Thunder Bay

Data, Methods, and Assumptions Manual

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Completed by SSG & Whatif?Technologies

Contents

1. Summary

The Data, Methods and Assumptions (DMA) manual has been created for Thunder Bay to illustrate the modeling approach used to provide energy and emissions benchmarks and projections. The DMA will also 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 lay a foundation for the scope of data required for future modelling efforts that the City can build upon.

2. Accounting and Reporting Principles

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 Thunder Bayal boundary. The inventory will also serve the decision-making needs of Thunder Bay, 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 & 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.

3. Assessment Characteristics

3.1 Geographic boundary

The geographic boundary for this assessment consists of the City as shown in Figure 1.

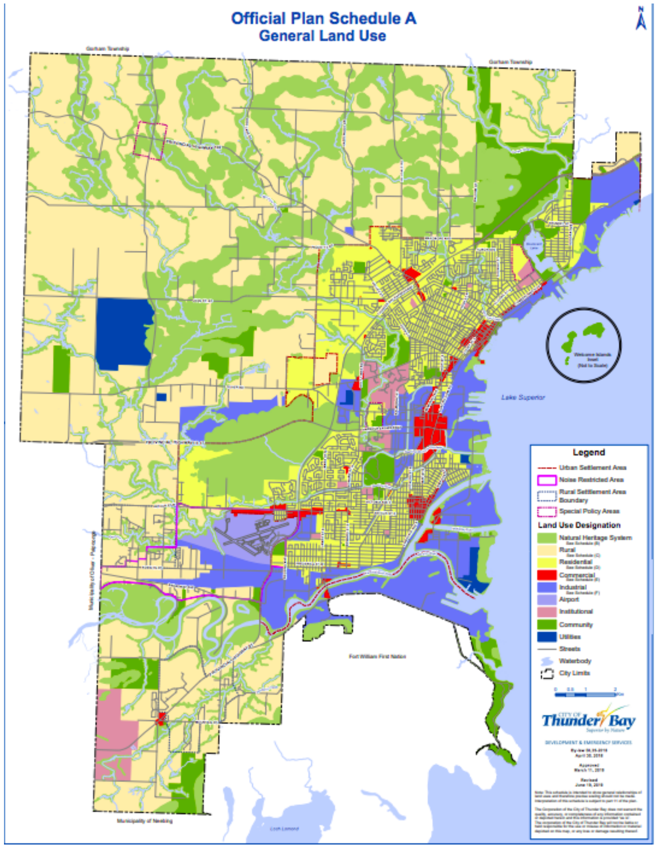


Figure 1. Thunder Bay geographic boundary.

3.2 Time Frame of Assessment

The time frame for assessment of Thunder Bay will be from 2016-2050, with 2016 as a baseline year. The census of 2016 is a key data source used to establish the baseline year. Further, the baseline year is based on model calibration which uses as much observed data as possible in order to provide the most accurate and consistent snapshot as possible.

Refer to Section 6. Scenario Development for more information on Model Calibration and Data & Assumptions.

3.3 Energy and Emissions Structure

The total energy for a community is defined as the sum of the energy from each of the aspects:

$$Energy_{city} = Energy_{transport} + Energy_{buildings} + Energy_{wastegen}$$

Where:

$Energy_{transport}$ is the movement of goods and people.
$Energy_{buildings}$ is the generation of heating, cooling and electricity.
$Energy_{wastegen}$ is energy generated from waste.

The total GHG for a community is defined as the sum of the GHG from each of the aspects:

$$GHG_{landuse} = GHG_{transport} + GHG_{energygen} + GHG_{waste} + GHG_{agriculture} + GHG_{forest} + GHG_{landconvert}$$

Where:

$GHG_{transport}$ is the movement of goods and people.
$GHG_{energygen}$ is the generation of heat and electricity.
GHG_{waste} is liquid and solid waste produced.
$GHG_{agriculture}$ is the production of food.
GHG_{forest} is the area of forest land.
$GHG_{landconvert}$ is the area of land in natural or modified conditions.

3.4 Scope

The inventory will include Scope 1 and 2, and some aspects of Scope 3. Refer to Appendix 1 for a list of GHG emission sources by Scope that are included.

Table 1. GPC 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.

3.5 Emission Factors

In order to compile a baseline of emissions within Thunder Bay, inputs such as energy use, activities by citizens and businesses, and waste products need to be converted to recordable emissions. The following table displays those conversions and their sources.

Table 2. Emissions Factors for Thunder Bay Baseline and Future Scenarios.

