Whitby Climate Emergency Response Plan

Phase 2: Mitigation

Data, Methods, and Assumptions

Overview

This Data, Methods, and Assumptions (DMA) manual was finalized in December 2023 to detail the modelling approach used to provide the community energy and emissions benchmarks and projections for the Town of Whitby (Town) Climate Emergency Response Plan (CERP) Phase 2: Mitigation Plan.

Modelling Scope

Global Protocol for Community-Scale GHG Emissions Inventories

The municipal inventory baseline year and scenario modelling approach correlate with the Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories (GPC) (Appendix A). The GPC uses the following five principles to ensure a fair, consistent, and true account of emissions:

1. Relevance: The reported greenhouse gas (GHG) emissions appropriately reflect emissions occurring as a result of activities and consumption within the municipal boundary. The inventory will also serve the decision-making needs of the Town, taking into consideration relevant local, state, and national regulations. Relevance applies when selecting data sources and determining and prioritizing data collection improvements
2. Completeness: All emissions sources within the inventory boundary shall be accounted for and any exclusions of sources shall be justified and explained.
3. Consistency: Emissions calculations shall be consistent in approach, boundary, and methodology.
4. Transparency: Activity data, emissions sources, emissions factors and accounting methodologies require adequate documentation and disclosure to enable verification.
5. Accuracy: The calculation of GHG emissions should not systematically overstate or understate actual GHG emissions. Accuracy should be 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.

Geographic Boundary

The geographic boundary of the modelling assessment is Whitby's municipal boundary. The model uses 137 traffic zones as the spatial dimension to assign energy use and GHG emissions (Figure 1).

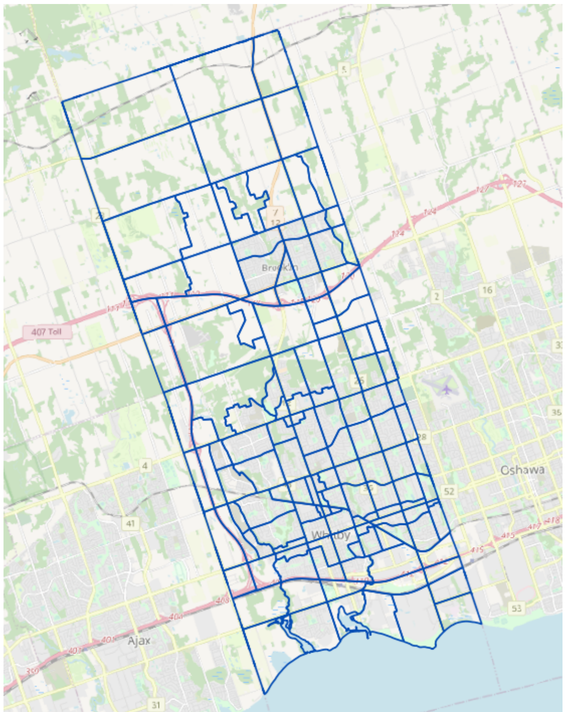

Figure 1. Map of Whitby, Ontario divided by traffic zone.

Time Scope

The CityInSight model, an integrated, spatially-disaggregated energy, emissions, and finance model developed by SSG, is a time-bound model with the following parameters and rationale:

- The assessment covers the years from 2020 to 2050:
    - Projections extend to 2045 to capture emission reductions at the target year, and 2050 to capture the full emission reductions of industrial decarbonization strategies.
- The year 2020 was selected as the base year. The rationale for using this as the baseline 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 town.
- A key data source for the model is Statistics Canada Census data.
- 1-year increments were modelled from the 2020 baseline year. 2020 is the first simulation period/year, as it is the most recent Statistics Canada Census year.

Emissions Scope

The inventory includes the GPC emissions Scopes 1 and 2 and some aspects of Scope 3 (Figure 2). Table 1 further defines each scope. The relevant emissions scope and associated GHG emissions for Whitby are detailed in Appendix A: Global-Protocol for Community-Scale Greenhouse Gas Inventories.

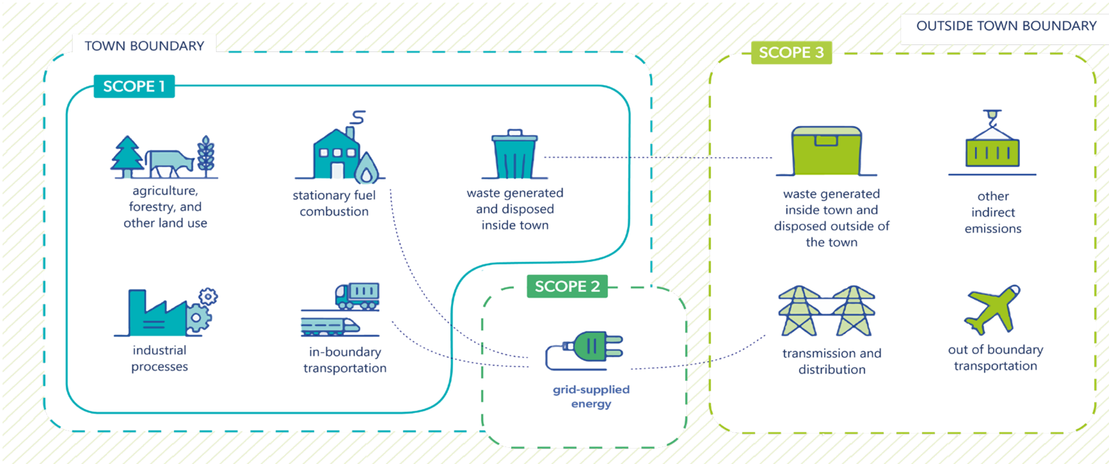

Figure 2. GPC emissions scopes as they relate to geographic and inventory boundaries.[1]

Table 1. GPC scope definitions

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

Emissions Scope

Emissions factors are representative values that relate the use of a given unit of an energy source to the average GHG emissions it emits, typically measured in carbon dioxide equivalents (CO_2e). Examples of emission factors include natural gas distribution and use, grid electricity, and waste and wastewater.

Table 2 describes the emissions accounting framework and sources for Global Warming Potentials (GWP)[2] used in the analysis and Table 3 describes the emissions accounting framework used in the CERP Phase 2: Mitigation Plan, and the locally relevant emissions factors for the baseline year.

Table 2. Emissions accounting framework and global warming potential.

CATEGORY	BASELINE DATA/ASSUMPTION	SOURCE
Accounting Framework	Global Protocol for Community-Scale GHG Emission Inventories (GPC)	GPC
Emissions Scope	Scope 1, 2 and partial scope 3	See GPC emissions scope table for scope 3 items included (Appendix A)

[1] Image created based on: Consumption-Based Inventories of C40 Cities. https://www.c40.org/researches/consumption-based-emissions.

