District of North Cowichan

Climate Action and Energy Plan Update

Data, Methods and Assumptions (DMA) Manual

Prepared by Sustainability Solutions Group
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CONTENTS

Summary

This Data, Methods and Assumptions (DMA) manual details the modelling approach used to provide community energy and emissions benchmarks and projections and provides a summary of the data and assumptions used in scenario modelling. The DMA makes the modelling elements fully transparent and illustrates the scope of data required for future modelling efforts.

Accounting and Reporting Principles

The municipal greenhouse gas (GHG) inventory baseline development and scenario modelling approach correlate with the Global Protocol for Community-Scale GHG Emissions Inventories (GPC). The GPC provides a fair and true account of emissions via its principles:

Relevance: The reported GHG emissions shall appropriately reflect emissions occurring as a result of activities and consumption within the Town boundary. The inventory will also serve the decision-making needs of the Town, taking into consideration relevant local, subnational, and national regulations. Relevance applies when selecting data sources and determining and prioritizing data collection improvements.

Completeness: All emissions sources within the inventory boundary shall be accounted for. Any exclusions of sources shall be justified and explained.

Consistency: Emissions calculations shall be consistent in approach, boundary, and methodology.

Transparency: Activity data, emissions sources, emissions factors and accounting methodologies require adequate documentation and disclosure to enable verification.

Accuracy: The calculation of GHG emissions should not systematically overstate or understate actual GHG emissions. Accuracy should be 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.

Scope

Geographic Boundary

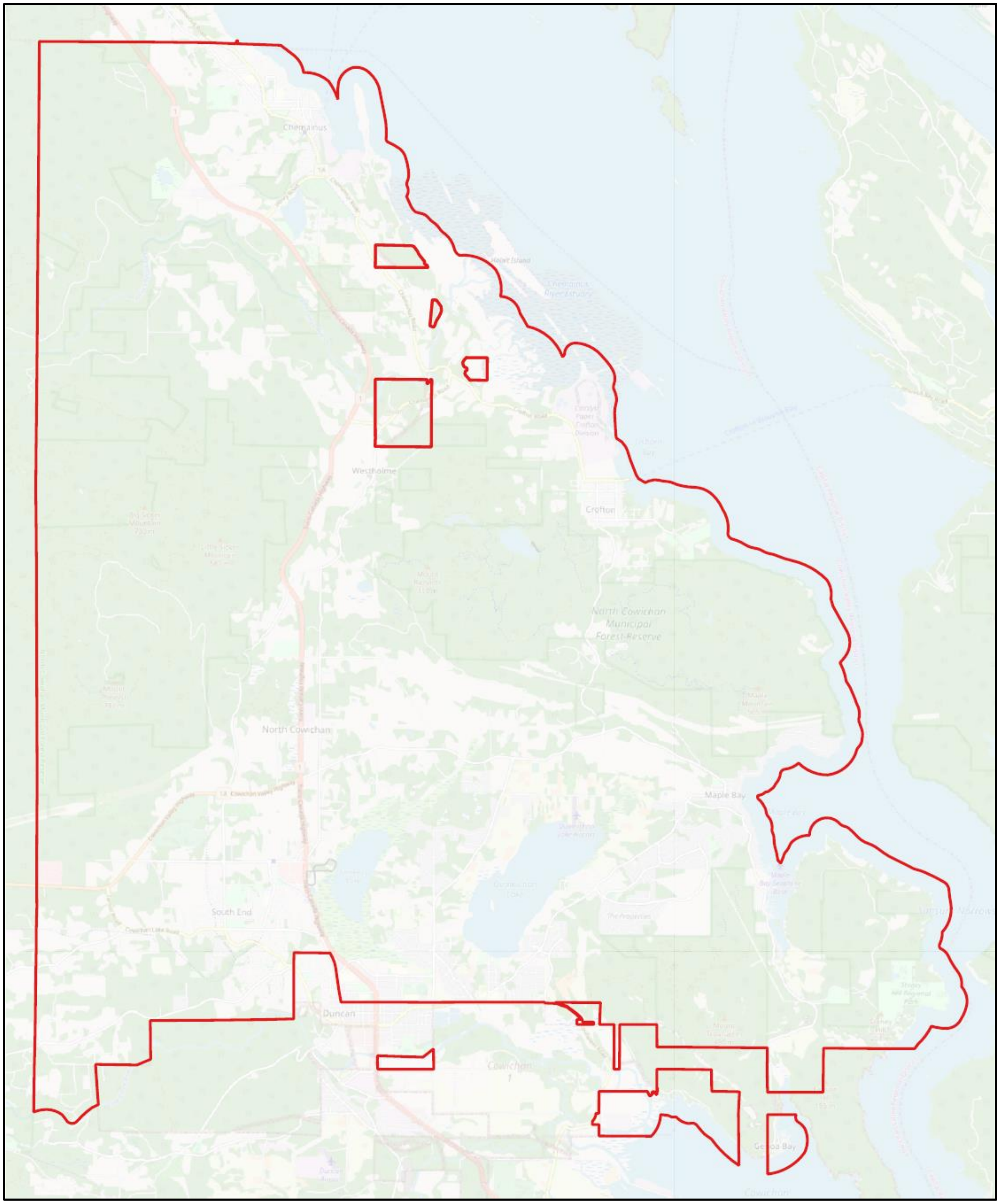

Figure 1: Geographical boundary considered for the project.

Time Frame of Assessment

The modelling time frame 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. Model calibration for the baseline year uses as much locally observed data as possible.