Category	Description	Comment
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, Emission Factors for Natural Gas.
Electricity	2016: 50.8 gCO_2e/kWh 2050: 83.7 gCO_2e/kwh 2016: CO_2: 28.9 g/kWh CH_4: 0.007 g/kWh N_2O: 0.001 g/kWh 2050: CO_2: 82.32 g/kWh CH_4: 0.02 g/kWh N_2O: 0.00 g/kWh	IESO, Annual Planning Outlook January 2020.
Gasoline	g/L CO_2: 2316 CH_4: 0.32 N_2O: 0.66	Environment and Climate Change Canada. National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada. 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	Environment and Climate Change Canada. National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada. Part 2. Table A6–12 Emission Factors for Energy Mobile Combustion Sources
Fuel oil	Residential g/L CO_2: 2560 CH_4: 0.026	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

	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	
Propane	g/L Transport CO_2: 1515.00 CH_4: 0.64 N_2O: 0.03 Residential CO_2: 1515.00 CH_4 : 0.027 N_2O: 0.108 All other sectors CO_2: 1515.00 CH_4: 0.024 N_2O: 0.108	Environment and Climate Change Canada. National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada. Part 2. Table A6–3 Emission Factors for Natural Gas Liquids Table A6–12 Emission Factors for Energy Mobile Combustion Sources
Agricultural: Live Stock	Varies per animal Type Kg CH_4/ head	Environment and Climate Change Canada. National Inventory Report 1990-2016: Greenhouse Gas Sources and Sinks in Canada. Part 2 Table A3-30 CH_4 Emission Factors for Enteric Fermentation for Cattle from 1990 to 2016 Table A3-37 Emission Factors to Estimate CH_4 Emissions from Manure Management for Cattle Subcategories
Waste	Landfill emissions are calculated from the first order decay of degradable organic carbon deposited in landfill. Derived emission factor in 2016 = 0.015	It is assumed there is no methane capture in Thunder Bay Landfill emissions: IPCC Guidelines Vol 5. Ch 3, Equation 3.1 ICI Waste tonnage was estimated using per capita numbers for Ontario from Statistics Canada, Table 38-10-0032-01: Disposal of waste, by source.

	kg CH_4/tonne solid waste (assuming 70% recovery of landfill methane); 0.050 kg CH_4/tonne solid waste not accounting for recovery. Incineration Emissions: CO_2 emissions are derived from the IPCC method presented in the 2006 Guidelines, Volume 5, Chapter 5, section 5.2.1.1. Composted Biological Emissions Factors: 4 gCH_4/kg solid organic waste and 0.3 gN20/kg solid organic waste.	
Wastewater	CH_4: 0.48 kg CH_4/kg BOD N_2O: 3.2 g / (person * year) from advanced treatment 0.005 g /g N from wastewater discharge	CH_4 wastewater: IPCC Guidelines Vol 5. Ch 6, Tables 6.2 and 6.3; MCF value for anaerobic digester N_2O from advanced treatment: IPCC Guidelines Vol 5. Ch 6, Box 6.1 N_2O from wastewater discharge: IPCC Guidelines Vol 5. Ch 6, Section 6.3.1.2

5. Modelling

For this project, *CityInSight* will be used as the main modelling tool.

5.1 About CityInSight

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

Energy and GHG emissions are derived from a series of connected stock and flow models, evolving on the basis of current and future geographic and technology decisions/assumptions (e.g. EV penetration rates). The model accounts for physical flows (i.e. energy use, new vehicles by technology, vehicle kilometres travelled) as determined by stocks (buildings, vehicles, heating equipment, etc).

CityInSight incorporates and adapts concepts from the system dynamics approach to complex systems analysis. 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, hydrogen) to end uses (e.g. personal vehicle use, space heating) to energy costs and to GHG emissions. 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.

Table 3. Characteristics of CityInSight.

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

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.

5.2 Model Structure

The major components of the model, and the first level of modelled relationships (influences), are represented by the blue arrows in Figure 2. Additional relationships may be modelled 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.

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. A zone type system is applied to break up the City into smaller configurations. This enables consideration of the impact of land-use patterns and urban form on energy use and emissions production from a baseline year to future dates using GIS-based platforms. CityInSight’s GIS outputs can be integrated with the City’s mapping systems.

5.3 Stocks and flows

For any given year various factors shape the picture of energy and emissions flows, 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—and the energy flow picture.