[2] The GWP is a measure of the ability of each GHG to trap heat in the atmosphere compared to carbon dioxide (CO_2).

CATEGORY	BASELINE DATA/ASSUMPTION	SOURCE
Sectors	Stationary energy (buildings) Transportation Waste	See GPC emissions scope table for sectors and sub-sectors included (Appendix A)
Reporting	GPC BASIC & partial BASIC+	Town of Whitby
Transportation Methodology	GPC induced activity method	GPC
Baseline Year	2020	Not Applicable (NA)
Projection Years	2045 and 2050	NA
Greenhouse Gas GWP	Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_20) 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

Table 3. Emissions factors for fuels in Whitby's model.

CATEGORY	BASELINE DATA/ASSUMPTION	SOURCE
Natural gas	49 kg CO_2e/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	2020: CO_2: 36.78 g/kWh CH_4: 0.0085 g/kWh N_2O: 0.001 g/kWh 2050: CO_2: 88.57 g/kWh CH_4: 0.02 g/kWh N_2O: 0.002 g/kWh	IESO, Annual Planning Outlook January 2021
Gasoline	CO_2: 2316 g/L CH_4: 0.32 g/L N_2O: 0.66 g/L	2016 NIR Part 2 Table A6–12 Emission Factors for Energy Mobile Combustion Sources
Diesel	CO_2: 2690.00 g/L CH_4: 0.07 g/L N_2O: 0.21 g/L	2016: NIR Part 2 Table A6–12 Emission Factors for Energy Mobile Combustion Sources

CATEGORY	BASELINE DATA/ASSUMPTION	SOURCE
Fuel oil	Residential CO_2: 2560 g/L CH_4: 0.026 g/L N_2O: 0.006 g/L Commercial CO_2: 2753 g/L CH_4: 0.026 g/L N_2O: 0.031 g/L Industrial CO_2: 2753 g/L CH_4: 0.006 g/L N_2O: 0.031 g/L	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 CO_2: 299.8 kg/GJ CH_4: 0.72 kg/GJ N_2O: 0.007 kg/GJ Commercial CO_2: 299.8 kg/GJ CH_4: 0.72 kg/GJ N_2O: 0.007 kg/GJ Industrial CO_2: 466.8 kg/GJ CH_4: 0.0052 kg/GJ N_2O: 0.0036 kg/GJ	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	Transport CO_2: 1515.00 g/L CH_4: 0.64 g/L N_2O: 0.03 g/L Residential CO_2: 1515.000 g/L CH_4: 0.027 g/L N_2O: 0.108 g/L All other sectors CO_2: 1515.000 g/L CH_4: 0.024 g/L N_2O: 0.108 g/L	NIR Part 2 Table A6–3 Emission Factors for Natural Gas Liquids Table A6–12 Emission Factors for Energy Mobile Combustion Sources

CATEGORY	BASELINE DATA/ASSUMPTION	SOURCE
Waste/Waste Water Natural Gas Fugitive Emissions	Wastewater emissions factors: CH_4: 0.024 kg CH_4/kg BOD N_2O: 3.20 kg / (person * year) from advanced treatment 0.01 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 = 0.57 tonnes CH_4/ tonnes solid waste Combustion emissions (Waste to Energy facility) CH_4 Emission Factor: 385 kg/Gg	CH4 wastewater: IPCC Guidelines Vol 5 Ch 6, Tables 6.2 and 6.3, we use the MCF value for central, aerobic treatment plant, well managed (MCF: 0.04) 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 Combustion emissions: IPCC Guidelines Vol 5 Ch5 Table 5.6 continuous incinerator
Natural Gas Fugitive Emissions	Natural Gas Mix.natural Gas CO_2 0.0001 Gg / m^3 CH_4 0.0069 Gg/m^3	CO2: Table 4.2.4 from 2006 IPCC Guidelines, Volume 2, Chapter 4, Fugitive Emissions CH4: Assumed 1% of NG throughput is unaccounted, and 0.964 fraction of methane in NG to determine emission factor

About CityInSight

CityInSight is an integrated, spatially-disaggregated energy, emissions, and finance model developed by SSG. 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).

The model 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 (i.e., 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 and assumptions (e.g., electric vehicle uptake rates). An energy balance, used to track energy within the system, is achieved by accounting for efficiencies, conservation rates, and trade and losses at each stage in the journey from source to end use.

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 municipality 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 municipal mapping systems. Characteristics of CityInSight are described in Table 4.

Table 4. Characteristics of CityInSight.

CHARACTERISTIC	DESCRIPTION
Integrated	CityInSight Adaptation is integrated in two ways. First, the variables in the model's network influence each other through causal links and feedback effects. For example, changing the characteristic of a hazard will change the risk estimates for the different assets exposed to it. Also, the effect of adding adaptive infrastructure can span multiple assets and hazards—adding green infrastructure to an urban area can reduce both population heat stress and building flood damages. Second, CityInSight Adaptation was designed to fully integrate with SSG's mitigation model: CityInSight Community. For example, a building retrofit action included as a mitigation strategy will affect resilience to heat by providing more comfortable living space.
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	Many hazards and assets are spatially distributed at a city-level resolution; their impacts and risks vary as a function of location. CityInSight Adaptation typically uses two different spatial resolutions for adaptation analysis: traffic zone/neighbourhood level for higher-level analysis and parcel level when hazard variance is highly location dependent (i.e. riverine and coastal flooding). The model can also be configured to use any other spatial resolution.
Dynamic	The core components of adaptation analysis are hazards and assets, which are both dynamic in nature. CityInSight Adaptation includes a time dimension, allowing the analysis to dynamically contrast hazard risk estimates influenced by evolving environments (built and natural) and climate. A present-day simulation of a city is compared to its simulated future state by projecting these core hazard risk drivers into the future.
Economic impacts	CityInSight Adaptation includes a quantitative analysis of monetary and non-monetary costs and benefits associated with hazard risk and adaptation measures. The integrated and dynamic nature of the model allows for cost and benefit impacts spanning multiple assets and hazards to be compared through time. This approach provides guidance for strategic decisions by considering the long-term consequences of near-term investments as part of an evolving environment.

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.