Energy and Emissions Structure

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

$$Energy_{city} = Energy_{transport} + Energy_{buildings} + Energy_{waste\&wastewatergen}$$

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:

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

Where:

$GHG_{transport}$ is emissions generated by the movement of goods and people.
$GHG_{energygen}$ is emissions generated by the generation of heat and electricity.
$GHG_{waste\&wastewater}$ is emissions generated by solid and liquid waste produced.
$GHG_{agriculture}$ is emissions generated by food production.
GHG_{forest} is emissions generated by forested land.
$GHG_{landconvert}$ is emissions generated by the lands converted from natural to modified conditions.

Emissions Scope

The inventory will include emissions Scopes 1 and 2, and some aspects of Scope 3 (Table 1, Figure 2). Refer to Appendix 1 for a list of included GHG emission sources by scope.

Table 1. GPC scope definitions.

Scope	Definition
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.

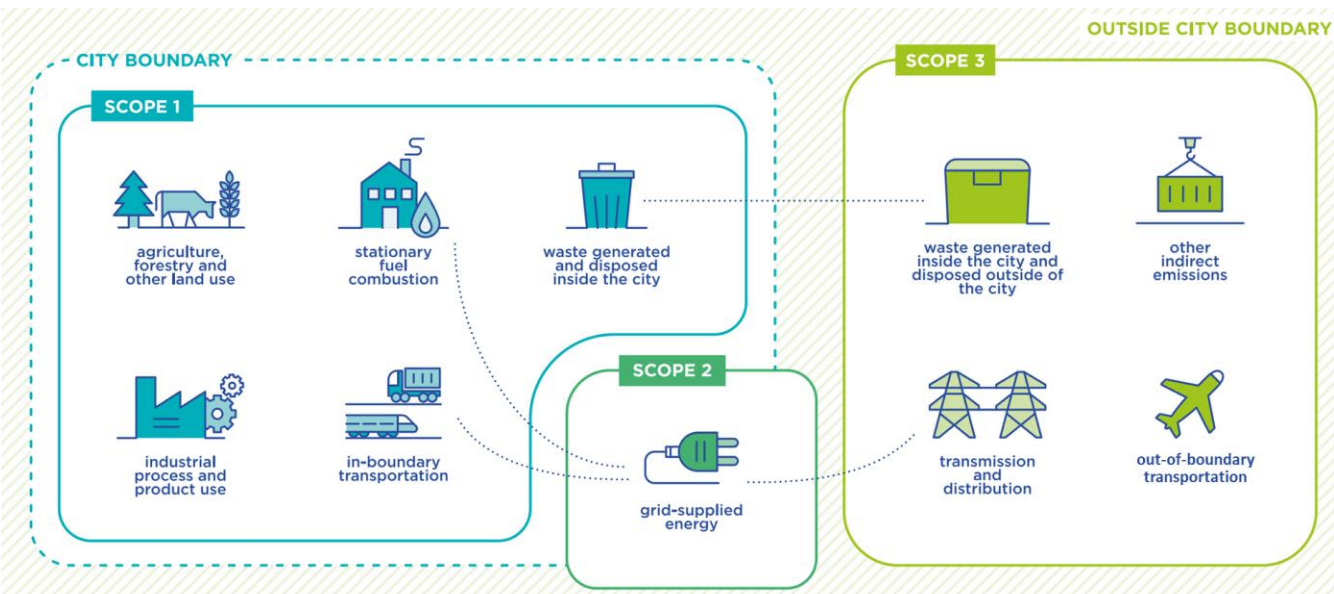

Figure 2: Emissions activities categorized by scope.

The Model

CityInSight is an energy, emissions, and finance model developed by Sustainability Solutions Group and whatIf? Technologies. The model integrates fuels, sectors, and land-uses and is partially disaggregated. It 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 values are derived from a series of connected stock and flow models, evolving based on current and future geographic and technology decisions/assumptions (e.g. EV uptake rates). The model accounts for physical flows (e.g. energy use, new vehicles by technology, VKT) 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, 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 2. CityInSight characteristics.

Characteristic	Rationale
Integrated	CityInSight models and accounts for all city-scale energy and emissions related sectors and captures 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	Built environment configuration determines walkability and cyclability, accessibility to transit, feasibility of district energy, and other aspects. CityInSight therefore includes spatial dimensions that can include as many zones (the smallest areas of geographic analysis) as deemed appropriate. The spatial components can be integrated with GIS systems, land-use projections, and transportation modelling.
GHG reporting framework	CityInSight is designed to report emissions according to the GHG Protocol for Cities (GPC) framework and principles.

Economic impacts	CityInSight incorporates a high-level 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. This allows for the generation of marginal abatement costs.

Model Structure

The major components of the model and the first level of their modelled relationships (influences) are represented by the blue arrows in Figure 3. 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 GHG emissions constraint.

The model is spatially explicit. All buildings, transportation, and land use data are tracked within the model through a GIS platform, and by varying degrees of spatial resolution. A zone type system is applied to divide the Town into smaller configurations, based on the Town's existing traffic zones (or another agreeable zone system). 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 Town's mapping systems.

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 harvesting technologies (e.g. electricity generating capacity).

