in Section 4.

Emissions Scope

GHG emissions scope

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

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 (CO_2), methane (CH_4) and nitrous oxide (N_20). Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6) and nitrogen trifluoride (NF_3) are not included. Emissions are expressed in CO_2 equivalents per the assumptions in Table 2.

Table 2. Global Warming Potentials for selected greenhouse gases.

Greenhouse Gas	CO_2 equivalents	Notes
CO_2	1	
CH_4	34	These have been updated in the IPCC 5th Assessment Report to include climate-carbon feedback.
N_20	298	These have been updated in the IPCC 5th Assessment Report to include climate-carbon feedback.

Modelling

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 base 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 GHG Protocol for Cities (GPC) framework and principles.
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.

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.

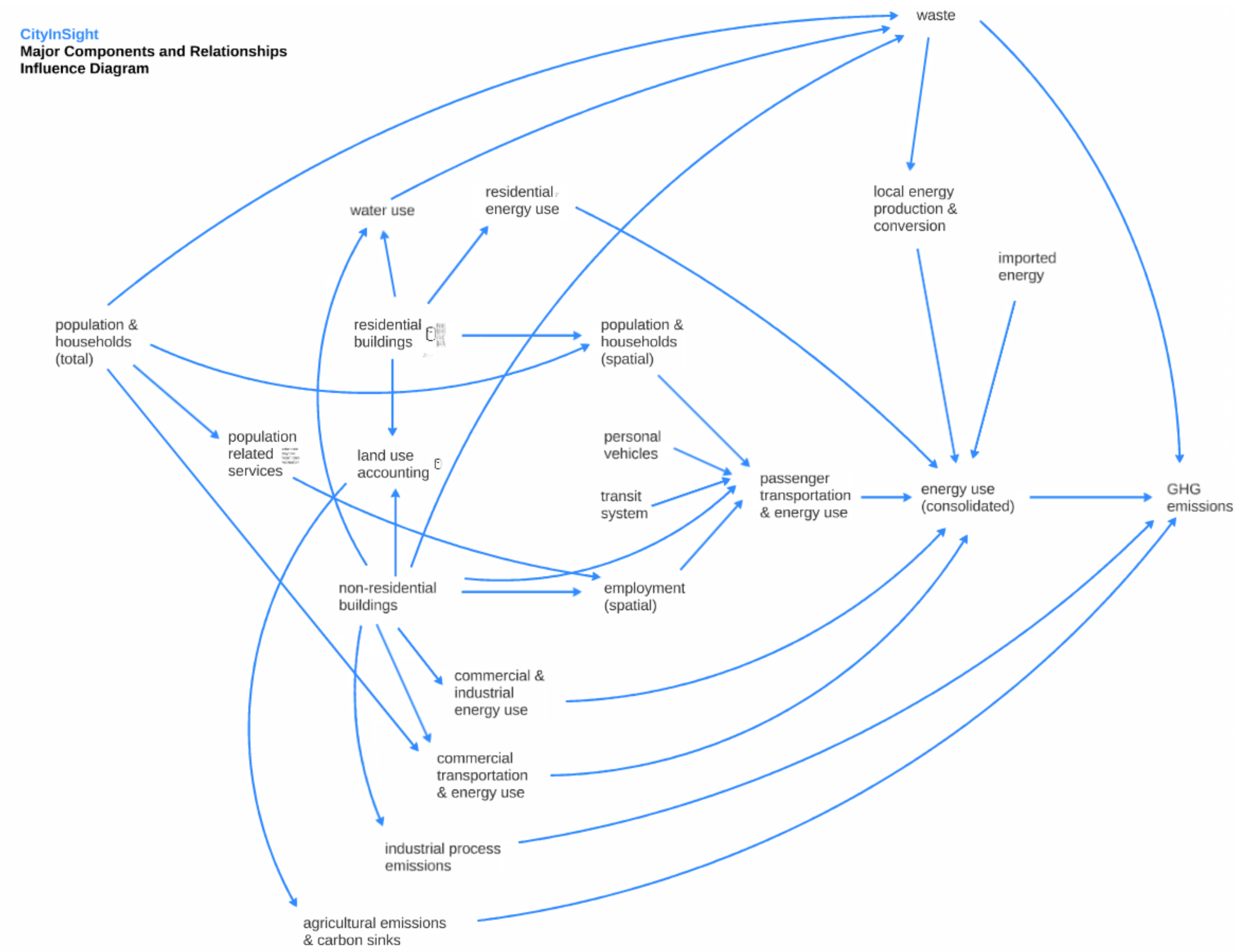

Figure 3. Representation of CityInSight's structure.