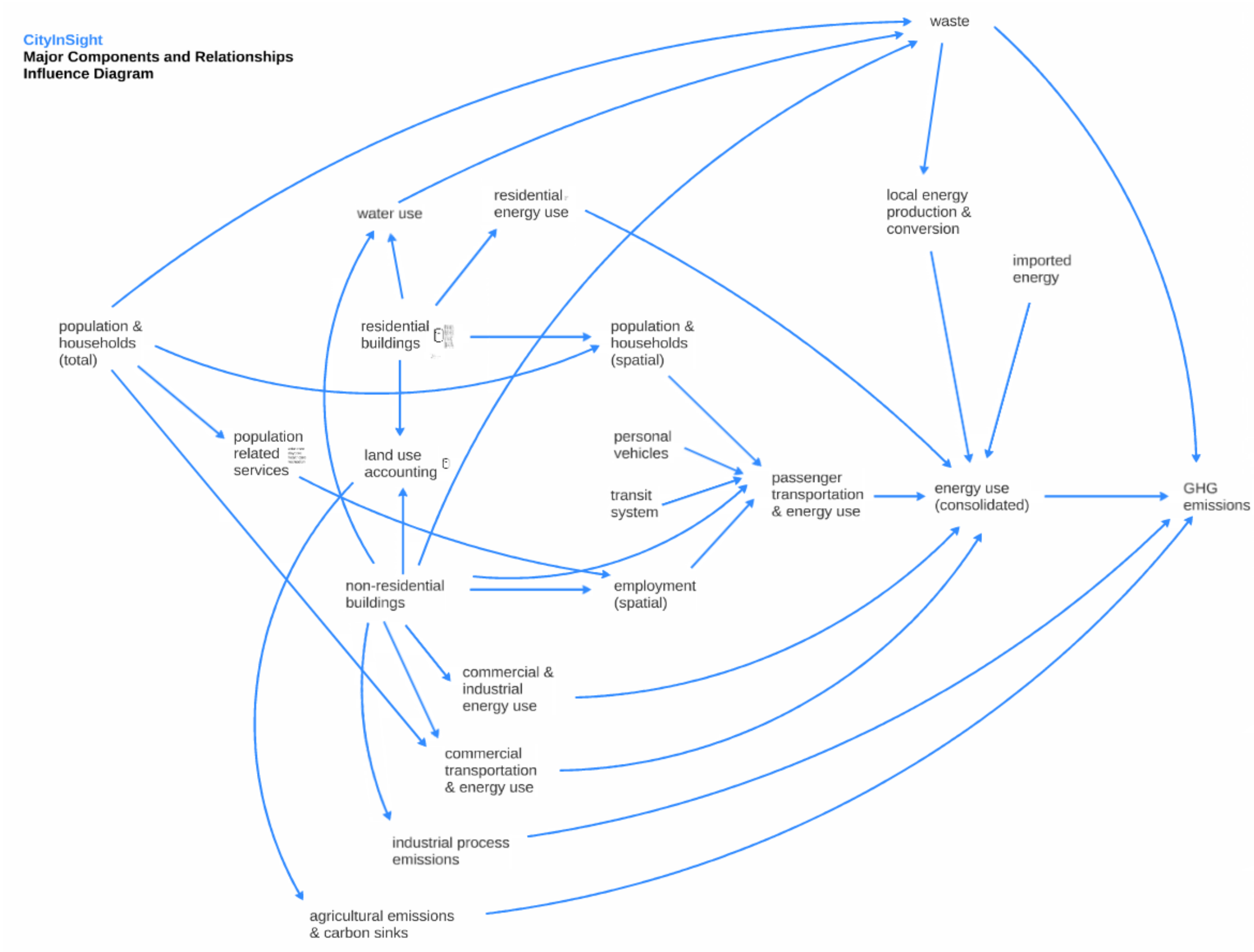
Some factors are modelled as stocks—counts of similar things, classified by various properties. For example, population is modelled as a stock of people classified by age and gender. Population change over time is projected by accounting for: the natural aging process, inflows (births, immigration) and 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).

5.4 Sub-models

Population and demographics

City-wide population is modelled using the standard population cohort-survival method, disaggregated by single year of age and gender. It accounts for various components of change: births, deaths, immigration and emigration. The age structured population is important for analysis of demographic trends, generational differences and implications for shifting energy use patterns. In CityInSight these numbers will be calibrated against existing projections developed for the City. New population data was provided by Thunder Bay planning department

Figure 2. Representation of CityInSight's structure.