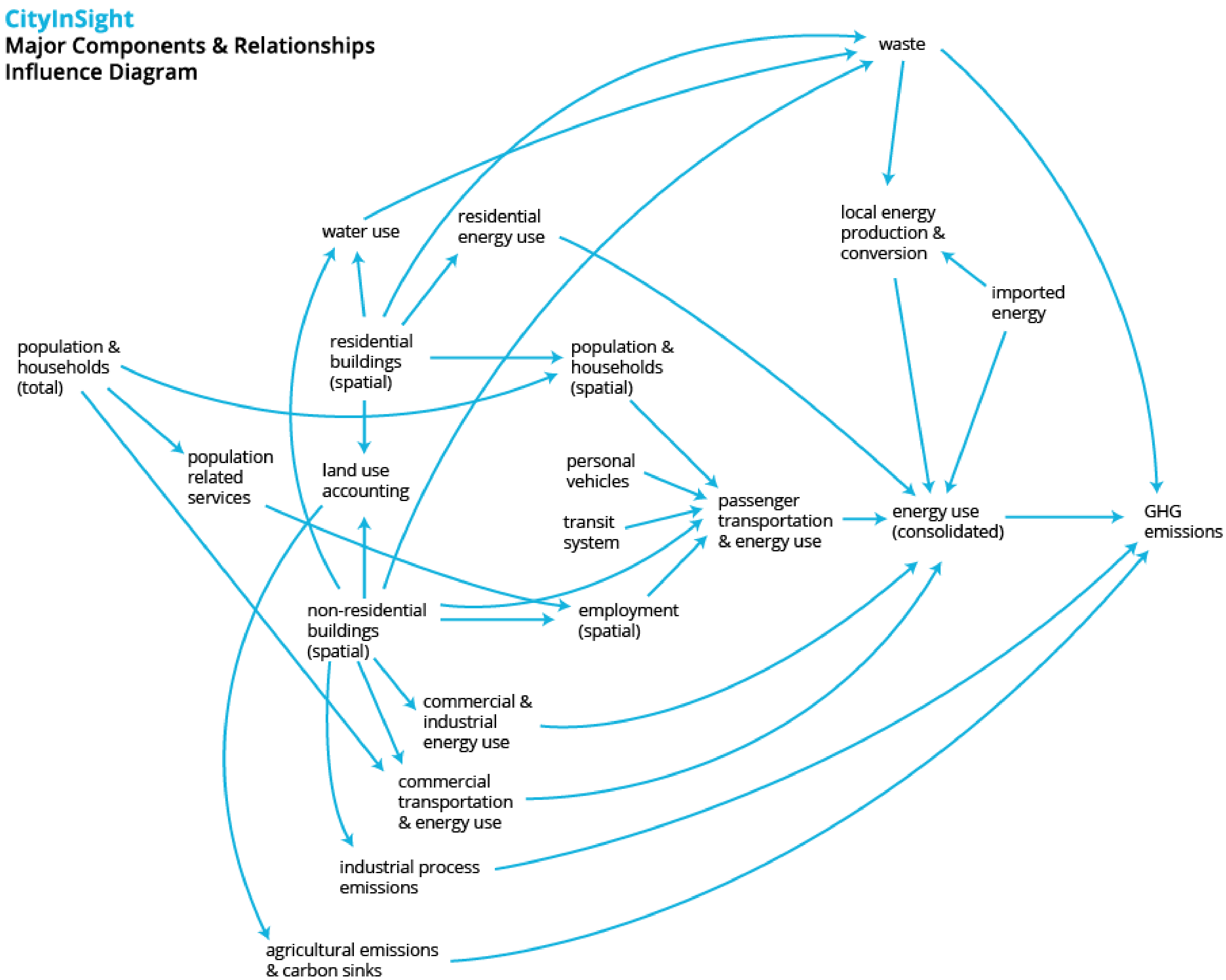

Figure 3. Representation of CityInSight's structure.

Sub-models

Population and demographics

Town-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. These numbers are calibrated against existing projections.

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 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 (obligation to use equipment/infrastructure/fuel type due to longevity of system implemented). 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. The floorspace of these archetypes can vary by location. Non-residential floorspace produces waste and demand for energy and water, and provides an anchor point for locating employment of various types.

Spatial population and employment

City-wide population is made spatial through 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 behaviour 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 different combinations of spatial drivers (population, employment, classrooms, non-residential floorspace). Trips are distributed - 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. A projection of total personal vehicles kilometres travelled (VKT) and a network distance matrix are produced following the mode share calculation. 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 the boundary) are accounted for, as well as half of the trips that terminate or originate within the municipal boundary. Figure 4 displays trip destination matrix conceptualization.