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).

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

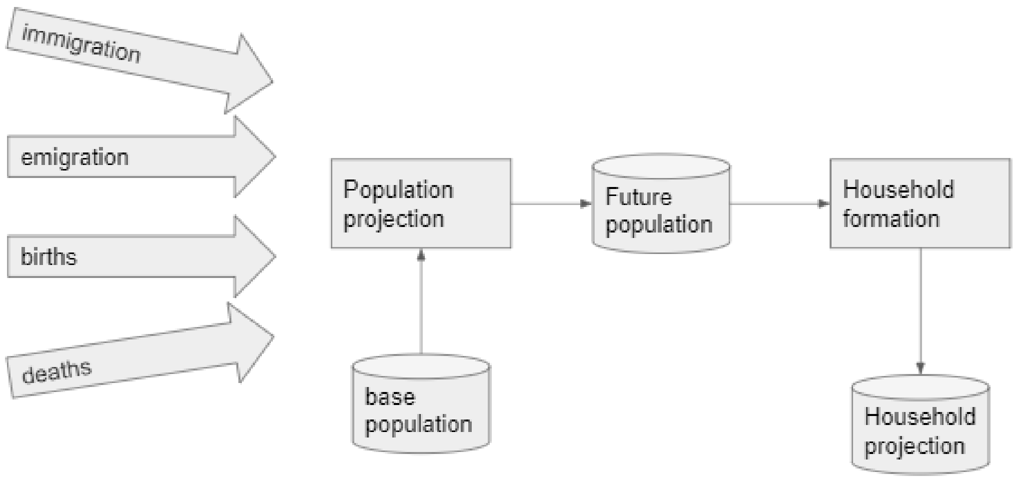

Figure 4. Representative diagram of stocks and flows in the population sub-model.

Building Land Use Accounting

Land use accounting identifies buildings in space and over time, through construction, retrofits and demolitions. In the base year, 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 Table 4).[4] 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

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

    ○ 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 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.

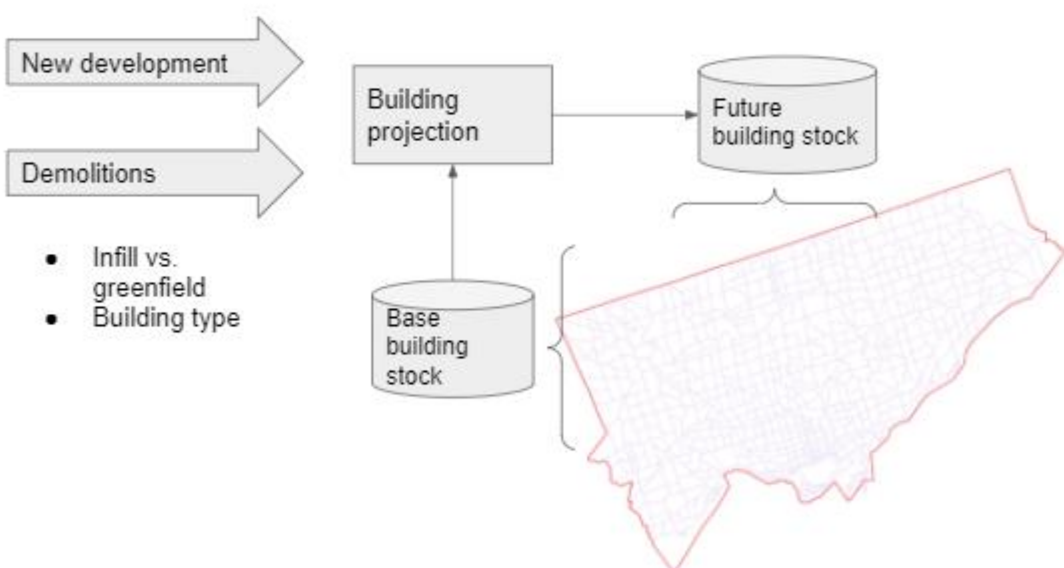

Figure 5. Diagram of land-use accounting sub-model.

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

college_university school	commercial_retail commercial

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

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 or dwelling 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:
    - 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.