Residential buildings

Residential buildings are spatially located and classified using a detailed set of 30+ building archetypes capturing footprint, height and type (single, double, row, apt. high, apt. low), in addition to year of construction. This enables a "box" model of buildings and the estimation of surface area. Coupled with thermal envelope performance and degree-days the model calculates space conditioning energy demand independent of any particular space heating or cooling technology and fuel. Energy service demand then drives stock levels of key service technologies (heating systems, air conditioners, water heaters). These stocks are modelled with a stock-turnover approach capturing equipment age, retirements, and additions—exposing opportunities for efficiency gains and fuel switching, but also showing the rate limits to new technology adoption and the effects of lock in. Residential building archetypes are also characterized by number of contained dwelling units, allowing the model to capture the energy effects of shared walls but also the urban form and transportation implications of population density.

Non-residential buildings

These are spatially located and classified by a detailed use/purpose-based set of 50+ archetypes, and the floorspace of these non-residential building archetypes can vary by location. Non-residential floorspace produces waste and demand for energy and water, and also provides an anchor point for locating employment of various types.

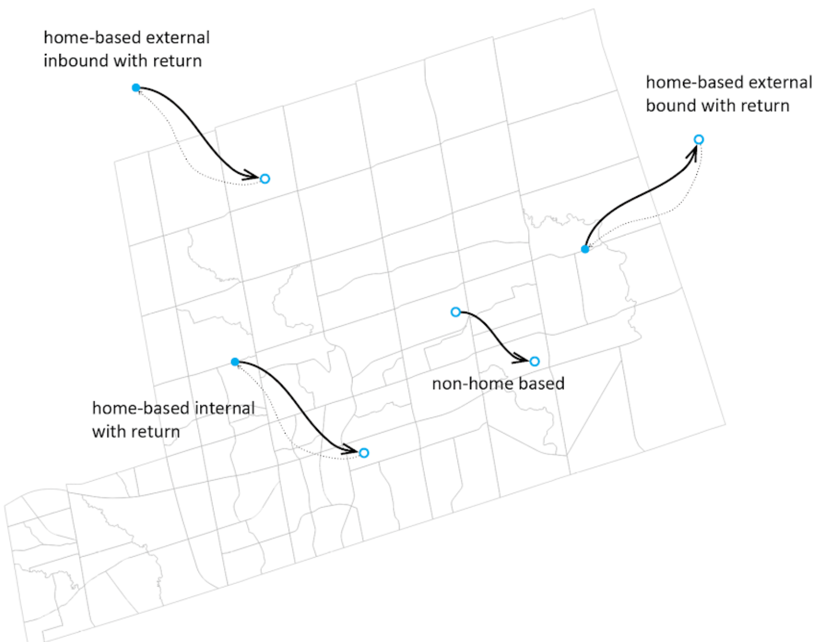
Spatial population and employment

City-wide population is made spatial by allocation to dwellings, using assumptions about persons-per-unit by dwelling type. Spatial employment is projected via two separate mechanisms: population-related services and employment, which is allocated to corresponding building floorspace (e.g. teachers to school floorspace); and floorspace-driven employment (e.g. retail employees per square metre).

Passenger Transportation

The model includes a spatially explicit passenger transportation sub-model that responds to changes in land use, transit infrastructure, vehicle technology, travel behavior change and other factors. Trips are divided into four types (home-work, home-school, home-other, and non-home-based), each produced and attracted by a different combination of spatial drivers (population, employment, classrooms, non-residential floorspace). Trips are distributed - that is, trip volumes are specified for each zone of origin and zone of destination pair. For each origin-destination pair trips are shared over walk/bike (for trips within the walkable distance threshold), public transit (for trips whose origin and destination are serviced by transit) and automobile. Following the mode share step, along with a network distance matrix, a projection of total personal vehicles kilometres travelled (VKT) is produced. The energy use and emissions associated with personal vehicles is calculated by assigning VKT to a stock-turnover personal vehicle model. The induced approach is used to track emissions. All internal trips (trips within Thunder Bay's boundary) are accounted for, as well as half of the trips that terminate or originate within the City's boundary. This approach allows Thunder Bay to better understand its impact on the peripheries.

Figure 3. Conceptual diagram of trip categories.



Waste

Households and non-residential buildings generate solid waste and wastewater, and the model traces various pathways to disposal, compost and sludge including those which capture energy from incineration and recovered gas. Emissions accounting is performed throughout the waste sub-model.

Energy flow and local energy production

Energy produced from primary sources (e.g. solar, wind) is modelled alongside energy converted from imported fuels (e.g. electricity generation, district energy, CHP). As with the transportation sub-model, the district energy supply model has an explicit spatial dimension and represents areas served by district energy networks.

