Assessing Municipal Climate Policies in British Columbia

by

Anusha Baji

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Name:	**Anusha Baji**
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Examining Committee:	**Chair:** Kaitlin Boyd, Master of Resource Management Candidate

Mark Jaccard
Senior Supervisor
Professor

Michael Wolinetz
Supervisor
Partner, Navius Research Inc.

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Abstract

This research project helped develop and experimentally apply a climate policy assessment tool designed to assist municipal governments in British Columbia with community energy and emissions planning. The Regional District of Nanaimo was chosen as a case study to assess the likely impacts of municipal climate policies under two scenarios: (1) a politically feasible scenario in which policies were applied at low to moderate settings; and (2) an incremental additions scenario in which policies were applied at increasingly stringent policy settings. Results indicate that the Regional District of Nanaimo can achieve its greatest emissions reductions through land-use densification policies, followed by policies related to the application of a vehicle operating charge. Despite these areas of influence, the extent of emissions reductions possible even under extreme policy settings suggests that municipalities in British Columbia may be constrained in their ability to achieve deep regional emissions reductions in the absence of effective climate policies at the provincial and national levels.

Keywords: climate change policy; simulation modeling; scenario analysis; municipal governments; british columbia

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Coast Salish Peoples on whose ancestral, traditional, and unceded territory I live and work.

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List of Acronyms

BAU	Business-as-Usual
BC	British Columbia
CO_2e	Carbon dioxide equivalent
DCC	Development Cost Charge
DPA	Development Permit Area
E^2	Energy and Emissions Modeling Tool
GGRTA	Greenhouse Gas Reductions Targets Act
GHG	Greenhouse gas
LGA	Local Government Act
OCP	Official Community Plan
POL-EX	Extreme Policy Scenario
POL-MOD	Moderate Policy Scenario
RGS	Regional Growth Strategy

1. Introduction

Climate scientists warn that an increase of two degrees Celsius in global temperature over pre-industrial times could trigger positive feedback loops within the climate system, and significantly increase the social, economic, and environmental risks associated with climate change. In the absence of effective greenhouse gas (GHG) emissions abatement policies, the two-degree threshold could be breached well before the end of this century (Intergovernmental Panel on Climate Change [IPCC], 2013).

But what constitutes an effective GHG emissions abatement policy? Policy effectiveness depends on the interplay between multiple factors, including economic efficiency, political and administrative feasibility, and likely environmental impacts (Jaccard, 2005; Goulder and Parry, 2008), but for the purposes of this project my initial focus was on policy *scale.* The scale at which a policy is implemented has a bearing on its likely effectiveness because design and implementation barriers exist to different extents depending on whether the policy is international, national, or regional in scope. In the case of GHG emissions abatement policies, despite a political emphasis on *globally* negotiated GHG emissions abatement agreements, local climate protection initiatives have been pursued for decades and may offer certain advantages to realizing GHG emissions reductions at the present time. For example, local GHG mitigation options typically offer greater incentives for undertaking climate action and can be enforced more easily than globally negotiated climate agreements (Kousky and Schneider, 2003). Levi (2009) suggests that, at present, the "core of the global effort to cut emissions will not come from a single global treaty; it will have to be built from the bottom-up."

My research project explores the efficacy of "bottom-up" climate policies at the municipal level, with a specific focus on the Regional District of Nanaimo (Nanaimo) in

British Columbia (BC), Canada. This region was selected on the basis of recent empowering provincial and municipal climate legislation in BC, recognition of Nanaimo's previous participation in climate protection initiatives, and the availability of high-resolution Nanaimo community data. Assuming this rationale has led me to select a case study area that has a local government committed to implementing effective climate protection initiatives, its decision-makers would still likely benefit from support in "interpreting complex and uncertain climate projections" (British Columbia Ministry of Environment, 2010).

The overarching goal of my research project is to help develop and experimentally apply a policy assessment tool to guide Nanaimo decision-makers in their pursuit of achieving the region's stated GHG emissions reduction targets[1]. The tool developed and used in this project – the CIMS-Community energy and emissions simulation model – uses technology, behavioural, and local data inputs to simulate energy consumption and GHG emissions within a region in response to climate policies in the residential, commercial, transportation, and solid waste sectors. My principal research goals include:

1. Contributing to the development of the CIMS-Community model. Associated research objectives include sector building, data population, and testing of the CIMS-Community model prototype.

2. Demonstrating the utility of CIMS-Community as a policy assessment tool for local governments in British Columbia. Associated research objectives include: (a) simulating a plausible business-as-usual (BAU) forecast of the energy and emissions profile for Nanaimo; (b) simulating two policy scenarios that may be of interest to Nanaimo decision-makers, namely a politically feasible policy package and a policy package that most closely approaches Nanaimo's stated emissions reduction targets; and (c) compiling a list of

[1] Nanaimo's stated targets are 33% below 2007 levels by 2020 and 80% below 2007 levels by 2050 (Regional District of Nanaimo, 2013).

recommendations for Nanaimo decision-makers based on my modeling results.

The remainder of this report is structured as follows: Chapter 2 provides background on the role and scope of municipal climate policy in BC and the policy assessment tools available to municipal decision-makers; Chapter 3 describes methodology related to CIMS-Community model development, Nanaimo BAU forecast development, and policy selection and simulation; Chapter 4 presents and discusses simulation results in the context of my research objectives; and Chapter 5 concludes with a summary of my project and recommendations for future research.

2. Background

Two primary areas of research inform my project. The first is the role municipal climate policy can play in realizing GHG emissions reductions. More specifically, I focus on the legislative authority held by local governments in British Columbia, and the mechanisms through which local governments can influence regional GHG emissions. The second relates to the evaluation of municipal climate policies using community energy and emissions models. I describe two popular modeling tools currently available to municipal decision-makers in BC, and compare them to the CIMS-Community model used in this project.