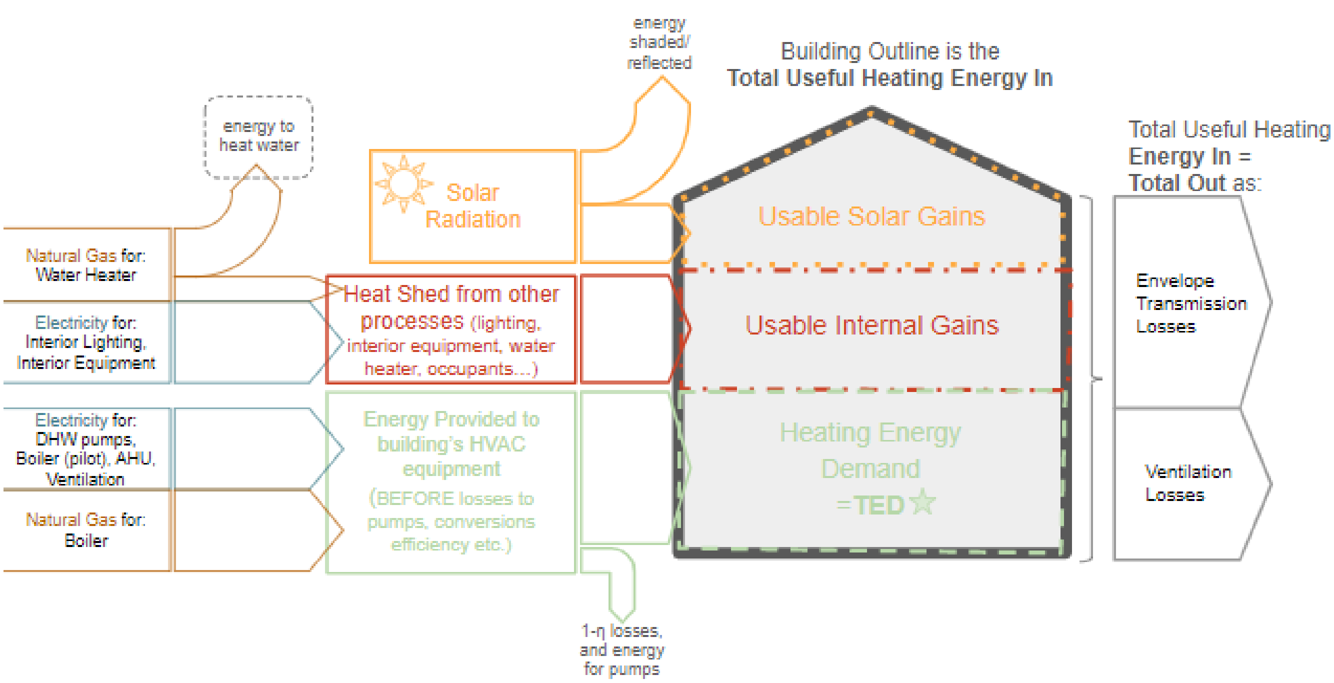

Figure 6. Building energy sub-model schematic.

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:
    1. 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.
    2. 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.
    3. Mode share. For each origin-destination pair, trips are shared over walk/bike, public transit and automobile.
        a. Walk / bike trips are identified based on a distance threshold: ~2km for walking, ~5-10km for biking.
        b. Transit trips are allocated to trips with an origin or destination within a certain distance to a transit station.
    4. 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.