Finance and employment

Energy related financial flows and employment impacts—while not shown explicitly—are captured through an additional layer of model logic. Calculated financial flows include the capital, operating and maintenance cost of energy consuming stocks and energy producing stocks, including fuel costs. Employment related to the construction of new buildings, retrofit activities and energy infrastructure is modelled. The financial impact on businesses and households of the strategies is assessed. Local economic multipliers are also applied to investments.

Land Based and Agriculture Emissions

Data used to calculate Agriculture, Forestry, and other Land Use (AFOLU) emissions was found in Statistics Canada Census of Agriculture CANSIM tables of livestock for Thunder Bay for 2016. Environment Canada's 2016 National Inventory Report was used to obtain emissions factors for livestock and croplands, and the total area classified as woodland was estimated from GIS mapping provided by Thunder Bay.

Agricultural and land-based emissions are calculated as change of activities, uses, and land over time. In the BAP and in future scenarios, land that is predominantly forested or agricultural based that is projected to be developed will have population and floor space per person associated with it. Floorspace is assigned through building type, and the resulting net loss of open or undeveloped land results in a net increase in GHG emissions associated with that land.

Carbon Sequestration

Carbon sequestration, or the capture and storage of GHG emissions, is a net effect of growing increased woodlands, forests, and street trees. An absorption factor is added to a type of tree, or land that is recovered and then provided as a total sequestration figure, or in other words as a GHG emissions reduction. This total is kept separate from the total GHG emissions produced in the community, then provided as a net GHG Emissions for the community.

Carbon absorption factors vary depending on the age of a forest, where an older forest is considered to be a carbon sink that already contains a maximum amount of carbon, whereas a newly planted or developing forest will continue to absorb increasing GHGs as it matures.

5.5 Data and Assumptions

A detailed table is available under Appendix 1 showing the data used and assumptions made to develop the BAP scenario for Thunder Bay. A separate breakdown of how the inventory complies with the GHG protocol can be found under Appendix 2.

6. Scenario Development

CityInSight is designed to support the use of scenarios as a mechanism to evaluate potential futures for 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. A good set of scenarios is both plausible and surprising but scenarios can also be misleading if, for example, there are too few so that one scenario is ‘‘good’’ and the other ‘‘bad”.

Another consideration is to ensure that the name of the scenario does not bias the audience. Lastly, scenarios must represent serious considerations defined not only by planning staff, but also by community members.

Scenarios are generated by identifying population projections 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.

6.1 Business-as-Planned Scenario

At this stage, using current and future planned policies, it is time to create the first scenario from our assumptions.

The business-as-planned (BAP) scenario will offer a scenario moving towards the year 2050, where there is an absence of new substantive policy measures.

Methodology:

1. Calibrate model and develop 2016 baseline using observed data and filling in gaps with assumptions where necessary;
2. Input existing projected quantitative data to 2050 where available:
    - Population, employment & households projections from City by transport zone;
    - Build out (buildings) projections from City by transport zone;
    - Transport modelling from City;
3. Where quantitative projections are not carried through to 2050 (e.g. completed to 2041), extrapolate the projected trend to 2050;
4. Where specific quantitative projections are not available, develop projections through:
    - Analysing current on the ground action in the City (reviewing actions plans, engagement with staff etc.), and where possible, quantifying the action;
    - Analysing existing policy that has potential impact for the city, and where possible, quantifying the potential impact.

A list of BAP data sources and assumptions can be found in the BAP Data and Assumptions Table. (Appendix 1)

6.2 Low-Carbon Scenario

Using the business as usual scenario as a jumping-off point, we now create the low-carbon scenario, mapped out to the target year (usually 2050). All potential actions are identified.

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), projecting energy services demand intensities, and projecting the composition of energy system infrastructure, often with stocks.

Policies, actions and strategies

Throughout the CityInSight accounting framework there are input variables—for user assumptions and projections—which collectively comprise an interface to controlling the physical trajectory of the urban energy system and resultant emissions. Different settings for these inputs can be interpreted as alternative behaviours of various actors or institutions in the energy system (e.g. households, various levels of government, industry, etc). This interface can be directly set or controlled by the model user, to create "what if" type scenarios. The modelling platform upon which CityInSight is built allows for a "higher layer" of logic to operate at this physical-behavioural interface, in effect enabling a flexible mix-and-match approach to behavioral models which connect to the same constraining physical model. CityInSight is able to explore a wide variety of policies, actions and strategies. The resolution of CityInSight enables the user to apply scenarios to specific neighbourhoods, technologies, building or vehicle types or eras, and configurations of the built environment.