2.1. Municipal Climate Policy in British Columbia

Major GHG mitigation commitments have traditionally been formulated at large international fora such as the United Nations' Conferences of the Parties. While it is true that global problems can benefit from global solutions – the successful Montreal Protocol to protect the ozone layer is a good example of this tenet – the international arena has thus far proved to be ill suited to effective climate action. This may be partly because, as Helm (2008) suggests, many of the conditions necessary for agreement, compliance, and enforcement are largely absent at the international level. For example, international agreement efforts can be hampered by individual nations that are more committed to pursuing their own national interests, such as developing nations adopting an equity-driven stance of common-but-differentiated responsibilities with respect to setting national GHG emissions reduction targets.

In addition to agreement, compliance, and enforcement challenges that are heightened at the international level, climate solutions at all levels are hampered by the fact that the atmosphere is considered a global common pool resource. As such, it creates incentives for entities (nations, municipalities, firms, individuals) to avoid paying the costs of climate change and "free-ride" on the mitigation efforts of others (Ward, 2006). Nonetheless, local governments in Canada have voluntarily participated in numerous climate protection initiatives over the last three decades. The following list highlights some of these initiatives in chronological order.

- *Our Changing Atmosphere Conference, Toronto, Canada (1988):* Scientists and policy makers from around the world gathered to discuss the implications of atmospheric changes to global security. Toronto became the first local government to commit to a quantitative GHG reduction target (20% below 1988 levels by 2005) at this conference.
- *World Conference of Local Governments for a Sustainable Future, New York, USA (1990):* The International Council for Local Environmental Initiatives (ICLEI) was established at this conference, which was attended by over 200 local governments from 43 countries.
- *Urban CO_2 Reduction Project (1991):* 14 cities from Europe and North America participated in this project. Each city committed to developing a local GHG emissions inventory and local action plans to achieve their stated GHG emissions reduction targets.
- The "20% Club" (1994-1996): Launched by the Federation of Canadian Municipalities, this initiative aimed to promote municipal government action. Each local government member committed to reducing their corporate GHG emissions to 20% below 1994 levels.
- *Local Governments Endorse Kyoto (2003)*: 290 local governments in Canada aligned themselves the recommended Kyoto GHG emissions reduction target of 6% below baseline emissions within 10 years (Federation of Canadian Municipalities, 2015).

Amongst the reasons that have been posited for why local governments may act to reduce emissions is a belief that: (1) GHG emissions abatement activities may have net positive economic benefits at the local level; (2) local benefits – such as improved air quality – that can be captured by GHG emissions reductions exceed the larger scale climate benefits that may be shared; and (3) municipalities may realize non-economic benefits, such as the political goodwill of their constituents, if they are seen to champion environmental initiatives (Kousky and Schneider, 2003). Moreover, since none of the commitments made at these initiatives was legally binding, there was nothing stopping a local government from garnering the goodwill of their constituents by participating in these initiatives only to later renege on their commitments at the first sign of public censure. One might even suggest that this set-up has benefited constituents as much as their political leaders. Canadian polls consistently show public support for environmental protection initiatives, provided they do not contain costs at an individual level (Environics Institute, 2014). This makes individual citizens complicit to some extent with politicians who set targets without implementing effective policies to achieve those targets.

Every choice of technology, building, and urban form presents a host of trade-offs that will determine its ultimate adoption, and a reluctance by citizens to accept personal economic costs lowers the political feasibility of truly effective compulsory climate policies like regulations and carbon pricing. For example, the convenience that comes from owning a personal vehicle may lead individuals to choose personal automobile travel over public transit options as their preferred mode of travel irrespective of their support for, or existence of, policies that incentivize transit. Individuals may also choose technologies that are not environmentally friendly because they are perceived to carry a lower financial risk than newer technologies that are less GHG intensive (Jaccard, 2005).

Even if local governments and their constituents were prepared to accept the financial costs associated with effective climate policies, local governments are constrained in terms of their legislative and policy authority when it comes to implementing effective GHG emissions abatement actions. For example, local governments do not have the authority to implement some of the compulsory policies that make it more costly for firms and households to keep emitting GHGs: they cannot institute a carbon tax or implement an economy-wide cap-and-trade agreement; they cannot regulate technologies or specify fuel economy standards; and in many cases, they cannot even set their own building code. Local governments also typically face more severe organizational, budgetary, and human resource constraints than higher levels of government (Meeting the Climate Challenge [MC^3], 2011).

Despite these challenges, local governments may be able to contribute to GHG mitigation. This is especially so in cases where well-designed GHG emissions reduction policies have the potential to advance a community's other social, economic, and environmental policies (BC Climate Action Toolkit, 2015). Potential co-benefits that have been identified by Hyslop (2006) and the BC Climate Action Toolkit (2015) in the areas of health, environment, and the local economy include:

- Air quality improvements due to reductions in air pollutants and smog precursors such as nitrous oxides, volatile organic compounds, carbon monoxide, and particulate matter due to reduced energy use and energy substitution;
- Health and quality of life benefits associated with a transition to more sustainable transportation choices, including more active lifestyles and lower exposure to air pollutants associated with vehicular travel;
- Protection of fragile ecosystems through higher density development that maintains more land area for green space rather than urban development;
- Direct cost savings due to lower electricity and fuel use;
- Local job creation and other economic stimuli through growth of new industries such as the energy conservation industry and renewable energy technologies; and
- Lower risks to infrastructure from extreme weather events.

The following section explores specific legislative and policy contexts that have a bearing on the ability of BC local governments to influence GHG emissions within their region.