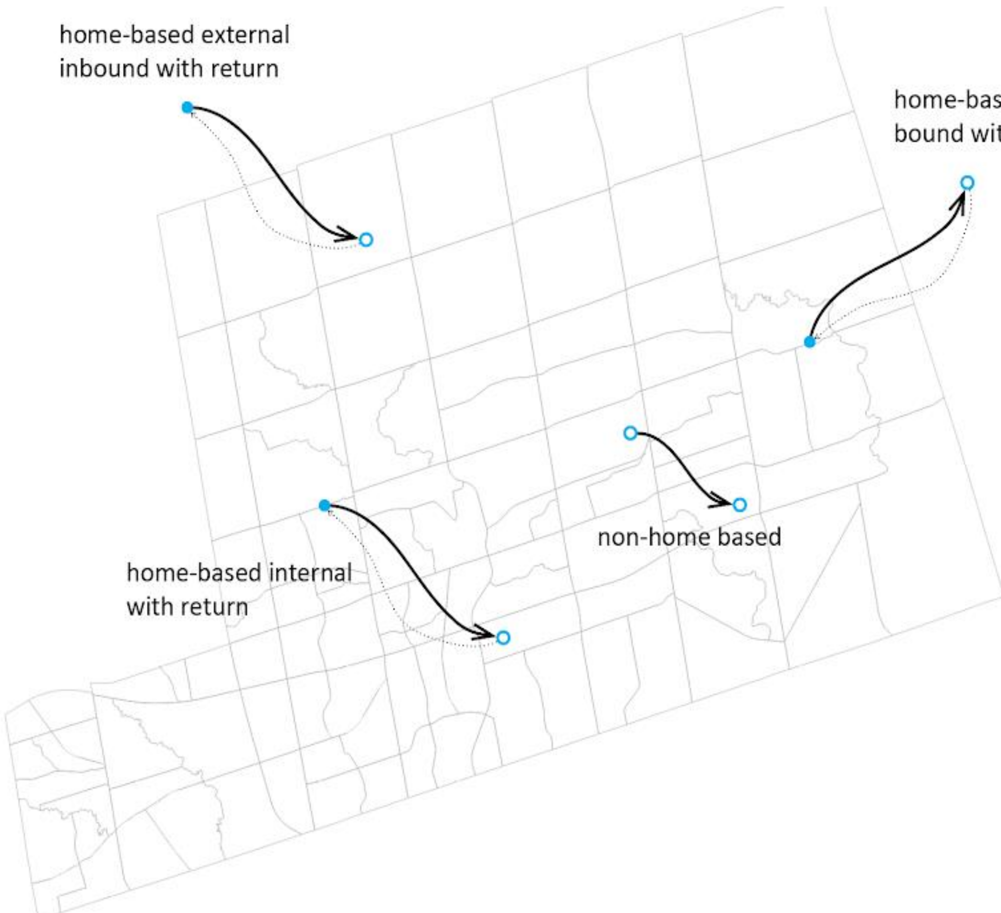

Figure 4. Conceptual diagram of trip categories.

Waste & Wastewater

Households and non-residential buildings generate solid waste and wastewater. 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 can represent areas served by district energy networks.

Finance and employment

Energy related financial flows and employment impacts are captured through an additional layer of model logic (not shown explicitly in Figure 2). 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.

Model Calibration for Local Context

Data request & collection

Local data was supplied by the municipality. Assumptions were identified to supplement any gaps in observed data. The data and assumptions were applied in modelling per the process described below.

Zone system

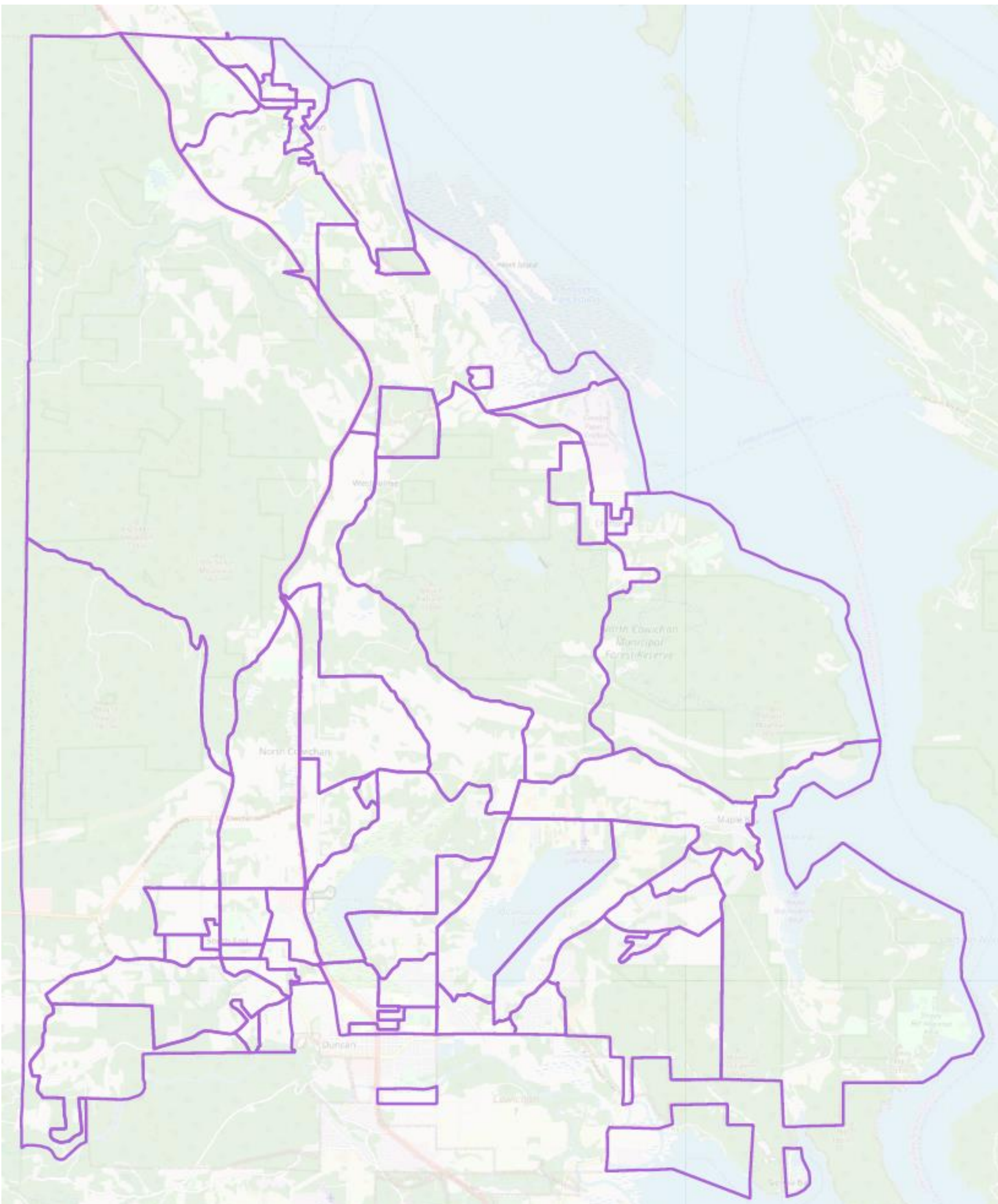

Figure 4. Zone system used in modelling.