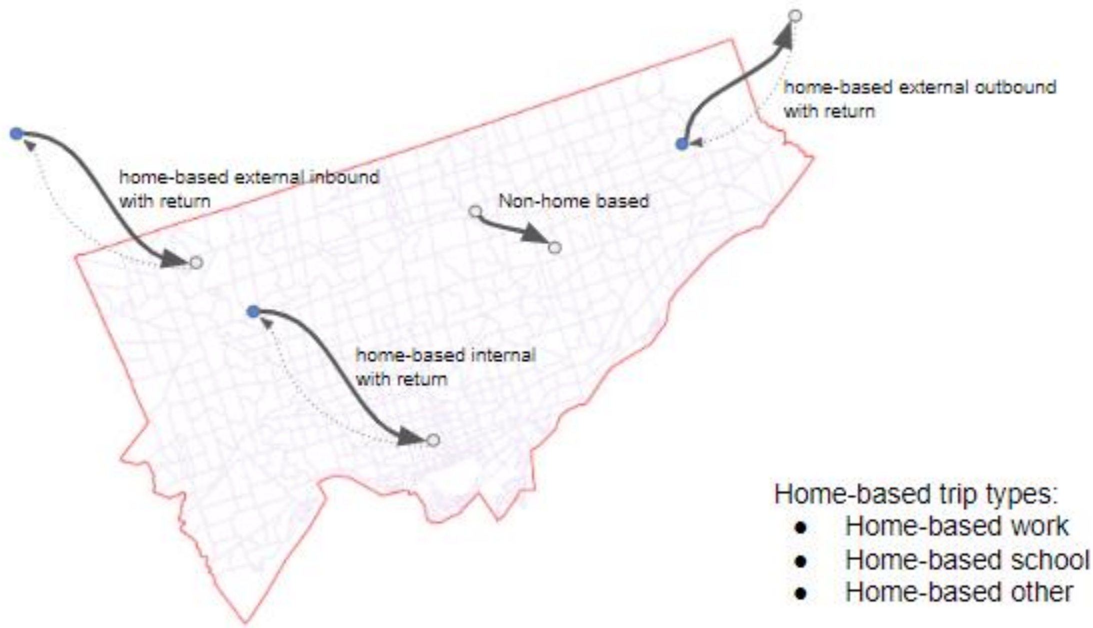

Figure 7. Trips assessed in the personal mobility sub-model.

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, or 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 the Financial Accounting section 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.

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.

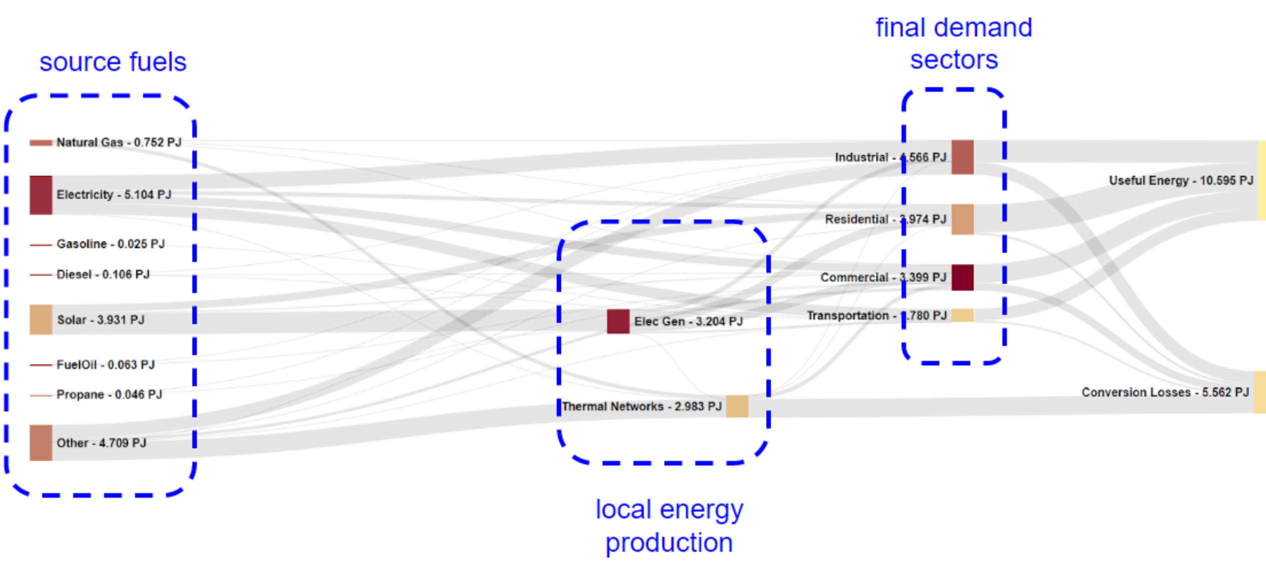

Figure 8. Energy flow Sankey diagram showing main node groups.

Figure 8 above shows the potential for ambiguity when energy is reported: which of the 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.