Current Legislative and Policy Context for Climate Action in BC

Bill 44 and the *BC Carbon Tax* are two important pieces of provincial legislation that promote climate protection.

- *Bill 44: Greenhouse Gas Reduction Targets Act (GGRTA):* The GGRTA came into effect in 2008 and legislated targets for reductions in aggregate provincial GHG emissions. The targets are based on the 2007 annual GHG emissions level of 66 million tonnes of CO_2e, and the GGRTA stipulates a 33% and 80% reduction in annual GHG emissions by 2020 and 2050 respectively from the 66 Mt CO_2e reference point. The GGRTA also requires public sector organizations, including provincial institutions, to be carbon neutral in their operations from 2010 by minimizing their GHG emissions and offsetting any remaining emissions.

- *BC Carbon Tax*: British Columbia was the first Canadian province to tax individuals and businesses on GHG emissions associated with fossil fuel combustion. The tax is revenue neutral in aggregate, but is not revenue neutral at the level of individual businesses or citizens and therefore still provides an incentive for GHG emissions reduction.

At the municipal level the most directly applicable piece of legislation is *Bill 27*, also known as the *Local Government (Green Communities) Statutes Amendment Act*. *Bill 27* stipulates the need for BC local governments to include quantitative GHG emissions reduction targets in their Official Community Plans and Regional Growth Strategies. The new legislative amendments to *Bill 27* provide local governments with additional powers to require, reward, and enforce different elements of sustainable development. Broadly speaking, these new powers focus on: (a) the ability to use reductions or exemptions in development cost charges to incentivize lower emissions buildings; (b) expanded authority in terms of designating development permit areas for lower emissions developments; and (c) greater flexibility related to off-street parking funds (BC Ministry of Community, Sport and Cultural Development, n.d.). Local governments can use these legislative powers to implement GHG emissions abatement policies such as those described below.

Adopting a Systemic Demand-Side Management Approach

Most energy-related GHG emissions in communities come from natural gas (building heating) and petroleum fuels (gasoline/diesel). Community GHG emissions can be lowered by improving the energy efficiency of technologies that use these fuels, or switching to fuels that emit lower GHG emissions per unit consumed. It is useful to consider the major determinants of energy use that are within the legislative and policy reach of municipal governments in BC, namely: (1) the quality of the built environment; and (2) urban form, density, and associated transportation patterns.

The Built Environment

The built environment comprises the building stock within a municipality, including residential, commercial, administrative and industrial buildings. The quality of this building stock (e.g. in terms of the insulation efficiency of building envelopes) affects the energy intensity (energy/m^2) associated with heating and cooling. For example, ultra-low energy buildings such as those that meet Passivhaus standards in Germany or MINERGIE-P standards in Switzerland use no more than 15 kWh/m^2 for floorspace heating annually, while low-energy houses can use up to 50 kWh/m^2 for the same purpose. This can increase to as much as 400 kWh/m^2 in houses with poor thermal insulation in mid-European latitudes (Global Energy Assessment, 2012). In general, large buildings are more energy intensive than small buildings. In the context of BC this can be seen in the differences in energy intensity by building type, where the 2012 energy-intensity was: single detached homes - 169 kWh/m^2; single-attached homes - 158 kWh/m^2; apartments - 144 kWh/m^2; and mobile homes - 225 kWh/m^2. The average 2012 energy intensity for a residential building in BC, given the split between housing types, was 167 kWh/m^2 (Natural Resources Canada, n.d.).

In BC, the provincial government has the legislative authority to improve the energy intensity of building stock over time by specifying higher energy efficiency requirements for building technologies within the BC Building Code. At the municipal level, *Bill 27* provides local governments with the following options to influence the built environment:

- Local governments can, under sections 919.1 and 920(10.1) of the *Local Government Act (LGA)*, attach GHG reduction conditions to a designated development permit area (DPA). For example, the guidelines could include a performance-based requirement that at least 10% of the development's energy needs be met through onsite renewable resources.

- Local governments can, under Section 933(4.01) of the *LGA*, pass a bylaw to designate eligibility criteria for low impact developments. These criteria can include building standards that exceed the energy efficiency requirement specified by the BC Building Code. Local governments can then waive or lower the development cost charges (DCC) for developments that meet the eligibility criteria defined in the bylaw. It should be noted that local governments have expressed some reservations about using DCC exemptions because this results in a loss of municipal revenue. Although this revenue could be recovered by passing another bylaw requiring DCC-exempt properties to pay an equivalent user-fee, this is likely to be politically unpopular because it passes the burden from the developer to future residents (West Coast Environmental Law, 2009).

Urban Form, Density, and Transportation Patterns

In addition to the energy efficiency standards of individual buildings, the building type (e.g. single detached home, apartment), building mix (e.g. residential, institutional, commercial), proximity to other building types, and building density each have a bearing on overall energy use within the region. These components of urban form directly impact the relative distances associated with urban activities, and therefore also affect transportation patterns within the area. Some of the literature that highlights the relationships between these determinants of energy use includes:

- A modeling study done by Newton *et al*. (2000), which compared the energy performance of detached homes to apartments across different climatic zones in Australia. The researchers found that while both building types had similar thermal intensities, people living in apartments used 10% to 30% less energy overall due to the smaller living area they occupied.

- Newman and Kenworthy (1989) examined the inverse relationship between urban density and personal automobile use and identified a large potential for lowering transportation energy by shifting to a high-density urban form. Another study by VandeWeghe and Kennedy (2007) analyzed the impact of urban form on residential GHG emissions in Toronto, and the researchers found automobile emissions to be higher for areas outside the transit intensive core of the Toronto Census Metropolitan Area. The VandeWeghe and Kennedy (2007) study is consistent with the findings of other researchers that suggest that an urban density above 50 people/ha is needed to support the economic feasibility of a public transit system (Global Energy Assessment, 2012).