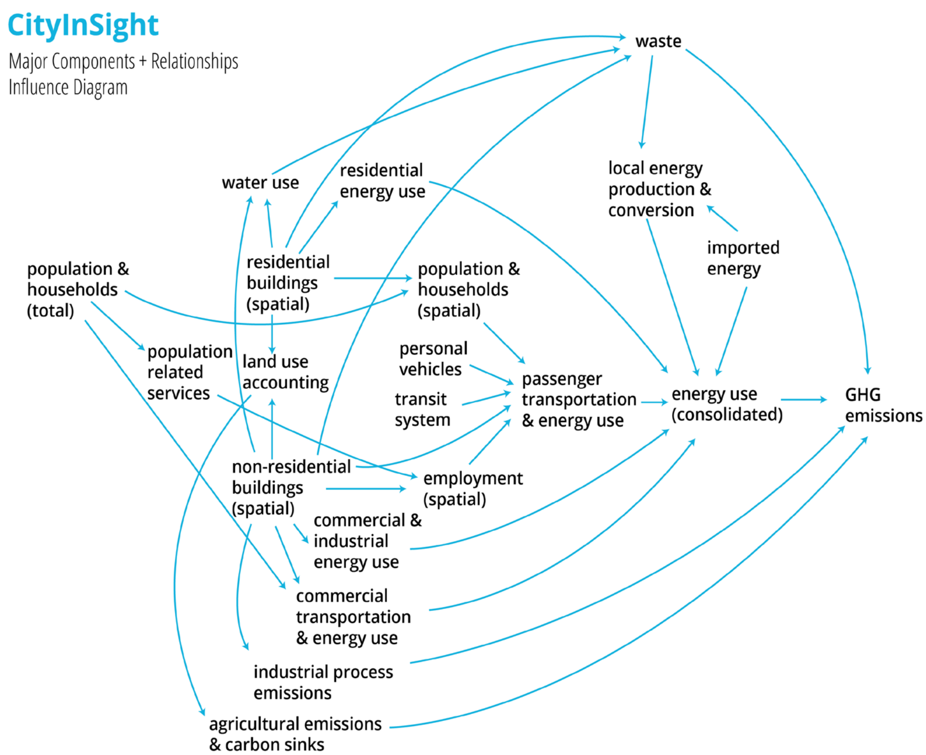

Figure 3. Representation of CityInSight's structure, including sub-models and relationships.

Stocks and Flows

Within each sub-model is a number of stocks and flows that represent energy and emissions processes in municipalities. For any given year, various factors shape the picture of energy and emissions flows in a municipality, 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 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

- Town-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

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 building-related geospatial data. Land use accounting consists of the following 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); and
    - Population 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 5). This allows for the model to account for differing intensities that would occur in relation to various non-residential buildings; and
    - 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; and

    - 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.

Table 5. Archetypes represented in the model.

MODEL ARCHETYPES	
• Office/Retail	• Industrial
• Hotel/Motel	• Roads
• Institutional and commercial	• Bridges/Culverts
• Single/Double/Row	• Utility infrastructure
• Apartment	• Agricultural crops
• Warehouse	• Green Infrastructure

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 is calculated in the model by considering:

- Total energy use intensity of the building type (including the proportion from thermal demand) is built 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.

- Energy use by fuel is determined based on the technologies used in each building (e.g. electricity, heating system types). Heating system types are assigned to building equipment stocks (e.g., 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 model has residential and non-residential building energy sub-models. They influence and produce important model outputs:

- Total residential energy consumption and emissions and residential energy and emissions by building type, by end use, and by fuel;
- Total non-residential energy consumption and emissions and residential energy and emissions by building type, by end use, and by fuel; and
- Local/imported energy balance: how much energy will need to be imported after considering local capacity and production.

Figure 4 details the flows in the building energy sub-model at the building level.

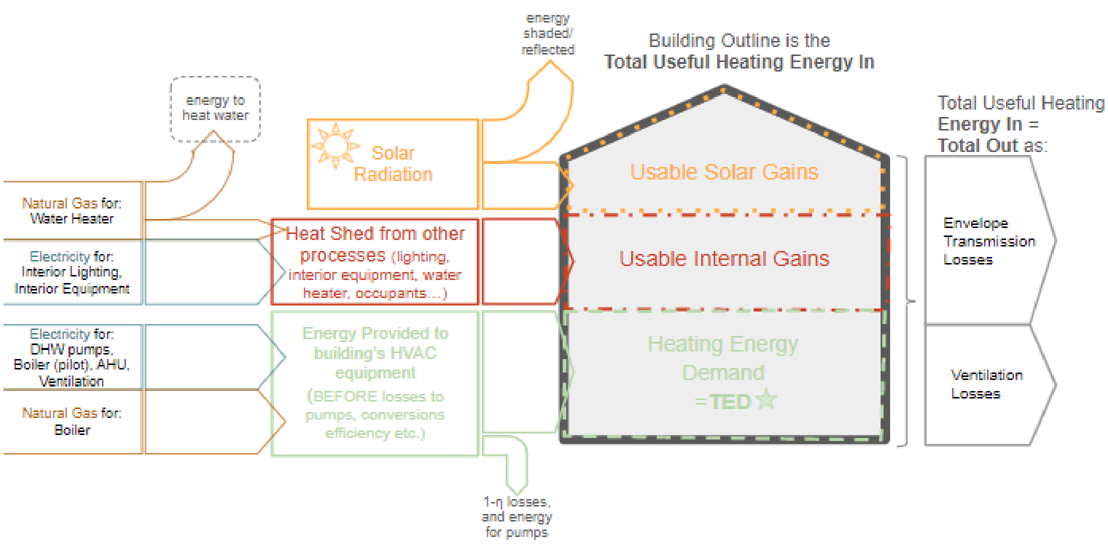

Figure 4. Building energy sub-model schematic.

TRANSPORTATION

CityInSight includes a spatially explicit passenger transportation sub-model that responds to changes in land use, transit infrastructure, vehicle technology, travel behaviour, 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 trips and 50% of transboundary trips that originate or terminate within the municipal 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.
4. Walk/bike trips are identified based on a distance threshold: ~2km for walking, ~5 to 10km for biking.
5. Transit trips are allocated to trips with an origin or destination within a certain distance to a transit station.
6. 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.
- The 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; and
    - Active trips and transit trips, by zone distance.

Trips accounted for in CityInSight are displayed in Figure 5.

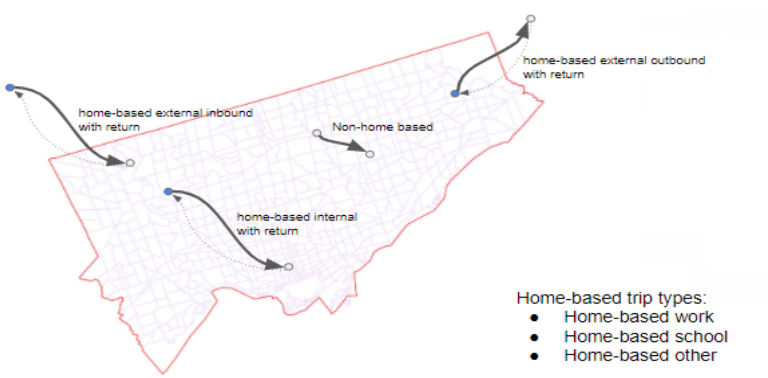

Figure 5. Trips assessed in the personal mobility sub-model.