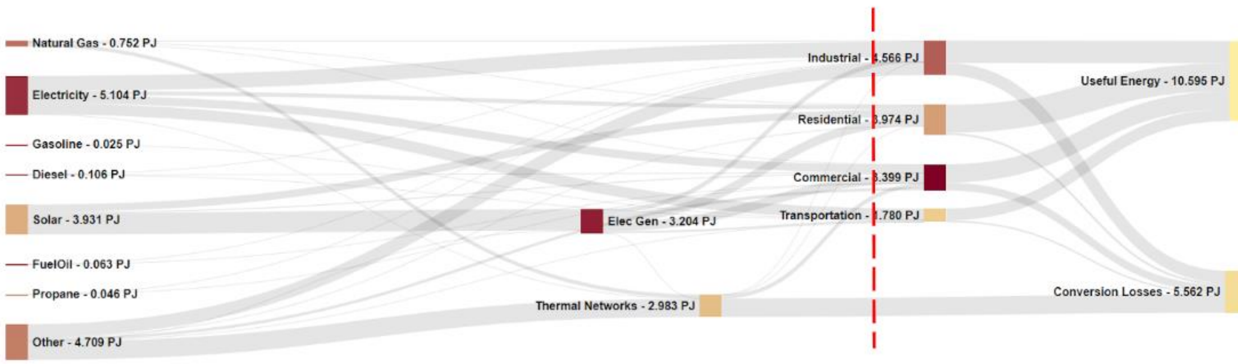

Figure 9. Energy Demand report definition.

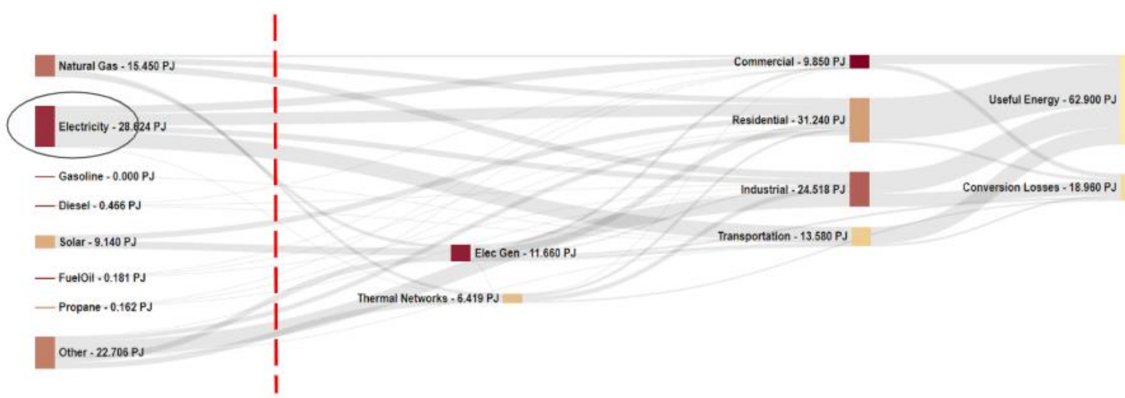

Figure 10. Energy Supply report definition.

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

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.
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:

1. Sign convention: Costs are negative, revenue and savings are positive.
2. The financial viability of investments will be measured by their net present value.
3. 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.
4. We will use a discount rate of 3% in evaluating the present value of future government costs and revenues.
5. Each category of stocks will have a different investment horizon
6. Any price increases included in our analysis for fuel, electricity, carbon, or capital costs will be real price increases, net of inflation.

7. 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.
8. In presenting results of the financial analysis, results will be rounded to the nearest thousand dollars, unless additional precision is meaningful.
9. Only actual cash flows will be included in the financial analysis.

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.

Base Year

For the base 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 as 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.

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 base 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.

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 the Base Year

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 base year, with corresponding visualizations.

The Base Year and Reference Projection

Once the base year is completed, a reference projection to the target year of the scenario exercise is developed. The purpose of the reference projection is to build an informed projection of what future energy and emissions might look like. This projection helps ensure that the net-zero scenario is designed in a manner that strategically addresses likely future energy use and emissions sources.

The reference projection is based on a suite of input assumptions into the model that reflect 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 net-zero 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 net-zero scenario is analyzed relative to the reference projection. The actions in the net-zero scenario are together to ensure that there is no double counting and that interactive effects of the proposed measures are captured in the analysis.

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:

1. 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 (Keirstead, Jennings, & Sivakumar, 2012).
    a. 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.
2. 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.
    a. 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.

3. 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.
    a. Approach: The model will develop a reference scenario.
4. Transparency: The provision of detailed sources for all assumptions is critical to enabling policy-makers to understand the uncertainty intrinsic in a model.
    a. Approach: The assumptions and inputs are presented in this document.