Even prior to the new amendments to *Bill* 27, local governments had considerable authority to influence urban form. For example, they were able to use land-use zoning, except where a higher level of government had jurisdiction, as in agricultural land reserves, or owned property, as with the Canadian Navy. The new amendments to *Bill 27* provide local governments with some additional policy options that they can now leverage to reduce energy use related to urban density, form, and transportation. For example:

- Local governments can manipulate tax levels to incentivize high-density, mixed-use, brownfield developments. For example, they could design

Official Community Plans (OCP) and Regional Growth Strategies (RGS) that designate a differential tax structure for property taxes within infill areas. All zoning bylaws, bylaw variances, and subdivision approvals would need to be consistent with OCP and RGS designations. Local governments can also offer a revitalization tax exemption to developments that meet these criteria under Section 226 of the *Community Charter*.

- Local governments can, under Section 904 of the *LGA,* provide density bonuses – such as increasing the allowable floorspace – to developments that meet desired criteria such as those specified above.

- Local governments can waive or lower development cost charges for developments that meet desired criteria under Section 933 of the *LGA*.

The literature review in this section summarizes some of the legislative and policy authority that local governments have in reducing GHG emissions within their regions. The major determinants of energy use under their influence include the quality of the built environment, land-use density (and by extension transportation patterns) and urban form, and local energy systems. The following section explores three policy assessment tools that can help guide municipal decision-makers in selecting between competing GHG emissions reduction options.

2.2. Policy Assessment Tools

Local governments are increasingly relying on the use of modeling tools to guide them in setting achievable GHG emissions reductions targets and assessing the likely impacts of competing climate policies (Community Energy Association, 2010). Two community energy and emissions models widely used by local governments in BC are

GHGProof and the *Energy and Emissions (E^2) Tool*. Both models are described briefly below, and then compared to the CIMS-Community model used in this project. The section concludes with my rationale for selecting the CIMS-Community model as the policy assessment tool to be used in this research project.

Each of the three models described in this section are able to forecast the evolution of a particular energy system over time in the absence of any policy (BAU) and in the presence of a specific policy (such as a fuel economy standard). The ability of the model to accurately forecast the evolution of an energy system depends on attributes such as technological explicitness, behavioural realism, and macroeconomic feedbacks (Jaccard, 2005). Technological explicitness refers to the extent to which individual energy intensive technologies in an energy system are represented in the model. Behavioural realism is a measure of how well a model represents the actual choices of individuals and firms while making investments in energy-utilizing technologies or infrastructure. Macroeconomic feedbacks measure the sensitivity of the model to representing a change in costs and output in one area of the economy in response to climate policies. *GHGProof*, *E^2 Tool*, and CIMS-Community differ in their technological explicitness, behavioural realism, and macroeconomic feedbacks as described below.

GHGProof

This open-source model uses a combination of Microsoft Excel, and Geographical Information System (GIS) analysis[2] when available, to enable municipal decision-makers to assess the impact of land-use changes and associated transportation patterns on the region's GHG emissions under different policy scenarios. The methodology used when the model "runs", that is solves the policy to generate outputs, is illustrated by examining the transportation sector in detail. Other sectors covered in the model are buildings, waste, and biomass. As of 2015, 18 local governments in BC have used this model.

[2] ESRI ArcMap with Network Analyst extension or equivalent software is necessary to support the highest level of *GHGProof* analysis (Sustainability Solutions Group, n.d.b).

The BAU reference forecast is generated using primary data obtained from free-to-use sources such as Statistics Canada or BCStats. Primary data include: total households; total population road length; dwelling mix (detached, attached, apartments); solid waste; agricultural data; and forest cover. If no GIS data are available, the numerical data and paper mapping or hand blocking techniques of land use changes under different policy scenarios can be used to generate estimates for the Excel inputs. If GIS data are available, the model derives secondary data through GIS analysis of these primary inputs. Secondary data include: trip length; public transit access; community energy estimates; and liquid waste.

The model simulation compares the spatial location and mix of dwelling units under BAU and policy scenarios. For example, a policy scenario that incentivizes new developments near the town centre would shift the location and composition of dwelling units with respect to BAU. Numerical and graphical results are automatically generated in real time based on the model inputs, and include aggregate and per capita GHG emissions by sector. The user is also presented with annualized GHG savings in relation to the BAU forecast (Sustainability Solutions Group, n.d.a).

But how specifically do inputs and user-defined assumptions lead to model outputs? In other words, what algorithms is the model using to generate the results that are presented to the user? For the transportation sector, in general terms, *GHGProof* uses user-defined or literature informed assumptions about distance to transit, work, schools, and services to translate spatially explicit assumptions about development into estimates of VKT and mode share. From here, the model uses additional assumptions about fuel efficiency and emissions factors under different densification scenarios to generate energy and emissions outputs for the user.

More specifically, the model requires the user to specify the spatial location of new dwellings whenever a new policy scenario is being designed. Different GIS layers are loaded and analyzed under the policy scenario. One layer, called the “Destinations Layer” comprises the spatial position of primary destinations within the community, including major employers, recreational facilities, commerce locations, and public transportation sites[3]. Data for these destinations are primarily obtained through land use and zoning records and BC Transit. The GIS *Network Analyst* program determines the average trip distance to each destination by calculating individual distances from each dwelling to each destination, making an assumption about the relative frequencies to each destination based on travel surveys and trip diaries, and calculating a weighted average for the community. The formula used by the model to calculate the weighted average trip length is: Sum of (#Dwellings*Trip Distance)/ Sum of #Dwellings.