WASTE

Households and non-residential buildings generate solid waste and wastewater. The model traces various pathways to disposal, compost and sludge. If present in the municipality, 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 municipal 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. 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 6.

Source fuels crossing the geographic boundary are shown on the left. The four “final demand” sectors—residential, commercial, industrial, and transportation—are shown on 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.

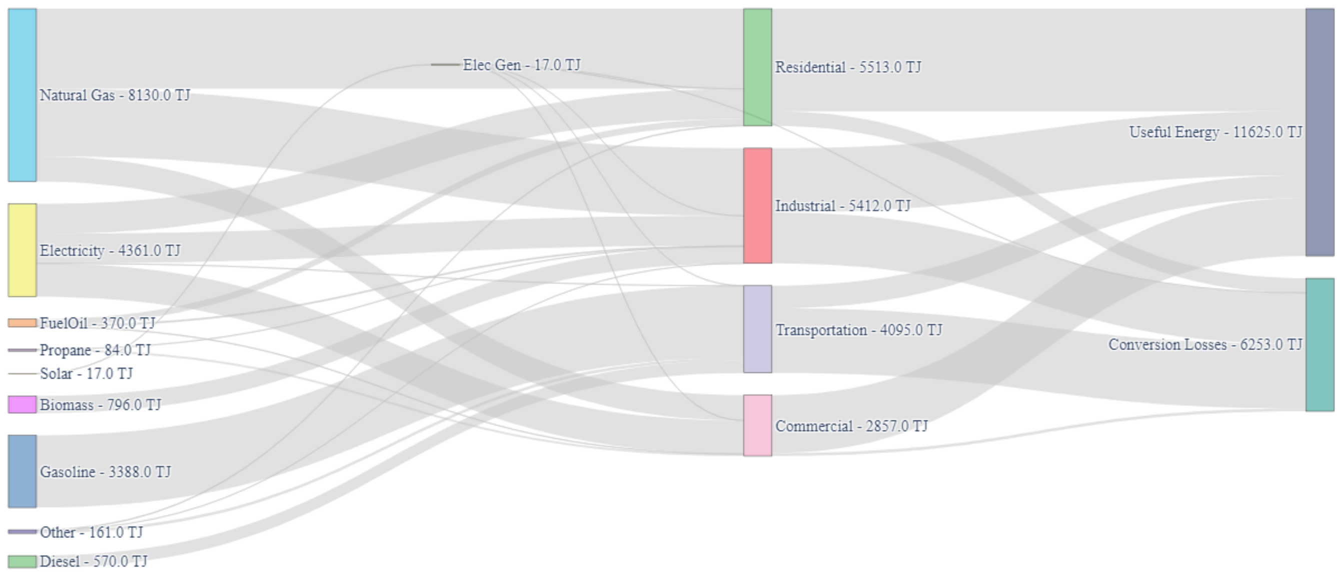

Figure 6. Energy flow Sankey diagram for the Town of Whitby's low-carbon scenario showing main node groups.

To address ambiguities related to inclusion of energy flows and prevention of double counting, CityInSight defines two main energy reports:

Energy Demand (shown in Figure 7) 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 8) 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.

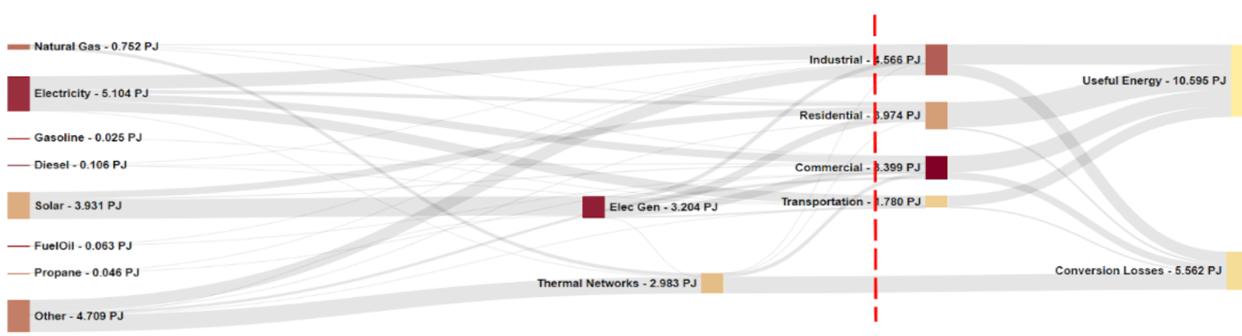

Figure 7. Energy Demand report definition.

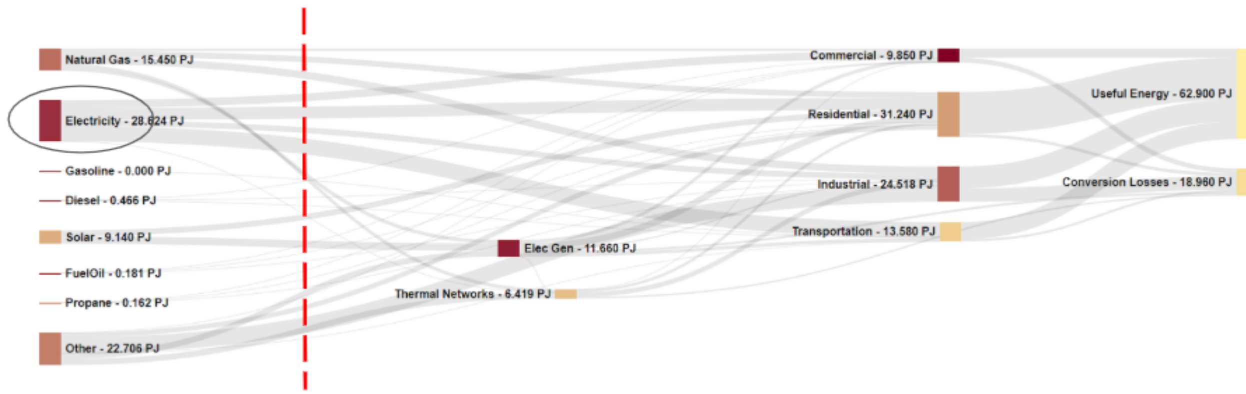

Figure 8. Energy Supply report definition.

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.
- Carbon pricing: calculated by emissions generation.

Expenditure types that are evaluated in the model are summarized in Table 6.

Table 6. 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.

CATEGORY	DESCRIPTION
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.
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 are 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. A discount rate of 3% evaluates 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 (2020), many model inputs come from calibrating the model with real energy datasets. This includes real building and transportation fuel data, town 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, and the efficiency of solar photovoltaics (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); and
- 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, 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 produced from a baseline year to future points in the study horizon. CityInSight outputs can be integrated with municipal 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 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 GHG emissions by origin or destination.