Data and Assumptions for the Town of Halton Hills

Assessment Scope

Geographic Boundary

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

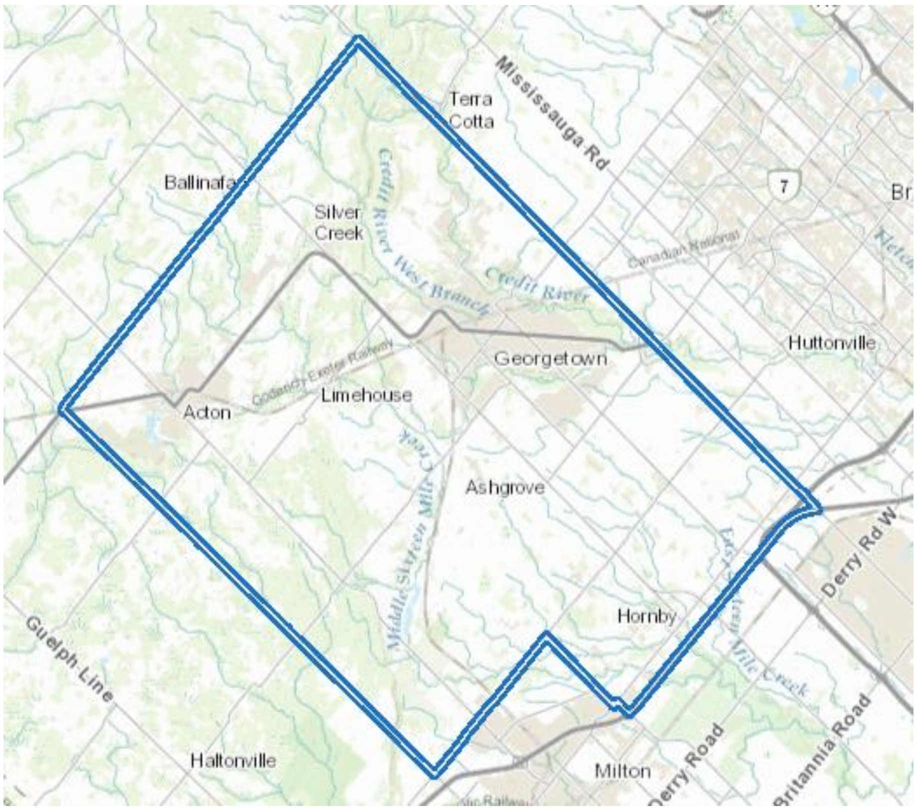

Figure 11. Assessment boundary for the Town of Halton Hills.

Time Scope

- The assessment will cover the years from 2016 to 2030.
- The year 2016 will be used as the base 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 base 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	Y			

systems				
Transportation				
On-road	Y	Y		
Railways	Y	Y		
Waterborne navigation				NA
Aviation				NA
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				
Agriculture, forestry and other land use (AFOLU)				
Livestock	Y			
Land	Y			
Aggregate sources and non-CO2 emissions sources on land	Y			
Other Scope 3			Y	

Base Year Data

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

Table 7. Base year data used to populate the Halton Hills model.

Dataset	Unit	Description	Source(s)
Demographics			
Population	# persons	Total by zone College and university student enrollment	Halton Hills Official Plan
Households / Dwellings	# households	Total (households from census)	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	For the Region	GIS: Building footprints shapefile (anything available)	From Town of Halton Hills
Property assessment roll	For the Region	MPAC tables: general, structure	Municipal Property Assessment Corporation Data
Residential (dwellings)	# 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 (CD & CSDs?)	Statistics Canada. 2016 Census
Policy boundaries		GIS maps showing: built boundary, designated greenfields, 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.
Land Cover		GIS: Agricultural (include type- crop, dairy, etc.), forest (include status- woodlot, protected, or indicate that you don't have this), urban forest (street trees, shrubs, green roofs), roads, parks, vacant, etc.	
Fuel Consumption			
Natural gas	GJ preferred; m3 ok	2016-2019 (annual) Total natural gas consumption by as much sectoral and geographic detail as possible; from all natural gas providers. Cost ($/m3) by sector.	From Town of Halton Hills, via Enbridge Gas.