CityInSight is spatially explicit; population, employment, residential and non-residential floorspace, are allocated and tracked spatially within the model's zone system. These elements drive stationary energy demand. The passenger transportation sub-model, which drives transportation energy demand, also operates within the same zone system.

Buildings

Buildings data, including building type, building footprint area, number of storeys, total floorspace area, number of units, and year built was sourced from provincial property assessment data. Buildings were allocated to specific zones using their spatial attributes, based on the zone system.

Buildings are classified using a detailed set of buildings archetypes (see Appendix 2). These archetypes capture footprint, height and type (e.g. single-family home, semi-attached home, etc.), enabling the creation of a "box" model of buildings, and an estimation of surface area for all buildings.

Residential buildings

The model multiplies the residential building surface area by an estimated thermal conductance (heat flow per unit surface area per degree day) and the number of degree days (heating and cooling) to derive the energy transferred out of the building during winter months and into the building during summer months. The energy transferred through the building envelope, the solar gain through the building windows, and the heat gains from equipment inside the building constitute the space conditioning load to be provided by the heat systems and the air conditioning. The initial thermal conductance estimate is a provincial average by dwelling type from the Canadian Energy System Simulator (CanESS). This initial estimate is adjusted through the calibration process as the modelled energy consumption in the residential sector is forced to track on observed residential fuel consumption in the baseline year.

Non-residential buildings

The model calculates the space conditioning load as it does for residential buildings with one distinction: the thermal conductance parameter for non-residential buildings is based on floor space area instead of surface area. CanESS provides the initial estimate of the non-residential thermal conductance by building sector.

Starting values for output energy intensities and equipment efficiencies for other residential and non-residential end uses are also provincial averages from CanESS. All parameter estimates are further adjusted during the calibration process. The calibration target for non-residential building energy use is the observed commercial and industrial fuel consumption in the baseline year.

Using assumptions for thermal envelope performance for each building type, the model calculates total energy demand for all buildings, independent of any space heating or cooling technology and fuel.

Population and employment

Federal census population and employment data was spatially allocated to residential (population) and non-residential (employment) buildings. This enables indicators to be derived from the model (such as emissions per household) and drives the BAP energy and emissions projections (buildings, transportation, waste).

Population for 2016 was spatially allocated to residential buildings using initial assumptions about persons-per-unit (PPU) by dwelling type. These initial PPUs are then adjusted so that the total population in the model (which is driven by the number of residential units by type multiplied by PPU by type) matches the total population from census/regional data.

Employment for 2016 was spatially allocated to non-residential buildings using initial assumptions for two main categories: population-related services and employment, allocated to corresponding building floorspace (e.g. teachers to school floorspace); and floorspace-driven employment (e.g. retail employees per square metre). Like population, these initial ratios are adjusted within the model so that the total employment derived by the model matches total employment from census/regional data.

Transportation

The model includes a spatially explicit passenger transportation sub-model that responds to changes in land-use, transit infrastructure, vehicle technology, travel behaviour 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 different combination of spatial drivers (population, employment, classrooms, non-residential floorspace). Trip volumes are distributed as pairs for each zone of origin and zone of destination (Figure 4). 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. Total personal VKT is produced when modelling mode shares and distances. The energy use and emissions associated with personal vehicles is calculated by assigning VKT to model of personal vehicle ownership.

Passenger transportation model was anchored with the travel demand forecasting models found in the Travel Demand Forecasting: Parameters and Techniques paper informing the spatial travel demand model and the results compared for reasonableness against indicators such as average annual VKT per vehicle. For medium-heavy duty commercial vehicle transportation, the ratio of local retail diesel fuel sales to provincial retail diesel fuel sales was applied to estimate non-retail diesel use.

The modelled stock of personal vehicles (by size, fuel type, efficiency, vintage) was informed by provincial vehicle registration obtained from Statistics Canada. The total number of personal use and corporate vehicles is proportional to the projected number of households in the BAP.

The GPC induced activity approach is used to account for emissions. All internal trips (within boundary) as well as half of the trips that terminate or originate within the municipal boundary are accounted for. This approach allows the municipality to understand its transportation impacts on its peripheries and the region.

Transit VKT and fuel consumption was modelled based on data provided by BC Transit.

Waste

Solid waste stream composition and routing data (landfill, composting, recycling) was sourced from local data sources. The base carbon content in the landfill was estimated based on historical waste production data. Total methane emissions were estimated for landfills using the first order decay model, with the methane generation constant and methane correction factor set to default, as recommended by and based on values from IPCC Guidelines for landfill emissions. Data on methane removed via recovery was provided by the landfill.

Data and Assumptions

Refer to Appendices 3 and 4 for a detailed list of data sources and assumptions used for CityInSight modelling.