Methodology

1. Develop list of potential actions and strategies from consultant expertise, input from city staff and community engagement (ie. catalogue);
2. Identify the technological potential of each action (or group of actions) to reduce energy and emissions by quantifying actions:

    a. Firstly if the action or strategy specifically incorporates a projection or target; or,
    b. Secondly, if there is a stated intention or goal, review best practices and literature to quantify that goal;
    c. Thirdly, identify any actions that are either overlapping and/or include dependencies on other actions;
3. Translate the actions into quantified assumptions over time;
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 80x50 target;
6. If the target is not achieved, Identify variables which can be scaled up and provide a rationale for doing so;
7. Iteratively adjust variables to identify a pathway to 80x50;
8. Develop marginal abatement curve for low carbon scenario;
9. Define criteria to evaluate low carbon scenario (i.e., identify criteria for multi-criteria analysis);
10. Prioritize actions of low carbon scenario through multi-criteria analysis (along with other criteria e.g. health, prosperity etc.);
11. Revise scenario to reflect prioritization for final low carbon scenario, removing and scaling the level of ambition of actions according to the evaluation results.

7. 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").

An analysis of land-use models used to assess climate change impacts for Sydney, Australia, emphasised that the models should be used only for scenario testing and not forecasting because of limits to the possible precision. The importance of this point is demonstrated by the fact that the models considered in this analysis can generate a range of outcomes from the same starting point (Oydell et al., 2007, pg. 10).

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 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 1: BAP Data and Assumptions

MODEL VARIABLE	ASSUMPTION	SOURCE	NOTES
ENERGY GENERATION			
Local energy generation			
Biomass	62.4 MW	IESO Contracted Renewable Generation list (as of June 30, 2019)	CHP. Owned by Resolute Pulp & Paper. Contracted from 2011-2021. Transmission Connected. Nameplate capacity of 62.4 MW, of which 40 MW is contracted to the OPA. CHP capacity is held constant to 2050.
Hydro	0.5 MW	IESO Contracted Renewable Generation list (as of June 30, 2019)	Hydro capacity held constant to 2050.
Landfill gas	3.2 MW	IESO Contracted Renewable Generation list (as of June 30, 2019); City website	Landfill gas capacity held constant to 2050.
Anaerobic Digester methane	0.6 MW	Thunder Bay Wastewater Treatment (Annual Report) 2017-2018	Wastewater anaerobic digestion is used for process heat
Solar PV	1.5173 MW	IESO Contracted Renewable Generation list (as of June 30, 2019)	Solar capacity in 2016 is held constant to 2050.
Natural Gas	3 MW	Thunder Bay Regional Health Sciences Centre.	Cogeneration at hospital, held constant to 2050.
Energy Storage			No storage deployed.
TRANSPORTATION			
Transit			
Expansion of transit	Existing transit service unchanged 2016-2050; no expansion of transit assumed.	Thunder Bay Transit Master Plan (2019); EarthCare Sustainability Plan report (2014-2020)	No change in transit mode share assumed 2016-2050.
Electric vehicle transit	No electrification of the transit vehicle fleet assumed.	Corporate Energy Management Plan 2019-2024	No electrification of the transit vehicle fleet assumed 2016-2050.

Active			
Cycling & walking infrastructure	An increase of 1% from 2016 by 2020 (from 6-7%).	Census data; Thunder Bay Active Transport Plan (2019); EarthCare Sustainability Report (2017).	An increase of 1% from 2016 by 2020 (from 6-7%). Held constant to 2050.
Private & commercial vehicles			
Vehicle kilometers travelled	No data from City or other, derived from the model.	Expert estimates derived from location of residents, jobs, schools, and other services; Average trip lengths derived from Statistics Canada; Car registrations.	Vehicle kilometres travelled projections are driven by buildings projections. The number and location of dwellings and non-residential buildings over time in the BAP drive the total number of internal and external person trips. Person trips are converted to vehicle trips using the baseline vehicle occupancy. Vehicle kilometres travelled is calculated from vehicle trips using the baseline distances between zones and average external trip distances.
Vehicle fuel efficiencies	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.	EPA. (2012). EPA and NHTSA set standards to reduce greenhouse gases and improve fuel economy for model years 2017-2025 cars and light trucks.	Fuel efficiency standards are applied to all new vehicle stocks starting in 2016.
Vehicle share	Personal vehicle stock share changes between 2016-2050. Commercial vehicle stock unchanged 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 BAP.
Electric vehicles	14% new sales by 2030; share holds constant to 2050	Jonn Axsena, Michael Wolinetz, Transportation Research Part D: Transport and Environment Volume 65, December 2018, Pages 596-617.	Conservative estimate from study used. Moving out to 2050, we assume subsidies do not stay in place, and new sales are held constant.
WASTE			