Electricity	kWh	2016-2019 (annual) Total electricity consumption by as much sectoral and geographic detail as possible; from all electricity providers. 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	CO2, CH4, N2O	CanESS model
Decentralized electricity generation (excluding district energy); behind the meter and grid-connected generation	kWh (elec); GJ (preferred) or volume for fuel use	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 (preferred) or volume for fuel use	2016-2019 (annual) DE 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.	-
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	GJ	2016-2019 (annual)	IESO. (2020). Active Contracted Generation List March 2020.

fuel use			
Energy costs			Halton Hills Hydro. Electricity. Retrieved from: https://haltonhillshydro.com/for-home/rates/electricity/ Ontario Energy Board. Historical natural gas rates. Retrieved from: 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 zones Any additional zone systems used for transportation modelling by the City 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 in the region.	Transportation Information Steering Committee. (2018). 2016 Transportation Tomorrow Survey.
Corporate vehicle fleet		2016-2019 (annual) 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 Route/network GIS files; 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 *www.metrolinx.com/en/regionalplanning/projectevaluation/benefitscases/2019-11-14-Kitchener-Mid-Term-Service-Expansion-IBC-Update-FINAL.pdf*
School bus fleet		2016-2019 (annual) Fleet by fuel type; VKT; fuel consumption.	
VKT	km	2016-2019 (annual) Any existing 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 region indicate whether transit fuel use is included in this data	Statistics Canada. Table: 25-10-0029-01 (formerly CANSIM 128-0016) Provincial data will be allocated to region 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 region on the basis of population by default
Waste			
Solid waste produced	tonne / year	2016-2019 (annual)By 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 city, by type	From Town of Halton Hills
Solid waste facilities capacity	tonne	Waste handling facilities capacity (within and outside of city 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 What percentage of waste taken in by handling facilities is imported?	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.
Industry			
Industrial processes & product use		Any information on industrial processes, production levels & emissions; by location	Government of Canada. National Pollutant Release Inventory.
Waste heat		GIS: 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.

Emissions Factors

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

GWP			
	Greenhouse gases	Carbon dioxide (CO2), methane (CH4) and nitrous oxide (N20) are included. GWP: CO_2 = 1 CH_4 = 34 N_2O = 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: CO_2: 7.47 g/kWh CH_4: 0.000403 g/kWh N_2O: 0.0000175 g/kWh 2051: CO_2: 10.7 g/kWh CH_4: 0.000952 g/kWh N_2O: 0.000243 g/kWh	National Energy Board. (2016). Canada's Energy Future 2016. Government of Canada. Retrieved from www.neb-one.gc.ca/nrg/ntgrtd/ftr/2016pt/nrgyftrs_rprt-2016-eng.pdf IESO. (2020) Annual Planning Outlook
	Gasoline	g / L CO_2: 2316 CH_4: 0.32 N_2O: 0.66	NIR Part 2 Table A6–12 Emission Factors for Energy Mobile Combustion Sources

	Diesel	g / L CO_2: 2690.00 CH_4: 0.07 N_2O: 0.21	NIR Part 2 Table A6–12 Emission Factors for Energy Mobile Combustion Sources
	Fuel oil	Residential g/L CO_2: 2560 CH_4: 0.026 N_2O: 0.006 Commercial g/L CO_2: 2753 CH_4: 0.026 N_2O: 0.031 Industrial g/L CO_2: 2753 CH_4: 0.006 N_2O: 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 CO_2: 299.8 CH_4: 0.72 N_2O: 0.007 Commercial kg/GJ CO_2: 299.8 CH_4: 0.72 N_2O: 0.007 Industrial kg/GJ CO_2: 466.8 CH_4: 0.0052 N_2O: 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	NIR Part 2 Table A6–3 Emission Factors for Natural Gas Liquids Table A6–12 Emission Factors for Energy Mobile Combustion Sources
	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).

	2020	***2022***	***2024***	***2026***	***2028***	***2030***
CO2	36.78	35.62	54.79	68.24	69.35	68.69
CH4	0.01	0.01	0.01	0.02	0.02	0.02
N2O	0	0	0	0	0	0

Source:

- IESO. (2020). Annual Planning Outlook.

Reference Scenario Assumptions Summary

Table 10 summarized the reference scenario assumptions. Where assumptions are noted to be held constant, base year data is carried forward annually in the projection. Detailed inputs for each assumption are outlined in Section 8.5.