Scenario Development

CityInSight supports 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. Scenarios must represent serious considerations defined by planning staff and community members. They 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.

Business-As-Planned Scenario

The Business-As-Planned (BAP) scenario estimates energy use and emissions volumes from the baseline year (2016) to the target year (2050). It assumes an absence of substantially different policy measures from those currently in place.

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 and housing projections by transport zone
    - Build out (buildings) projections by transport zone
    - Transportation modelling 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 through:
    - Analyzing current on the ground action (reviewing action plans, engagement with staff, etc.), and where possible, quantifying the action.
    - Analyzing existing policy that has potential impact and, where possible, quantifying the potential impact.

Low Carbon Scenario

CityInSight projects how energy flow and emissions profiles will change in the long term by modelling potential changes in the context (e.g. population, development patterns), projecting energy services demand intensities, and projecting the composition of energy system infrastructure.

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 CityInSight'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. CityInSight can explore a wide variety of policies, actions and strategies via these variables. 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 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 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;
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 marginal abatement cost 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;
11. Reflect prioritization in final low-carbon scenario, removing and scaling the level of ambition of actions according to the evaluation results.

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

1. **Sensitivity analysis:** 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 drawn from a statistical distribution in order to capture the uncertainty in the parameter's true value (Keirstead, Jennings, & Sivakumar, 2012).

Approach: Each input variable is modified by ±10-20% to illustrate the impact that an error of that magnitude has on the overall total.

2. **Calibration:** One way to challenge 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, calibrating the model to better replicate observed data.

Approach: Variables are calibrated in the model using two independent sources of data. E.g. 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 and 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: Modelling assumptions and inputs are presented in this document.

Appendix 1: GPC Emissions Scope Table

Blue rows = Sources required for GPC BASIC inventory
Green rows = Sources required GPC BASIC+ inventory
Red rows = Sources required for territorial total but not for BASIC/BASIC+ reporting

Exclusion Rationale Legend

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

					in tonnes				
GPC ref No.	Scope	GHG Emissions Source	Inclusion	Exclusion rationale	CO2	CH4	N2O	Total CO2e	Total Emissions
I	STATIONARY ENERGY SOURCES								
I.1	Residential buildings								
I.1.1	1	Emissions from fuel combustion within the city boundary	Yes		20,409	4,879	654	25,942	
I.1.2	2	Emissions from grid-supplied energy consumed within the city boundary	Yes		1,346	2	9	1,358	
I.1.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	Yes		45	0	0	45	
I.2	Commercial and institutional buildings/facilities								
I.2.1	1	Emissions from fuel combustion within the city boundary	Yes		17,433	30	123	17,586	
I.2.2	2	Emissions from grid-supplied energy consumed within the city boundary	Yes		423	1	3	427	
I.2.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	Yes		14	0	0	14	
I.3	Manufacturing industry and construction								
I.3.1	1	Emissions from fuel combustion within the city boundary	Yes		96,345	64	505	96,914	
I.3.2	2	Emissions from grid-supplied energy consumed within the city boundary	Yes		7,481	14	52	7,547	**Buildings**

I.3.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	Yes		249	0	2	251	**150,084**
I.4	Energy industries								
I.4.1	1	Emissions from energy used in power plant auxiliary operations within the city boundary	No	NR	0	0	0	0	
I.4.2	2	Emissions from grid-supplied energy consumed in power plant auxiliary operations within the city boundary	No	NR	0	0	0	0	**Local energy**
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	**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 city boundary	No	NR	0	0	0	0	
I.5.2	2	Emissions from grid-supplied energy consumed within the city 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								
I.6.1	1	Emissions from fuel combustion within the city boundary	No	NR	0	0	0	0	
I.6.2	2	Emissions from grid-supplied energy consumed within the city 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 city boundary	No	NR	0	0	0	0	
I.8	Fugitive emissions from oil and natural gas systems								**Fug. emissions**
I.8.1	1	Emissions from fugitive emissions within the city boundary	Yes		3	15,917	0	15,921	**15,921**

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		78,275	150	433	78,858	
II.1.2	2	Emissions from grid-supplied energy consumed within the city boundary for on-road transportation	Yes		0	0	0	0	
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		38,546	77	145	38,769	
II.2	Railways								
II.2.1	1	Emissions from fuel combustion for railway transportation occurring within the city boundary	No	NR	0	0	0	0	
II.2.2	2	Emissions from grid-supplied energy consumed within the city boundary for railways	No	NR	0	0	0	0	
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	0	0	0	0	
II.3	Water-borne navigation								
II.3.1	1	Emissions from fuel combustion for waterborne navigation occurring within the city boundary	No	N/A	0	0	0	0	
II.3.2	2	Emissions from grid-supplied energy consumed within the city boundary for waterborne navigation	No	N/A	0	0	0	0	
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	0	0	0	0	
II.4	Aviation								