Modelling Process

Data Collection and Calibration

The modelling process began with data collection and model calibration. During calibration the model was systematically populated with data on a wide range of stocks and flows in the community that affect GHG emissions. The data collection and calibration helps establish common understanding among community stakeholders about how the GHG emissions are connected and begins the process of identifying where opportunities for climate change mitigation are likely found in the community.

Local data was supplied by the Town and Region of Durham. Relevant data was collected for variables that drive energy and emissions—such as characteristics of buildings and transportation technologies—and those datasets were reconciled with observed data from utilities and other databases. The surface area of buildings was modelled in order to most accurately estimate energy performance by end-use. Each building was tracked by vintage, structure, and location, and a similar process is used for transportation stocks. Additional analysis at this stage included 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.

Scenario Development

The model supports the use of scenarios as a mechanism to evaluate potential futures for the communities. A scenario is an internally consistent view of what the future might turn out to be - not a forecast, but one possible future outcome.

Scenarios are generated by identifying population projection into the future, identifying how many additional households are required, and then applying those additional households according to existing land-use plans and/or alternative scenarios. A simplified transportation model evaluates the impact of the new development on transportation behaviour, building types, agricultural and forest land, and other variables.

BUSINESS-AS-USUAL SCENARIO

A business-as-usual (BAU) scenario was used to account for the projected population growth, new building growth, transportation patterns, and decreased GHG emissions resulting from improvements to the electricity grid, federal fuel efficiency standards, and heating and cooling requirements in buildings.

This was 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 was calibrated against historical data, providing a technology stock as well as a historical trend for the model variables. This process ensures that the demographics were consistent, that the stocks of buildings and their energy consumption were consistent with observed data from natural gas and electricity utilities, and that the spatial/zonal system was consistent with the municipality's GIS and transportation modelling.

The projection includes approved developments and official plans in combination with a 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.

The following steps were used to develop the BAU scenario:

1. Calibrate model and develop 2020 base year using observed data and filling in gaps with assumptions where necessary.
2. Input existing projected quantitative data to 2045 (and 2050) where available:
    a. Population, employment, and housing projections by transport zone;
    b. Build out (buildings) projections by transport zone; and
    c. Transportation modeling from the municipality.
3. Where quantitative projections are not carried through to 2050, extrapolate the projected trend to 2050.
4. Where specific quantitative projections are not available, develop projections by:
    a. Analyzing current on-the-ground action (reviewing action plans, engagement with staff, etc.), and where possible, quantifying the action; and
    b. Analyzing existing policy that has potential impact and, where possible quantifying the potential impact.

BUSINESS-AS-PLANNED SCENARIO AND LOW-CARBON SCENARIO

A business-as-planned (BAP) scenario was used to project emission and energy reductions based on locally available utility, transportation, and demographic data, and projections for population and empowerment changes. The scenario uses current policies and practices to project the emissions and energy levels in 2045. It assumes no additional policies or climate action interventions are completed beyond the existing policies, and serves as a benchmark for measuring the effectiveness of Whitby's existing efforts.

A low-carbon scenario was used to project emission and energy reductions in order to mitigate the effects of climate change. The scenario uses a combination of current policies and practices, such as those identified in the Zero Carbon Whitby Framework, and additional measures such as increasing renewable energy generation, improving energy efficiency, and reducing the consumption of fossil fuels, to develop a pathway to the Town's climate targets. This scenario goes beyond the BAP scenario by identifying additional policies and climate action interventions.

The BAP and low-carbon scenarios used policies, actions, and strategies. Alternative behaviours of various energy system actors (e.g., households, various levels of government, industry, etc.) can be mimicked in the model by changing the values of the model's user input variables. Varying their values creates "what if" type scenarios, enabling a flexible mix-and-match approach to behavioral models which connect to the physical model. The model can explore a wide variety of policies, actions and strategies via these variables. The resolution of the model enables the user to apply scenarios to specific neighbourhoods, technologies, building or vehicle types or eras, and configurations of the built environment.

The following steps were used to develop the BAP and low-carbon scenarios:

1. Develop a list of potential actions and strategies.
2. Identify the technological potential of each action or group of actions to reduce energy and emissions by quantifying the actions:
    a. If the action or strategy specifically incorporates a projection or target; or,
    b. If there is a stated intention or goal, review best practices and literature to quantify that goal; and
    c. Identify any actions that are overlapping and/or include dependencies on other actions.
3. Translate the actions into quantified assumptions over time (Appendix B).
4. Apply the assumptions to relevant sectors in the model to develop a low-carbon scenario (i.e. apply the technological potential of the actions to the model).
5. Analyze results of the low-carbon scenario against the overall target.
6. If the target is not achieved, identify variables to scale up and provide a rationale for doing so.
7. Iteratively adjust variables to identify a pathway to the target.
8. Develop a marginal abatement cost curve for the low-carbon scenario.

Following the development of the low-carbon scenario, a five-year Implementation Plan was developed to identify policies, programs, initiatives, infrastructure, advocacy, and education strategies to achieve the low-carbon scenario's targets. These strategies were influenced by several factors, including:

- Research on best practices;
- Industry-leading expertise and knowledge;
- Input from the Project Team; and
- Input from the community received from community focus groups and survey responses.

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).

- 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.

   - 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 which imply that no one scenario is more likely than another.

   - 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.

   - Approach: The assumptions and inputs are presented in this document.

Appendix A: Global Protocol for Community-Scale Greenhouse Gas Inventories

The Global Protocol for Community-Scale GHG Inventories (GPC) provides municipalities with a standard approach to define GHG emission sources within the inventory boundary. The GPC classifies emissions into six sectors: stationary energy, transportation, waste, industrial processes and product use (IPPU), and agriculture, forestry and other land use (AFOLU). The GPC inventory helps to differentiate emissions occurring within the town's boundary (scope 1), from those occurring outside of the town's boundary (scope 3), and from the use of electricity, steam, and/or heating and cooling supplied by grids either within or outside of the town's boundary (scope 2). The BASIC level reporting includes emissions from scope 1 and scope 2 stationary and transport sectors and scope 1 and scope 3 emissions from waste sectors. BASIC+ level reporting requires additional scope 3 emissions from energy consumption in stationary and transport.

Table Legend

TABLE LEGEND
Green rows = sources required for GPC Basic inventory
Blue rows = sources required for GPC Basic+ inventory
Orange rows = sources required for territorial total but not for BASIC/BASIC+ reporting

GPC, Global Protocol for Community-Scale GHG Inventories; ID, insufficient data; N/A, not applicable/not included in scope; NR, not relevant or limited activities identified; Other, reason provided under Comments.