Modal shifts are represented within the model on the basis of literature-informed assumptions. For example, the National Personal Transportation Survey conducted in 1983 indicated that respondents claimed public transit would be a viable transportation mode if the transit points were located within 300 meters. GHGProof uses this literature-based assumption to incorporate local transit ridership rates for dwellings that are located within 400 meters of public transit. For a mode shift to walking, the model's assumption is that walking will be chosen 21% of the time for trip lengths of 400m or less, again based on an American study conducted in 2001 (Sustainability Solutions Group, n.d.). Mode shifts to transit and walking are then subtracted for the total VKT. In order to translate trip lengths into energy and emissions outputs, the model then makes user-defined assumptions about fuel efficiency and fuel emissions factors under each policy scenario.

The methodology outlined above seems to be the same for other sectors covered by the model, in the sense that a set of user-defined assumptions is used by the model's algorithm to solve for the energy and emissions outputs that are presented to the user. These assumptions are based on previous studies or user knowledge.

With respect to the criteria of technological explicitness, behavioural realism, and macroeconomic feedbacks, the *GHGProof* model scores poorly on each criterion. Consider, for example, how the model represents modal shifts. For dwellings located within 400m of a transit point, 40% of trips will use public transit. This assumption is

[3] Spatial data for schools is loaded in a separate layer.

based on a transportation survey conducted in 1983, but does not consider: (1) how stated preferences – when a respondent does not actually need to face the consequences associated with their claims – differs from revealed preferences; and (2) the heterogeneity within the commuter population with respect to their willingness to use different modes of travel based on perceived convenience, trip distance, personal circumstances, etc. Neglecting these considerations within *GHGProof* leads to the model scoring low against the criterion of behavioural realism. The model is also not technologically explicit, relying rather on explicit spatial differences between BAU and policy scenarios to model the impact of climate policies. The model also does not incorporate macroeconomic feedbacks into its analysis.

Energy and Emissions (E^2) Tool

This model is designed for use with readily available data and minimal requirement for inputs from municipal decision-makers. It provides a rapid assessment of endogenous and user-defined opportunities for energy and GHG emissions reductions for target years to 2050. The sectors covered in the model are buildings (residential, commercial, and industrial where data is available), transportation (personal and commercial), solid waste, and agriculture. As of 2012, 35 BC local governments had used this model. Like CIMS-Community, this is a Microsoft Excel-based tool that requires no additional specialized software, and the model can be scaled for application at any community size for which input data is available.

The model relies on community-level data from the Community Energy and Emissions Inventories, population and housing data from Statistics Canada, and other local data that can be obtained from local government staff such as more refined estimates of population growth or projected forecasts for changes in housing type within the community. Like CIMS-Community, the BAU forecast includes currently existing provincial and federal climate policies, namely the Federal Vehicle Emissions Standard and the existing BC Building Code. It is unclear from the literature whether the BAU forecast also simulates the effect of the BC Carbon Tax.

Once the input data has been selected and modified by the user as needed, the user is presented with a pre-defined library of energy and emissions reductions options to select from. The user may also design their own policies, provided they are able to define: (a) the reduction potential of the option (e.g. in terms of % GHG reduction or % energy efficiency improvement over time); and (b) the level of uptake within the community (e.g. in terms of (% of residential buildings that will undergo the specified energy efficiency improvements by 2050). The E^2 model then uses these data to compute the likely impact of the selected policy options (Stantec Consulting, n.d.).

In general terms, running the model seems to involve a spreadsheet multiplication of the reduction potential and level of uptake specified by the user under a specific policy scenario. For example, a DCC exemption for commercial buildings that are built to over 40% of the current building code would be solved within the model as follows: (a) the user defines, subjectively, the level of uptake for this policy (e.g. 10% of all new commercial buildings will accept the DCC exemption and develop buildings that are 40% more energy efficient than the current code); and (b) the model calculates the reduction in energy consumption (and therefore GHG emissions) as a result of this policy.

The fact that the *E^2 Model* is not a free-to-use tool makes it challenging to describe the methodology of policy simulation in the model, but there does not appear to be empirical evidence guiding the exogenous user-defined assumptions that define the reduction potential of a particular policy. It seems like the assumptions can be whatever the user believes the potential to be, and the model then simply uses these user-defined inputs about rates of change in efficiency or fuel type to generate the energy and emissions reductions under each policy scenario. The model's methodology does not minimize costs, optimize consumer preference, or indeed simulate policies in a behaviourally realistic way that takes into account any intangible costs or consumer heterogeneity. The model also does not seem to be technologically explicit or include macroeconomic feedbacks.

CIMS-Community Model

The CIMS-Community model is a "hybrid" model. This means that it provides detailed information on the technologies eligible to provide the various energy service demands (e.g. lighting, space heating, mobility), while simulating technological choices of firms and households with a behaviourally realistic set of micro-economic decisions. Behavioural realism is addressed in CIMS by including behavioural parameters (non-financial values, time preference when assessing future and present costs of each option, and business and consumer heterogeneity) in the model's key market share formula (Rivers and Jaccard, 2005).

The CIMS-Community model represents demand for energy services (e.g. space heating) as being supplied using "capital stock" (e.g. furnaces). The make up of capital stock technologies used to meet energy demand – which can be influenced through policy - is what determines the region's energy consumption and GHG emissions[4]. For example, a switch away from personal vehicular travel could be encouraged through local government policy such as a road charge in the form of a congestion fee; this would change the cost of driving simulated in CIMS-Community, and under such a scenario some residents might opt to drive less or use public transit. Capital stock changes within the model in response to changing policy and market conditions based on the simulation sequence shown below (Jaccard, 2009; Bataille *et al.,* 2006; Navius, 2012):

1. Assess community energy service demand for a 5-year period
2. Retire old capital stock based on technology lifespan assumptions
3. Retrofit capital stock based on policy and/or market conditions
4. Add new stock to meet the shortfall between supply and demand for each energy service
5. Calculate energy consumption and GHG emissions for current 5-year period
6. Repeat the process for the next 5-year iteration

[4] While this is implicitly true for the *GHGProof* and *E2* models as well, they do not explicitly track the changes in technologies under BAU and policy scenarios. Moreover, these models likely just include guesstimates about the relationship between technology costs, consumer preferences, and capital stock turnover rates and the influences of specific policies aimed at changing them. As mentioned about, this lowers the behavioural realism of the policies being simulated.