Waste generation	46,516 kg residential waste in 2017	Solid Waste Management Strategy (2014); EarthCare Sustainability Plan report (2017) .	Waste generation per capita held constant from 2016-2050.
Waste diversion	27% waste diversion from landfill in 2018	Solid Waste Management Strategy (2014); EarthCare Sustainability Plan report (2017) .	Waste diversion rates held constant from to 2050.
Waste treatment	Existing waste treatment processes unchanged.		No change in waste treatment processes assumed 2016-2050.
FINANCIAL			
Energy costs	Energy intensity costs by fuel increase incrementally between 2016-2050 per projections.	National Energy Board. (2019). Canada's Energy Future 2016.	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.
Carbon price	April 2019 (20$/tonne); April 2020 ($30/tonne); April 2021 ($40/tonne); April 2022 (50$/tonne)	Federal government	Held constant after 2022 due to political uncertainty. Only applies to combustion emissions (i.e. not waste); and to small emitters (i.e. below 10kt/year). Large emitters (25kt+) are subject to a cap & trade-type system, where they could potentially profit. Medium emitters can opt in (10kt-25kt) and are likely to do so as it is likely to be financially advantageous.
Agricultural / Natural Systems			

Agricultural: Live Stock	Varies per animal Type Kg CH4/ head Assume no change towards 2050 in livestock	Census; Environment and Climate Change Canada. National Inventory Report 1990-2016: Greenhouse Gas Sources and Sinks in Canada. Part 2 Table A3-30 CH4 Emission Factors for Enteric Fermentation for Cattle from 1990 to 2016 Table A3-37 Emission Factors to Estimate CH4 Emissions from Manure Management for Cattle Subcategories	
Agricultural Land Use	Reflects development patterns by the City (2016-2050)	Census; 2019 Refinement to the 2006 IPCC Guidelines on National Greenhouse Gas Inventories (2019 Refinement), Volume 4, Chapter 4, Table 4.9 (Updated), Temperate, Continental, Secondary > 20 years 2019 Refinement to the 2006 IPCC Guidelines on National Greenhouse Gas Inventories (2019 Refinement), Volume 4, Chapter 4, Table 4.4 (Updated), Temperate, Continental, North and South America, Natural (Other Broadleaf) 2006 IPCC Guidelines on National Greenhouse Gas Inventories, Volume 4, Chapter 4, Table 4.3, Temperate, All (No Refinement in 2019)	Agricultural and land based emissions are calculated as change of activities, uses, and land over time. Land that is currently predominantly forested or agriculturally based and is projected to be developed will have population and floor space per person associated with it. Floorspace is assigned through building type (single detached, apartment, row, etc), and the resulting net loss of open or undeveloped land results in a net increase in GHG emissions associated with that land.

Appendix 2: GPC Emissions Scope

GPC ref No.	Scope	GHG Emissions Source	Inclusion	Reason for exclusion (if applicable)
I		STATIONARY ENERGY SOURCES		
I.1		**Residential buildings**		
I.1.1	1	Emissions from fuel combustion within the city boundary	**Yes**	
I.1.2	2	Emissions from grid-supplied energy consumed within the city boundary	**Yes**	
I.1.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	**Yes**	
I.2		**Commercial and institutional buildings/facilities**		
I.2.1	1	Emissions from fuel combustion within the city boundary	**Yes**	
I.2.2	2	Emissions from grid-supplied energy consumed within the city boundary	**Yes**	
I.2.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	**Yes**	
I.3		**Manufacturing industry and construction**		
I.3.1	1	Emissions from fuel combustion within the city boundary	**Yes**	
I.3.2	2	Emissions from grid-supplied energy consumed within the city boundary	**Yes**	
I.3.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	**Yes**	
I.4		**Energy industries**		
I.4.1	1	Emissions from energy used in power plant auxiliary operations within the city boundary	**Yes**	
I.4.2	2	Emissions from grid-supplied energy consumed in power plant auxiliary operations within the city boundary	**Yes**	