Table 1A.GPC emission sources using in Whitby's modelling.

					TONNES			
GPC REF NO.	**SCOPE**	**GHG EMISSIONS SOURCE**	**INCLUSION**	**REASON FOR EXCLUSION (IF APPLICABLE)**	**CO2**	**CH4**	**N2O**	**TOTAL CO2E**
I		STATIONARY ENERGY SOURCES						
I.1		Residential buildings						
I.1.1	1	Emissions from fuel combustion within the town boundary	Yes		207,203	743	1,089	209,035

					TONNES			
GPC REF NO.	**SCOPE**	**GHG EMISSIONS SOURCE**	**INCLUSION**	**REASON FOR EXCLUSION (IF APPLICABLE)**	**CO2**	**CH4**	**N2O**	**TOTAL CO2E**
I.1.2	2	Emissions from grid-supplied energy consumed within the town boundary	Yes		14,348	113	116	14,577
I.1.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	Yes		1,257	10	10	1,277
I.2		Commercial and institutional buildings/facilities						
I.2.1	1	Emissions from fuel combustion within the town boundary	Yes		64,484	42	432	64,958
I.2.2	2	Emissions from grid-supplied energy consumed within the town boundary	Yes		15,983	126	129	16,238
I.2.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	Yes		1,400	11	11	1,422
I.3		Manufacturing industry and construction						
I.3.1	1	Emissions from fuel combustion within the town boundary	Yes		156,269	162	899	157,330
I.3.2	2	Emissions from grid-supplied energy consumed within the town boundary	Yes		14,209	112	115	14,436
I.3.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	Yes		1,245	10	10	1,265
I.4		Energy industries						

					TONNES			
GPC REF NO.	**SCOPE**	**GHG EMISSIONS SOURCE**	**INCLUSION**	**REASON FOR EXCLUSION (IF APPLICABLE)**	**CO2**	**CH4**	**N2O**	**TOTAL CO2E**
I.4.1	1	Emissions from energy used in power plant auxiliary operations within the town boundary	No	Other The emissions from the Whitby Cogeneration Plant are captured in the modelling of the Gerdau Steel Plant	0	0	0	0
I.4.2	2	Emissions from grid-supplied energy consumed in power plant auxiliary operations within the town boundary	No	NR	0	0	0	0
I.4.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption in power plant auxiliary operations	No	NR	0	0	0	0
I.4.4	1	Emissions from energy generation supplied to the grid	No	NR	0	0	0	0
I.5		Agriculture, forestry, and fishing activities						
I.5.1	1	Emissions from fuel combustion within the town boundary	No	NR	2,738	1	9	2,748
I.5.2	2	Emissions from grid-supplied energy consumed within the town boundary	No	NR	0	0	0	0
I.5.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	No	NR	0	0	0	0
I.6		Non-specified sources						

					TONNES			
GPC REF NO.	**SCOPE**	**GHG EMISSIONS SOURCE**	**INCLUSION**	**REASON FOR EXCLUSION (IF APPLICABLE)**	**CO2**	**CH4**	**N2O**	**TOTAL CO2E**
I.6.1	1	Emissions from fuel combustion within the town boundary	No	NR	0	0	0	0
I.6.2	2	Emissions from grid-supplied energy consumed within the town boundary	No	NR	0	0	0	0
I.6.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	No	NR	0	0	0	0
I.7		Fugitive emissions from mining, processing, storage, and transportation of coal						
I.7.1	1	Emissions from fugitive emissions within the town boundary	No	NR	0	0	0	0
I.8		Fugitive emissions from oil and natural gas systems						
I.8.1	1	Emissions from fugitive emissions within the town boundary	Yes		11	49,421	0	49,432
II		TRANSPORTATION						
II.1		On-road transportation						
II.1.1	1	Emissions from fuel combustion for on-road transportation occurring within the town boundary	Yes		159,836	299	1,051	161,186
II.1.2	2	Emissions from grid-supplied energy consumed within the town boundary for on-road transportation	Yes		24	0.19	0.20	25

					TONNES			
GPC REF NO.	**SCOPE**	**GHG EMISSIONS SOURCE**	**INCLUSION**	**REASON FOR EXCLUSION (IF APPLICABLE)**	**CO2**	**CH4**	**N2O**	**TOTAL CO2E**
II.1.3	3	Emissions from portion of transboundary journeys occurring outside the town boundary, and transmission and distribution losses from grid-supplied energy consumption	Yes		74,278	152	229	74,659
II.2		Railways						
II.2.1	1	Emissions from fuel combustion for railway transportation occurring within the town boundary	No	NR	3,415	6	391	3,812
II.2.2	2	Emissions from grid-supplied energy consumed within the town boundary for railways	No	NR	0	0	0	0
II.2.3	3	Emissions from portion of transboundary journeys occurring outside the town boundary, and transmission and distribution losses from grid-supplied energy consumption	No	NR	0	0	0	0
II.3		Water-borne navigation						
II.3.1	1	Emissions from fuel combustion for waterborne navigation occurring within the town boundary	Yes		0	0	0	0

					TONNES			
GPC REF NO.	**SCOPE**	**GHG EMISSIONS SOURCE**	**INCLUSION**	**REASON FOR EXCLUSION (IF APPLICABLE)**	**CO2**	**CH4**	**N2O**	**TOTAL CO2E**
II.3.2	2	Emissions from grid-supplied energy consumed within the town boundary for waterborne navigation	No	N/A	0	0	0	0
II.3.3	3	Emissions from portion of transboundary journeys occurring outside the town boundary, and transmission and distribution losses from grid-supplied energy consumption	No	N/A	0	0	0	0
II.4		Aviation						
II.4.1	1	Emissions from fuel combustion for aviation occurring within the town boundary	No	N/A	0	0	0	0
II.4.2	2	Emissions from grid-supplied energy consumed within the town boundary for aviation	No	N/A	0	0	0	0
II.4.3	3	Emissions from portion of transboundary journeys occurring outside the town boundary, and transmission and distribution losses from grid-supplied energy consumption	No	N/A	0	0	0	0
II.5		Off-road						

					TONNES			
GPC REF NO.	**SCOPE**	**GHG EMISSIONS SOURCE**	**INCLUSION**	**REASON FOR EXCLUSION (IF APPLICABLE)**	**CO2**	**CH4**	**N2O**	**TOTAL CO2E**
II.5.1	1	Emissions from fuel combustion for off-road transportation occurring within the town boundary	Yes		25,718	4,021	43	29,782
II.5.2	2	Emissions from grid-supplied energy consumed within the town boundary for off-road transportation	No	NR	0	0	0	0
III		WASTE						
III.1		Solid waste disposal						
III.1.1	1	Emissions from solid waste generated within the town boundary and disposed in landfills or open dumps within the town boundary	No	N/A	0	0	0	0
III.1.2	3	Emissions from solid waste generated within the town boundary but disposed in landfills or open dumps outside the town boundary	Yes		0	29,911	0	29,911
III.1.3	1	Emissions from waste generated outside the town boundary and disposed in landfills or open dumps within the town boundary	No	N/A	0	0	0	0
III.2		Biological treatment of waste						