Policy Analysis Using CIMS-Community

The CIMS-Community model incorporates a behaviourally realistic technology acquisition algorithm, and therefore offers a realistic analysis of individual or layered policy scenarios in terms of their likely impacts on energy consumption and GHG emissions. The algorithm considers intangible costs, market heterogeneity, and revealed discount rates when acquiring, using, and retiring technologies. Intangible costs are non-financial costs that affect human decision-making, such as a quality preference for LED light bulbs over any others. Revealed discount rates rely on purchasing behaviour to model how people weigh current versus future cost savings while making purchasing decisions. Market heterogeneity captures the assumption that the market for a given technology is heterogeneous. Behavioural data on intangible costs and market heterogeneity can be estimated from discrete choice surveys (Axsen, 2006), while discount rates can be measured through market data (Nyober, 1997).

How does the CIMS-Community model fare in terms of the utility it can provide local government decision makers? I approach this question by identifying criteria in the modeling literature that have been used to assess model utility, and evaluating the CIMS-Community model and two other community energy and emissions models described above.

Evaluation of CIMS-Community Model

A review of the modeling literature suggests that - in addition to the criteria of technological explicitness, behavioural realism, and macroeconomic feedbacks - the following criteria can also be used to assess the utility of community energy and emissions models:

Sectors of Analysis

CIMS-Community has sector representation in the following sectors:

- Transportation, including personal vehicles, commercial vehicles, transit, bicycling, walking modes of travel.

- Buildings, including residential, commercial and institutional buildings. CIMS-Community does not cover large industrial buildings. Of the other models being evaluated against CIMS-Community, only the E^2 Tool covers large industrial buildings. However, this model was not chosen for analysis in this research project in part because the model is not freely available, but also because it does possess the levels of technological explicitness and behavioural realism that are present in the CIMS-Community model.
- Solid waste. CIMS-Community does not have the ability to capture energy and emissions data related to liquid waste, as these data are not available in CEEI. Within Nanaimo, the majority of emissions for the 2007 base year came from buildings and on-road transportation (roughly 98%), and therefore the GHG emissions associated with liquid waste in the region is low (Regional District of Nanaimo, 2013). E^2 is able to capture emissions associated with liquid waste, but was not used in this project for the reasons mentioned above.

CIMS-Community does not represent some of the other sectors included in the other models, including energy and emissions data related to agriculture, forests, and energy supply facilities. I chose to use the model in this research project despite these and other shortcomings because of its overall utility, which is summarized at the end of this chapter.

Spatial Scale

CIMS-Community can currently be applied to the municipal and regional district levels, although planned future updates include a neighbourhood version of the model. *GHGProof* is the only competing model to offer better scalability, and can be applied to the following, higher resolution, spatial scales: parcel, building block, and neighbourhood. Despite these advantages, *GHGProof* was not used in this project because: (a) my case study focused on GHG emissions reductions at the regional district level so the higher resolution capabilities were not relevant; (b) *GHGProof* benefits from specialized GIS analysis skills that I do not possess; and (c) *GHGProof* does not possess the level of technological explicitness and behavioural realism present in the CIMS-Community model.

Benefits of Policy Analysis Using CIMS-Community Model

Dill (2009) identifies additional criteria that can be used to judge a model's utility, including its:

- Affordability: inexpensive to acquire, learn, and use (Batty, 2008);
- Accessibility: utilizes standard software (Moore, 2008);
- Relevance: uses variables that are wholly or partially under local government control (Moore, 2007);
- Transparency: able to link each variable to specific outcomes or impacts (Klosterman, 2008);
- Timeliness: capable of modelling scenarios quickly for interactive use;
- Simplicity: adaptable to the limited and specific data available to different local governments (Klosterman, 2008); and
- Comprehensiveness: designed to incorporate all major factors contributing to GHG emissions (Deal *et al.,* 2008).

The CIMS-Community model meets all but the last of these criteria. Of Nanaimo's GHG emissions, the following sectors are covered by the CIMS-Community model: (a) transportation (personal and commercial vehicles); (b) buildings (residential, commercial, small-medium industrial), and (c) solid waste. In the transportation sector, CIMS-Community does not cover emissions associated with motorcycles, mopeds, or motorhomes, though the energy consumption from these modes of transportation in 2007 was estimated to be less than 1% of the total energy associated with on-road transportation. In terms of GHG emissions associated with buildings, CIMS-Community does not cover large industrial buildings. This information, for example with respect to natural gas consumption, is publicly unavailable (Regional District of Nanaimo, 2013).

Land use changes associated with agriculture and deforestation is also not included in CIMS-Community.

The use of the CIMS-Community model in this research project contributes to the literature through the testing and application of a nascent modeling framework that assesses policies affecting capital stock turnover and land-use and transportation infrastructure. The next chapter describes the development of the CIMS-Community model.

3. Methodology

This chapter describes the development of the CIMS-Community energy and emissions model, as well as my methodology for Nanaimo's BAU forecast development and policy selection and simulation.