I.4.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption in power plant auxiliary operations	**Yes**	
I.4.4	1	Emissions from energy generation supplied to the grid	**Yes**	
I.5		**Agriculture, forestry and fishing activities**		
I.5.1	1	Emissions from fuel combustion within the city boundary	**No**	NR
I.5.2	2	Emissions from grid-supplied energy consumed within the city boundary	**No**	NR
I.5.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	**No**	NR
I.6		**Non-specified sources**		
I.6.1	1	Emissions from fuel combustion within the city boundary	**No**	NR
I.6.2	2	Emissions from grid-supplied energy consumed within the city boundary	**No**	NR
I.6.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	**No**	NR
I.7		**Fugitive emissions from mining, processing, storage, and transportation of coal**		
I.7.1	1	Emissions from fugitive emissions within the city boundary	**No**	NR
I.8		**Fugitive emissions from oil and natural gas systems**		
I.8.1	1	Emissions from fugitive emissions within the city boundary	**Yes**	

II		**TRANSPORTATION**		
II.1		**On-road transportation**		
II.1.1	1	Emissions from fuel combustion for on-road transportation occurring within the city boundary	**Yes**	
II.1.2	2	Emissions from grid-supplied energy consumed within the city boundary for on-road transportation	**Yes**	
II.1.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	**Yes**	
II.2		**Railways**		
II.2.1	1	Emissions from fuel combustion for railway transportation occurring within the city boundary	**No**	NR
II.2.2	2	Emissions from grid-supplied energy consumed within the city boundary for railways	**No**	NR

II.2.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	**No**	NR
II.3		**Water-borne navigation**		
II.3.1	1	Emissions from fuel combustion for waterborne navigation occurring within the city boundary	**No**	N/A
II.3.2	2	Emissions from grid-supplied energy consumed within the city boundary for waterborne navigation	**No**	N/A
II.3.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	**No**	N/A
II.4		**Aviation**		
II.4.1	1	Emissions from fuel combustion for aviation occurring within the city boundary	**No**	N/A
II.4.2	2	Emissions from grid-supplied energy consumed within the city boundary for aviation	**No**	N/A
II.4.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	**No**	N/A
II.5		**Off-road**		
II.5.1	1	Emissions from fuel combustion for off-road transportation occurring within the city boundary	**No**	NR
II.5.2	2	Emissions from grid-supplied energy consumed within the city boundary for off-road transportation	**No**	NR

III		**WASTE**		
III.1		**Solid waste disposal**		
III.1.1	1	Emissions from solid waste generated within the city boundary and disposed in landfills or open dumps within the city boundary	**Yes**	
III.1.2	3	Emissions from solid waste generated within the city boundary but disposed in landfills or open dumps outside the city boundary	**Yes**	
III.1.3	1	Emissions from waste generated outside the city boundary and disposed in landfills or open dumps within the city boundary	**No**	N/A
III.2		**Biological treatment of waste**		
III.2.1	1	Emissions from solid waste generated within the city boundary that is treated biologically within the city boundary	**Yes**	

III.2.2	3	Emissions from solid waste generated within the city boundary but treated biologically outside of the city boundary	**No**	N/A
III.2.3	1	Emissions from waste generated outside the city boundary but treated biologically within the city boundary	**No**	N/A
III.3		**Incineration and open burning**		
III.3.1	1	Emissions from solid waste generated and treated within the city boundary	**No**	N/A
III.3.2	3	Emissions from solid waste generated within the city boundary but treated outside of the city boundary	**No**	N/A
III.3.3	1	Emissions from waste generated outside the city boundary but treated within the city boundary	**No**	N/A
III.4		**Wastewater treatment and discharge**		
III.4.1	1	Emissions from wastewater generated and treated within the city boundary	**Yes**	
III.4.2	3	Emissions from wastewater generated within the city boundary but treated outside of the city boundary	**No**	NR
III.4.3	1	Emissions from wastewater generated outside the city boundary	**No**	N/A

IV		INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)		
IV.1	1	Emissions from industrial processes occurring within the city boundary	**No**	ID
IV.2	1	Emissions from product use occurring within the city boundary	**No**	ID

V		AGRICULTURE, FORESTRY AND LAND USE (AFOLU)		
V.1	1	Emissions from livestock within the city boundary	**No**	NR
V.2	1	Emissions from land within the city boundary	**No**	NR
V.3	1	Emissions from aggregate sources and non-CO2 emission sources on land within the city boundary	**No**	NR

VI		OTHER SCOPE 3		
VI.1	3	Other Scope 3	**No**	N/A

Reasons for Exclusions	**N/A**	Not Applicable, or not included in scope
	ID	Insufficient Data
	NR	No Relevance, or limited activities identified
	Other	Reason provided in other comments