II.4.1	1	Emissions from fuel combustion for aviation occurring within the city boundary	No	N/A	0	0	0	0	
II.4.2	2	Emissions from grid-supplied energy consumed within the city boundary for aviation	No	N/A	0	0	0	0	
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	0	0	0	0	
II.5	Off-road								
II.5.1	1	Emissions from fuel combustion for off-road transportation occurring within the city boundary	No	NR	23	0	3	26	**Transport**
II.5.2	2	Emissions from grid-supplied energy consumed within the city boundary for off-road transportation	No	NR	0	0	0	0	**117,653**
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		0	0	0	0	
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		0	0	0	0	
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	0	0	0	0	
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		0	511	336	846	
III.2.2	3	Emissions from solid waste generated within the city boundary but treated biologically outside of the city boundary	No	N/A	0	0	0	0	
III.2.3	1	Emissions from waste generated outside the city boundary but treated biologically within the city 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 city boundary	No	N/A	0	0	0	0	
III.3.2	3	Emissions from solid waste generated within the city boundary but treated outside of the city boundary	No	N/A	0	0	0	0	
III.3.3	1	Emissions from waste generated outside the city boundary but treated within the city boundary	No	N/A	0	0	0	0	
III.4	Wastewater treatment and discharge									
III.4.1	1	Emissions from wastewater generated and treated within the city boundary	Yes		0	557	132	689	
III.4.2	3	Emissions from wastewater generated within the city boundary but treated outside of the city boundary	No	NR	0	0	0	0	**Waste & WW**
III.4.3	1	Emissions from wastewater generated outside the city boundary	No	N/A	0	0	0	0	**1,535**
IV	INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)									
IV.1	1	Emissions from industrial processes occurring within the city boundary	No	ID	0	0	0	0	
IV.2	1	Emissions from product use occurring within the city boundary	No	ID	0	0	0	0	
V	AGRICULTURE, FORESTRY AND LAND USE (AFOLU)									
V.1	1	Emissions from livestock within the city boundary	No	NR	0	0	0	0	
V.2	1	Emissions from land within the city boundary	No	NR	0	0	0	0	
V.3	1	Emissions from aggregate sources and non-CO2 emission sources on land within the city boundary	No	NR	0	0	0	0	
VI	OTHER SCOPE 3									
VI.1	3	Other Scope 3	No	N/A	0	0	0	0	
TOTAL										**285,194**

Appendix 2: Building Types in CityInSight

Residential Building Types	Non-residential Building Types	
Single_detached_1Storey_tiny	college_university	commercial_retail
Single_detached_2Storey_tiny	school	commercial
Single_detached_3Storey_tiny	retirement_or_nursing_home	commercial_residential
Single_detached_1Storey_small	special_care_home	retail_residential
Single_detached_2Storey_small	hospital	warehouse_commercial
Single_detached_3Storey_small	municipal_building	warehouse
Single_detached_1Storey_medium	fire_station	religious_institution
Single_detached_2Storey_medium	penal_institution	surface_infrastructure
Single_detached_3Storey_medium	police_station	energy_utility
Single_detached_1Storey_large	military_base_or_camp	water_pumping_or_treatment_station
Single_detached_2Storey_large	transit_terminal_or_station	industrial_generic
Single_detached_3Storey_large	airport	food_processing_plants
Double_detached_1Storey_small	parking	textile_manufacturing_plants
Double_detached_2Storey_small	hotel_motel_inn	furniture_manufacturing_plants
Double_detached_3Storey_small	greenhouse	refineries_all_types
Double_detached_1Storey_large	greenspace	chemical_manufacturing_plants
Double_detached_2Storey_large	recreation	printing_and_publishing_plants
Double_detached_3Storey_large	community_centre	fabricated_metal_product_plants
Row_house_1Storey_small	golf_course	manufacturing_plants_miscellaneous_
Row_house_2Storey_small	museums_art_gallery	processing_plants
Row_house_3Storey_small	retail	asphalt_manufacturing_plants
Row_house_1Storey_large	vehicle_and_heavy_equiptment_service	concrete_manufacturing_plants
Row_house_2Storey_large	warehouse_retail	industrial_farm
Row_house_3Storey_large	restaurant	barn
Apartment_1To4Storey_small		
Apartment_1To4Storey_large		
Apartment_5To14Storey_small		
Apartment_5To14Storey_large		
Apartment_15To24Storey_small		
Apartment_15To24Storey_large		
Apartment_25AndUpStorey_small		
Apartment_25AndUpStorey_large		
inMultiUseBldg		

Appendix 3: Emissions Factors Used

Category	Value	Comment
Natural gas	49 kg CO2e/GJ	Environment and Climate Change Canada. National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada. Part 2. Tables A6-1 and A6-2, Emission Factors for Natural Gas.
Electricity	2016 CO2: 10.7 g/kWh CH4: 0.000403 g/kWh N2O: 0.0000175 g/kWh 2050 CO2: 10.7 g/kWh CH4: 0.000952 g/kWh N2O: 0.000243 g/kWh	Projected using CanESS modeling using data from National Energy Board. (2016). Canada's Energy Future 2016. Government of Canada. Retrieved from https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2016pt/nrgyftrs_rprt-2016-eng.pdf
Gasoline	g/L CO2: 2316 CH4: 0.32 N2O: 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 CO2: 2690 CH4: 0.07 N2O: 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 CO2: 2560 CH4: 0.026 N2O: 0.006 Commercial g/L CO2: 2753 CH4: 0.026 N2O: 0.031 Industrial g/L CO2: 2753 CH4: 0.006 N2O: 0.031	Environment and Climate Change Canada. National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada. Part 2. Table A6–4 Emission Factors for Refined Petroleum Products
Wood	Residential kg/GJ CO2: 299.8 CH4: 0.72 N2O: 0.007	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