3.1 CIMS-Community Development

The CIMS-Community model represents a recent adaptation of models using the CIMS methodology by energy-economy modellers at Navius Research Inc. in partnership with the Energy and Materials Research Group (EMRG) at Simon Fraser University and the Pacific Institute for Climate Solutions. Models using the CIMS methodology simulate the purchase, use, and retirement of technologies used within a community until the year 2050, under BAU and different user-defined policy scenarios. The energy-utilizing sectors covered in the model include the residential, commercial, transportation and solid waste sectors. Policy analysts at EMRG and Navius have previously used CIMS models for analysis at the national, international, provincial, and community levels. CIMS-Community builds on these CIMS models by introducing limited spatial analysis into the model, in the form of the impact of changing urban form, which is simulated using user assumptions about transportation demand, building type, and building area.

My involvement with the project was limited to Phase I (*Model Prototyping*), which included initial model development and testing in collaboration with two community partners: the Sunshine Coast Regional District and the Regional District of Nanaimo. The Model Prototyping phase of CIMS-Community development consisted of two main stages – community partner engagement and model functionality and design - which are described in the section below. Phase II (*General Rollout*) will cover model refinement (through increased community engagement), in-house capacity building (through training workshops for local government staff), and model dissemination to interested parties (MKJA, 2010).

Community Partner Engagement

This stage involved the identification of needs and priorities for the model, including technology options, user-defined assumptions, policy options, and results indicators. Community partner input was sought in four key areas of model development – inputs, structure, outputs, and use (MKJA[5], 2011). Engagement with Nanaimo revealed policies of interest to this local government, and access to these policy preferences formed part of my rationale in selecting Nanaimo as the case study area for this project.

Model inputs form the foundation of any model and have a direct bearing on the quality of its results. Community partners helped identify model inputs (e.g. data on transit fuel use within communities) that could be used to improve the accuracy of the model's baseline forecast. Community partners were asked to provide specific input on the following questions:

- What data inputs do you currently have access to?
- How would you rate the quality of these data on a scale from 1 (poor quality) to 10 (high quality)?
- What are the limitations of these data and how could they be improved?
- What additional data inputs would you like to have for the purposes of community energy modelling?

[5] Navius Research Inc. was previously M. K. Jaccard & Associates (MKJA).

- How difficult do you think it would be to collect such data for your community on a scale from 1 (not difficult at all) to 10 (very difficult)?

- Please provide input on the suggested data for users to manipulate

- Please provide input on suggested forecast assumptions for users to manipulate.

Feedback from community partners helped refine aspects of model functionality, design, and documentation.

Model structure determines the scope of a model and its applicability to community-level policy analysis. Community partners provided input on desired sector coverage and disaggregation, and the most appropriate representation for industry within the model. The sector coverage and disaggregation suggested to community partners was: residential, commercial, urban freight, government and institutional, landfill management, industry by sub-sector archetype, light industry, and personal transportation. Community partners were also able to suggest additional sectors for consideration during model development.

Model outputs are the end result of model simulations and should be tailored to intended model use. Community partners were asked to suggest region and sector outputs and results indicators, as well as provide specific input on the following questions:

- What do you want to report? At what scale? Using what measurements?

- How do you intend to use these outputs now and in the future?

- What are your current reporting requirements for various provincial and community policies and programs?

- How do you measure growth, policy success, and policy failure? What metrics will you use to quantify these measurements?

With respect to *model use and policy analysis*, community partners were asked to provide input on the policies they would like to see simulated directly in the model (e.g. building codes, technology standards, etc.) and policies they would like to see simulated indirectly via archetypical policy responses (e.g. reduced greenfield development, increased parking charges, etc.). Community partners were also asked to provide specific input on the following questions:

- What would you like to be able to do with the model?
- What are the types of policies that will be modelled?
- What jurisdictional levels of policy will be modelled?

Model Functionality and Design

I assisted with sector building and data population during this stage of model development. Sector structures were derived from previous CIMS models. The demand for energy services (e.g. space heating) within a sector is supplied through capital stock (e.g. furnaces) available to that sector. Each sector is structured such that its capital stock splits from primary nodes (primary drivers of energy use within a sector) through intermediate nodes (main energy-consuming stock categories) to competition nodes (stock technologies that offer the same end-user service). Technologies can themselves demand services (e.g. dishwashers demand the water heating service). Technology and service splits used to build the Residential, Commercial/Small Industrial, and Transportation Sectors in CIMS-Community are shown in Tables 3.1 to 3.3. CIMS also has a solid waste sector, but I omit it from my analysis since solid waste accounted for less than 8% of Nanaimo's emissions in 2010 (Regional District of Nanaimo, 2014). Final energy consumption and greenhouse gas emissions associated with a sector depend on the magnitude of energy services demanded and the mix of capital stock chosen by CIMS-Community to meet that demand.

The number of households (estimated from population forecasts) drives energy consumption in the Residential sector. Within households, energy-consuming categories (intermediate nodes) include appliances, floor space (which requires lighting, heating, and cooling), and hot water. Multiple technology archetypes compete within each technology competition node to meet the energy demand for a particular end-use service. For example, incandescent, CFL and LED lighting archetypes complete with each other to satisfy the demand for lighting in the Residential sector (Navius, 2012).

Table 3.1. CIMS-Community Structure: Residential Sector

Primary Driver of Energy Use	Energy Consumers and Greenhouse Gas Emissions Producers		Technology Competition Node	Services Demanded by Technologies	
Households	Appliances		Dish Washers	Water Heating	
			Refrigerators		
			Freezers		
			Ranges		
			Clothes Washers	Water Heating	Clothes Dryers
			Clothes Dryers		
			Tap Hot Water	Water Heating	
			Other Appliances		
	Floor Space	Lighting	Lighting		
		Building Envelope	Detached Homes	Heating: Furnaces + Heat Pumps (and Furnace Fans)	Air Conditioning
			Attached Homes	Heating: Furnaces + Heat Pumps (and Furnace Fans)	Air Conditioning
			Apartments	Heating: Furnaces + Heat Pumps (and Furnace Fans)	Air Conditioning
			Mobile Homes	Heating: Furnaces + Heat Pumps (and Furnace Fans)	Air Conditioning
		Solar	Solar		

The number of commercial, small industrial, and institutional buildings (estimated from population forecasts) drives energy consumption in the Commercial / Small Industrial sector. Energy-consuming capital stock categories include building shells, electronics and appliances, and hot water.