					TONNES			
GPC REF NO.	**SCOPE**	**GHG EMISSIONS SOURCE**	**INCLUSION**	**REASON FOR EXCLUSION (IF APPLICABLE)**	**CO2**	**CH4**	**N2O**	**TOTAL CO2E**
III.2.1	1	Emissions from solid waste generated within the town boundary that is treated biologically within the town boundary	No	N/A	0	0	0	0
III.2.2	3	Emissions from solid waste generated within the town boundary but treated biologically outside the town boundary	Yes		0	2,161	1,420	3,581
III.2.3	1	Emissions from waste generated outside the town boundary but treated biologically within the town boundary	No	N/A	0	0	0	0
III.3		Incineration and open burning						
III.3.1	1	Emissions from solid waste generated and treated within the town boundary	No	N/A	0	0	0	0
III.3.2	3	Emissions from solid waste generated within the town boundary but treated outside the town boundary	Yes		0	489	852	1,341
III.3.3	1	Emissions from waste generated outside the town boundary but treated within the town boundary	No	N/A	0	0	0	0
III.4		Wastewater treatment and discharge						

					TONNES			
GPC REF NO.	**SCOPE**	**GHG EMISSIONS SOURCE**	**INCLUSION**	**REASON FOR EXCLUSION (IF APPLICABLE)**	**CO2**	**CH4**	**N2O**	**TOTAL CO2E**
III.4.1	1	Emissions from wastewater generated and treated within the town boundary	Yes		0	0	0	0
III.4.2	3	Emissions from wastewater generated within the town boundary but treated outside the town boundary	Yes		0	2,114	200	2,314
III.4.3	1	Emissions from wastewater generated outside the town boundary	No	N/A	0	0	0	0
IV		INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)						
IV.1	1	Emissions from industrial processes occurring within the town boundary	No	NR	0	0	0	0
IV.2	1	Emissions from product use occurring within the town boundary	No	ID	0	0	0	0
V		AGRICULTURE, FORESTRY AND LAND USE (AFOLU)						
V.1	1	Emissions from livestock within the town boundary	Yes		0	1,707	47	1,754
V.2	1	Emissions from land within the town boundary	No	NR	0	0	0	0
V.3	1	Emissions from aggregate sources and non-CO_2 emission sources on land within the town boundary	No	NR	0	0	0	0
VI		OTHER SCOPE 3						

					TONNES			
GPC REF NO.	**SCOPE**	**GHG EMISSIONS SOURCE**	**INCLUSION**	**REASON FOR EXCLUSION (IF APPLICABLE)**	**CO2**	**CH4**	**N2O**	**TOTAL CO2E**
VI.1	3	Other Scope 3 (e.g., GHG emissions embodied in fuels, water, food and construction materials)	No	N/A	0	0	0	0
							TOTAL	**841,080**

Appendix B: Modelling Assumptions

The following provides a consolidated version of the modelling assumptions and sources used for the business-as-planned (BAP) and low-carbon scenarios.

Table 1B.Modelling assumptions and sources used in the BAP and low-carbon scenarios.

CATEGORY	BAP ASSUMPTION	SOURCE(S)	LOW-CARBON SCENARIO ACTION
DEMOGRAPHICS			
Population & employment			
Population	2020: 136,562 2030: 179,006 2031: 186,855 2040: 232,981 growth trend 2050: 283,831 growth trend	Durham Regional Official Plan (data sourced 2020-2031) Places to Grow Forecast for the Region of Durham (data sourced 2041) Projected a growth trend of 20% from 2041 - 2050	Held the same as BAP
Employment	2020: 44,519 2030: 61,916 2031: 64,151 2040: 90,713 growth trend 2050: 120,346 growth trend	Town of Whitby: 2021 Consolidated Development Charges Background Study (data sourced 2020-2031) Projected a growth trend from 2040 - 2050	Held the same as BAP
BUILDINGS			
New buildings growth			
Building growth projections	2020: 1,247 2030: 3,910 2040: 2,838 2050: 1,380	Town of Whitby: 2021 Consolidated Development Charges Background Study 2018 Durham Population and Land Use Model (PLUM) (cross-referenced as a secondary data source)	Held the same as BAP
New buildings energy performance			

CATEGORY	BAP ASSUMPTION	SOURCE(S)	LOW-CARBON SCENARIO ACTION
Residential	Aligned with Whitby Green Standard Performance Requirements and OBC requirements for energy performance	Whitby Green Standard Performance Requirements Ministry of Municipal Affairs: Supplementary Standard SB-10 Energy Efficiency Requirements Report by the Environmental Commissioner of Ontario. Conservation: Let's Get Serious 2015-2016	Shifted the BAP improvement timeline by 5 years, new buildings built to net-ready standards by 2030
Multi-residential			
Commercial & Institutional			
Industrial			
Municipal	Design the building to achieve Tier 3 TEUI, TEDI and GHGI targets by building type (required) OR target the CaGBC Zero Carbon Building Standard (ZCBS)	Zero Carbon Whitby: The Corporate Plan to Reduce GHG Emissions Whitby Green Standard Performance Requirements	Held the same as BAP
Existing buildings energy performance			
Existing Residential Buildings Energy Performance	On an annual basis 1% of building stock was renovated annually, resulting in 10% reduction in Energy Use Intensity (EUI)	SSG	By 2045, 100% of buildings achieve a 30% reduction in electrical load and a 50% reduction in thermal load
Multi-residential			
Commercial & Institutional Buildings Energy Performance			
Industrial			
Municipal Buildings Energy Performance	Aligned with the Zero Carbon Whitby Framework's actions	Zero Carbon Whitby Framework and Costing Study Efficiency Engineering Energy Audit Summary Report: Town of Whitby (2021)	Held the same as BAP
End use			
Space heating	Fuel shares for end use unchanged; held from 2016-2050	Canadian Energy Systems Analysis Research Canadian Energy System Simulator	Aligning with the building retrofit schedule, shift to air-source heat pumps and water heaters By 2040, all new construction install air source heat pumps and electric water heaters
Water heating			
Space cooling			
Projected climate impacts			
Heating & cooling degree days	Used warming scenario RCP8.5. Heating Degree Days (HDD) are expected to decrease, and Cooling Degree Days (CDD) are expected to increase	Historical Data: weatherstats Projected Data: climateatlas	Used warming scenario 8.5 RCP, HDD and CDD are held constant
ENERGY GENERATION			
Low or zero carbon energy generation (state scale)			