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	Employment growth according to Town projections	
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. (res)	*Town of Halton Hills. 2014. Green Development Standard.*
Multi-residential	2016-2020: 20% better than OBC 2012 2020-2026: 15% better than OBC 2020	*Assumption development as per assumptions made in Town of Halton Hills. (2018). Vision Georgetown Energy Master Plan.*
Commercial & Institutional	non-res: 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.	
Industrial		*Post 2020 assumptions as per discussions with HH*
Existing buildings energy performance		

Residential Multi-residential Commercial & Institutional Industrial	Existing building stock efficiency remains constant	
End use		
Space heating Water heating Space cooling	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 .
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 active generation contract list (as of March 2020) www.ieso.ca/en/Power-Data/Supply-Overview/Distribution-Connected-Generation*
Ground mount solar	0.5 MW	*IESO active generation contract list (as of March 2020) 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 active generation contract list (as of March 2020)* [*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 active generation contract list (as of March 2020)* *www.ieso.ca/en/Power-Data/Supply-Overview/Distribution-Connected-Generation*
TRANSPORT			
Transit			
	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* *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: *www.gotransit.com/static_files/gotransit/assets/pdf/TripPlanning/FullSchedules/FS20062020/Table31.pdf* *Town of Halton Hills. (2019). Transit Service Strategy. WSP.* *https://drive.google.com/file/d/1QJzcEhCFLIRnhVuxi1sHiOxtmVDLIkVs/view*
	Electrify transit system	No electrification on GO or Universal Access Service. Go train remains diesel.	*Metrolinx. 2019. Kitchener go expansion initial business case* *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.*

		https://drive.google.com/file/d/1QJzcEhCFLlRnhVuxi1sHiOxtmVDLIkVs/view.
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. https://drive.google.com/file/d/1CDEdQhEwkRzB84Ol5Eq3ZF-1zek63Z_l/view*
Private/personal use		
Electrify municipal fleet	No change to municipal fleets.	*Town of Halton Hills. 2019. 2020-2025 Corporate Energy Plan.*
Electrify personal vehicles	14% new sales by 2030	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
Electrify commercial vehicles	No change	
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:**	*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* www.nhtsa.gov/fuel-economy *SOR/2010-201. Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations. Available from: http://laws-*

	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	*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	Base year 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 landfill gas electricity generation. No change is waste treatment.	
Wastewater	No change to wastewater treatment systems.	
OTHER		
Industrial efficiencies	No change.	
Agriculture	No change.	
Aviation	No change.	

Detailed Reference Scenario Assumptions

Population and Employment

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

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
Industrial floor space				

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

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 according 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 achieve 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

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	Target Total Energy Use Intensity	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%

Non-municipal existing building stock efficiency remains constant to base year levels, as there are no comprehensive retrofit programs available. Assuming that potential efficiencies may be offset by increasing plug loads.

Building Energy End Use

Fuel shares for end uses remain unchanged.

Source:

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

Heating and Cooling Degree Days

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.The table below 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	4235.3	4301.8	3969.7	3882	3700.4	3255.8
CDD	201.6	191.4	261.8	331.6	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

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: 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

Although there is an existing 641.5 MW natural gas generating station in Halton Hills, it is not included in the reference scenario projectiongt 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: www.ieso.ca/en/Power-Data/Supply-Overview/Distribution-Connected-Generation

Transit

Kitchener GO Line Expansion is assumed to increase ridership in Halton Hills. The expansion is assumed to be operational in 2025. Trains will remain fueled by diesel. The ridership assumptions are as follows:

- Trips:
    - 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.

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

Source

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

Active Transportation

Active transportation 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

Municipal fleet

- Municipal fleet remains constant at 213 vehicles, and is not electrified.

Electrification of personal vehicles

- EVs make up 14% of new sales by 2030; share holds 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: 200 gCO2e/km
  - 2025: 119 gCO2e/km
  - 2030: 105 g/COEe/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., Wolinetx, 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

Waste generation is assumed to remain constant at 1250 kg/household/year. The waste diversion rate 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 the total waste generation and diversion patterns described in Table 19.

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

Waste destined to landfill	tonne/year			
	2016	2020	2025	2030
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 waste	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	tonne/year			
	2016	2020	2025	2030
Compostable waste	n/a	n/a	n/a	n/a
Paper waste	18,926	23,267	25,341	27,086
Plastic and metal	329	464	698	751
Other waste	4,771	6,713	10,367	11,457
Food and beverage	2,078	2,942	4,334	4,541
Textile	n/a	n/a	n/a	n/a
Wood	n/a	n/a	n/a	n/a
Pulp and paper	n/a	n/a	n/a	n/a

Petroleum products	807	885	945	986
Rubbers	684	750	801	836
Construction and demolition	n/a	n/a	n/a	n/a
Waste diversion	tonne/year			
	2016	2020	2025	2030
	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.

Table 20. Wastewater treatment volumes.

	2016	2020	2025	2030
Wastewater treatment volumes (m3)	9,415,476	10,353,024	11,420,400	12,484,611

Source:

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

Other

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