	Commercial kg/GJ CO2: 299.8 CH4: 0.72 N2O: 0.007 Industrial kg/GJ CO2: 466.8 CH4: 0.0052 N2O: 0.0036	
Propane	Transport g/L CO2: 1515 CH4: 0.64 N2O: 0.03 Residential g/L CO2: 1515 CH4 : 0.027 N2O: 0.108 All other sectors g/L CO2: 1515 CH4: 0.024 N2O: 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
Waste	Landfill emissions are calculated from first order decay of degradable organic carbon deposited in landfill. Derived emission factor in 2016 = 0.015 kg CH4/tonne solid waste (assuming 70% recovery of landfill methane); 0.050 kg CH4/tonne solid waste not accounting for recovery.	Landfill emissions: IPCC Guidelines Vol 5. Ch 3, Equation 3.1
Wastewater	CH4: 0.48 kg CH4/kg BOD N2O: 3.2 g / (person * year) from advanced treatment 0.005 g /g N from wastewater discharge	CH4 wastewater: IPCC Guidelines Vol 5. Ch 6, Tables 6.2 and 6.3; MCF value for anaerobic digester N2O from advanced treatment: IPCC Guidelines Vol 5. Ch 6, Box 6.1 N2O from wastewater discharge: IPCC Guidelines Vol 5. Ch 6, Section 6.3.1.2

Greenhouse gases	Carbon dioxide (CO2), methane (CH4) and nitrous oxide (N20) are included. Global Warming Potential CO2 = 1 CH4 = 34 N2O = 298	Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF6), and nitrogen trifluoride (NF3) are not included.

Appendix 4: Data and Assumptions

Category	Assumption	Source	Comments/Notes
DEMOGRAPHICS			
Population & employment			
Population	29,676 (2016) to 38,612(2050); City projection to 2050.	Rennie intelligence report	
Employment	30,659 (2016) to 40,237 (2050); City projection to 2050.		
BUILDINGS			
New buildings growth			
Building growth projections	Single Detached _____ Double _____ Row _____ Apartment _____ Commercial _____ Industrial _____ Institutional _____	CityInSight Model projection	No current projections for North Cowichan. New residential dwelling units is based on population growth and current building mix. New non-residential floor space is based on additional jobs. Known planned developments will be taken into account.
New buildings energy performance			
Residential	New construction xx% more efficient every 5 years starting in 2020.	Use Step Code as a guideline now - 2021 no change 2022-2026 20% more efficient 2027-2031 40% more efficient 2032-2050 60% more efficient	
Multi-residential			
Commercial & Institutional			
Industrial			
Existing buildings energy performance			
Residential	Existing building stock unchanged; efficiency held constant from 2016-2050.		
Multi-residential			
Commercial & Institutional			
Industrial			
End use			
Space heating	Fuel shares for end use unchanged; held from 2016-2050.	CityInSight Modelling	
Water heating			

	Space cooling			
Projected climate impacts				
	Heating & cooling degree days	Heating Degree days are expected to decrease, and cooling degree days will increase	Source: https://www.pacificclimate.org/data/statistically-downscaled-climate-scenarios Climate Change Impacts on Energy Demand. Adaptation Canada (2016) https://adaptationcanada2016.ca/wp-content/uploads/2016/04/W4A-Wilson.pdf	
ENERGY GENERATION				
Low or zero carbon energy generation (community scale)				
	Solar PV	2016 solar capacity is held constant		
	Ground mount solar	No ground mount solar installation		
	District Energy Generation	DE held constant to 2050		
	Wind	No wind turbine installations		
TRANSPORT				
Transit				
	Expanded transit	No expansion expected.		
	Electrify transit system	No electrification expected.		
Active				
	Cycling & walking infrastructure	Modal Split expected to stay the same to 2050		
Private/personal use				
	Electrify municipal fleet	No further electrification expected.		
	Electrify personal vehicles	8% market share by 2030 trending up towards 2050	Canada's Electric Vehicle Policy Report Card 2016. Axsen, Goldberg, Melton (Simon Fraser University), Electric Mobility Canada	
	Electrify commercial vehicles	No major change expected		No Data at this time for trends

	Vehicle kilometers travelled	VKT is expected to increase towards 2050	CityInSight Model Assumptions based on population and job growth within the City	VKT projections are driven by buildings projections. The number and location of dwellings and non-residential buildings over time in the BAU 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	Vehicle fuel consumption rates reflect the implementation of the U.S. Corporate Average Fuel Economy (CAFE) Fuel Standard for Light-Duty Vehicles, and Phase 1 and Phase 2 of EPA HDV Fuel Standards for Medium- and Heavy-Duty Vehicles. Canada typically follows these standards as well.	EPA. (2012). EPA and NHTSA set standards to reduce greenhouse gases and improve fuel economy for model years 2017-2025 cars and light trucks. Retrieved from https://www3.epa.gov/otaq/climate/documents/420f12050.pdf http://www.nhtsa.gov/fuel-economy	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 BAU.
WASTE				
	Waste generation	Existing per capita waste generation rates unchanged.		Waste generation per capita held constant form 2016-2050.
	Waste diversion	Existing waste diversion rates unchanged.		Waste diversion rates held constant form 2016-2050.

	Waste treatment	Existing waste treatment processes unchanged. Under high growth scenarios, several wastewater facilities will need to be upgraded		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. (2016). Canada's Energy Future 2016. Government of Canada. Retrieved from https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2016pt/nrgyftrs_rprt-2016-eng.pdf Government of Ontario. (2016). Fuels Technical Report. https://www.ontario.ca/document/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.
	Carbon tax	2020: $40/tonne 2021: $50/tonne 2022-2029: +$15/ tonne per year 2030 onward: $170/tonne	BC Government https://www2.gov.bc.ca/gov/content/environment/climate-change/planning-and-action/carbon-tax	