CATEGORY	BAP ASSUMPTION	SOURCE(S)	LOW-CARBON SCENARIO ACTION
Renewable energy	Included in grid emissions factor projections	Table 2 and Table 3 DMA	Included in grid emissions factor projections
Low or zero carbon energy generation (community scale)			
Rooftop Solar PV	Held constant	IESO Pickering-Ajax-Whitby Sub-Region Integrated Regional Resource Plan Google Environmental Insights Explorer (Google EIE)	By 2045, 481 MW rooftop capacity installed on all building types
Ground mount solar	Held constant	IESO Pickering-Ajax-Whitby Sub-Region Integrated Regional Resource Plan Google Environmental Insights Explorer (Google EIE)	By 2045, 161 MW ground mount PV capacity installed
District Energy Generation	Dockside Development in Whitby includes wastewater energy transfer project	The Regional Municipality of Durham Report #2022-INFO-16: Proposed Wastewater Energy Transfer Project - Dockside Development in the Town of Whitby (2022)	No further action beyond Dockside Development
Wind	No action	Not applicable (NA)	No action
Renewable Energy Certificates	No action	NA	No action
Grid scale energy generation			
Centralized electricity generation	2020: CO_2: 36.78 g/kWh CH_4: 0.0085 g/kWh N_2O: 0.001 g/kWh 2050: CO_2: 88.57 g/kWh CH_2: 0.02 g/kWh N_2O: 0.002 g/kWh		Assumed in 2025 linearly decrease to 95% of EF by 2045
TRANSPORT			
Transit			
Expanded transit	Aligned with the Region of Durham Transportation Master Plan (2017) targets for personal-use-vehicles (PUV), public transit, walking, and biking	Region of Durham Transportation Master Plan (2017)	By 2045, increase transit trips to 15% of all trips

CATEGORY	BAP ASSUMPTION	SOURCE(S)	LOW-CARBON SCENARIO ACTION
Electrify transit system	Aligned with Region of Durham Transportation Master Plan (2017) electrification targets, and Region of Durham Corporate Climate Action Plan for transit fleet electrification	Region of Durham Transportation Master Plan (2017) Region of Durham Corporate Climate Change Action (2021)	By 2045, 100% of transit fleet is electrified
Active			
Mode share	Aligned with the Region of Durham Transportation Master Plan (2017) targets for mode-share targets	Region of Durham Transportation Master Plan (2017)	By 2045: Increase walking trip share to 25% (trips < 2 km) Increase biking trip share to 25% (trips 2-10km trips) Increase transit trip share to 15% (trips > 10 km)
Private/personal use			
Electrify municipal fleet	Maintain current split of diesel-gasoline fuel types in light-duty vehicles and medium duty vehicles	Region of Durham Corporate Climate Change Action (2021) Zero Carbon Whitby Framework	Aligned with Zero Carbon Whitby Framework
Electrify personal vehicles	Aligned with the federally mandated target of 100% electric vehicle (EV) light-duty cars and passenger truck sales by 2035	Regulations Amending the Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations 2030 Emissions Reduction Plan Canada's Action Plan for Clean On-Road Transportation	Held same as BAP
Electrify commercial vehicles	Aligned with the federally mandated target of 100% electric vehicle (EV) light-duty cars and passenger truck sales by 2035 No change in heavy-duty vehicles	Regulations Amending the Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations 2030 Emissions Reduction Plan Canada's Action Plan for Clean On-Road Transportation	By 2045, light-duty vehicles are electric and medium- and heavy-duty are combination of electric and hydrogen-fuel powered
Vehicle kilometers travelled	Calculated in the model	Estimates derived from location of residents, jobs, school, and other services in Whitby. Average trip lengths derived from Statistics Canada.	Reduce km travelled in personal vehicles by 10% for home to work (by 2045)

CATEGORY	BAP ASSUMPTION	SOURCE(S)	LOW-CARBON SCENARIO ACTION
Vehicle fuel efficiencies / tailpipe emission standards	Aligned with 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	EPA. (2012). EPA and NHTSA set standards to reduce greenhouse gases and improve fuel economy for model years 2017-2025 cars and light trucks SOR/2010-201. Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations 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	Efficiencies and tailpipe emissions calculated in model
Vehicle stock	Aligned with standard vehicle stock turnover rates Personal vehicle stock share changes between 2016-2050 and commercial vehicle stock unchanged from 2016-2050	CANSIM and Natural Resources Canada's Demand and Policy Analysis Division	The total number of personal use and corporate vehicles is proportional to the projected number of households in the BAU
WASTE			
Waste generation	No change from current practices; held constant from BAU	Durham Region Long-term Waste Management Plan (2022-2040)	Decrease waste per capita by 20% by 2030 and 30% by 2045
Waste diversion	No change from current practices; held constant from BAU	Durham Region Long-term Waste Management Plan (2022-2040)	Increase residential diversion (organics and recycling rates) 100% by 2045 Increase ICI diversion (recycling) and 70% by 2045. Increase ICI diversion (organics) and 70% by 2045
Waste treatment	Not modelled	NA	Not modelled
Wastewater	No change from current practices; held constant from BAU	NA	1% improvement per year over 20 years
INDUSTRY & AGRICULTURE			
Industrial efficiencies	Held constant	NA	Increase process efficiency by 30% by 2045 Electrify 50% of industrial processes by 2045

CATEGORY	BAP ASSUMPTION	SOURCE(S)	LOW-CARBON SCENARIO ACTION
Agriculture	Held constant	Durham Region Agriculture Sector Climate Adaptation Strategy (2019)	30% decrease in livestock emissions by 2045 to account for improvement in livestock breeding, feed sources, manure management Switch 70% of the off road fossil fuel use to electric by 2045 Switch agriculture industrial end uses - motive and process heat - to electricity by 2045
Big Industry - Gerdau	Aligned with Gerdau's company-wide Climate Plan to reduce GHG emissions by 2031	Gerdau Steel Industry Company Climate Commitment	Aligned with Gerdau's company-wide Climate Plan to reduce GHG emissions by 2031 and 2050 decarbonization of operations Included carbon capture as per Climate Plan
Big Industry - Atlantic Packaging	Held constant	Atlantic Packaging Sustainability Plan	Held constant
FINANCIAL			
Energy costs	Energy intensity costs by fuel increase incrementally between 2016-2050 per National Energy Board projections	National Energy Board. (2016). Canada's Energy Future 2016. Government of Canada Government of Ontario. (2016). Fuels Technical Report	NEB projections extend until 2040; extrapolated to 2050 Energy cost intensities are applied to energy consumption by fuel, derived by the model, to determine total annual energy and per household costs