Table 3.2. CIMS-Community Structure: Commercial/Small Industrial Sector

Primary Driver of Energy Use	Technology Competition Node	Services Demanded by Technologies		
Building Envelope	Wholesale Trade	Ventilation	Heating	Air Conditioning
	Retail Trade	Ventilation	Heating	Air Conditioning
	Transportation, Warehousing	Ventilation	Heating	Air Conditioning
	Information, Cultural	Ventilation	Heating	Air Conditioning
	Offices	Ventilation	Heating	Air Conditioning
	Educational Services	Ventilation	Heating	Air Conditioning
	Health Care	Ventilation	Heating	Air Conditioning
	Arts, Entertainment and Recreation	Ventilation	Heating	Air Conditioning
	Accommodation and Food Services	Ventilation	Heating	Air Conditioning
	Other Services	Ventilation	Heating	Air Conditioning
Lighting	General Area			
	Service Lighting			
	High-Bay			
Appliances and Electronics	Appliances and Electronics			
Hot Water				

Annual demand for person kilometers traveled (PKT) drives energy use in the Personal Transportation sector. PKT is calculated by multiplying the forecasted population with estimated per capita travel within the community. PKT demand is split based on implicit preferences in the historical data, that is intangible costs are adjusted so that the mode share matches in past years. When forecasting, the model uses that intangible cost to simulate mode share. Multiple technology archetypes complete within each mode to supply the fraction of PKT demanded of that mode.

Annual Freight Transportation demand, in vehicle kilometers traveled (VKT), is calculated by multiplying the forecasted population with the estimated per capita freight requirement. The rationale for using VKT rather than TKT is that CEEI data uses VKT.

VKT is related to TKT using provincial average data from NRCAN's comprehensive energy use database. VKT demand is exogenously split between commercial vehicles (light/medium trucks) and tractor-trailer trucks[6].

Table 3.3. CIMS-Community Structure: Transportation Sector

Primary Drivers of Energy Use	Energy-Consuming Capital Stock Categories		Technology Competition Node	Services Demanded by Technologies		
Personal Transpotation	Community Travel	Walk/Cycle	Walk/Cycle			
		Public Transit	Rapid Transit			Fuel Blends
			Bus			Fuel Blends
		Multi-Passenger Vehicle	Existing Vehicles	VKm from Cars or Trucks	Gas and Diesel Motors	Fuel Blends
			New Vehicles	VKm from Cars or Trucks	Gas and Diesel Motors	Fuel Blends
		Single Passenger Vehicle	Existing Vehicles	VKm from Cars or Trucks	Gas and Diesel Motors	Fuel Blends
			New Vehicles	VKm from Cars or Trucks	Gas and Diesel Motors	Fuel Blends
Freight Transportation	Road Freight		Commercial Vehicles			Fuel Blends
			Tractor Trailers			Fuel Blends

Data were input after the sector building stage. The types of data that comprise each sector are shown in Table 3.4 below. Technology and behavioural parameters remain the same in each sector, but community data are sector-specific. The data came from multiple sources, including community data from the British Columbia Community Energy and Emissions Inventories (n.d.) and BCStatistics (n.d.), and technology and behavioural data from previously developed models that use the CIMS methodology (EMRG, n.d.).

[6] NRCan defines Light trucks as vehicles under 10,000 lbs. Medium trucks are Mobile 6 classes 3-7 and Tractor-Trailer trucks are Mobile 6 classes 8a & 8b (BC Ministry of Environment, 2014).

Table 3.4. CIMS-Community: Sector Data

<table>
<tr><th colspan="2">Technology Data (All Sectors)</th><th colspan="2" rowspan="2">Community Data (Sector Specific)
(Units)</th></tr>
<tr><th>Technology Parameters
(Units)</th><th>Behavioural Parameters
(Units)</th></tr>
<tr><td rowspan="3">Capital Cost
($*)</td><td rowspan="7">Intangible Cost
($)</td><td rowspan="2">Population</td><td>Population: Historic and Projected to 2050
(Number)</td></tr>
<tr><td>Population: Annual Rate of Change
(%)</td></tr>
<tr><td rowspan="7">Residential Sector</td><td>People/Household
(Number)</td></tr>
<tr><td rowspan="3">Operating and Maintenance Cost
($)</td><td>Number of Households
(Number)</td></tr>
<tr><td>Average Floor Space/Home
(m^2)</td></tr>
<tr><td>Average Floor Space/Home: Annual Rate of Change
(%/Year)</td></tr>
<tr><td rowspan="2">Economic Lifespan
(Years)</td><td>Share of Dwellings by Building Type
(%)</td></tr>
<tr><td rowspan="4">Discount Rate
(%)</td><td>Fraction of Floor Space with Air Conditioning
(%)</td></tr>
<tr><td rowspan="2">Retirement Lifespan
(Years)</td><td>Energy Consumption and Greenhouse Gas Emissions by Fuel Type for Buildings
(GJ and tCO_2e)</td></tr>
<tr><td rowspan="3">Transportation Sector</td><td>Fraction of Person Kilometre Travelled by Mode: Single Occupant Vehicle; Multiple Occupant Vehicle; Transit; Active Transport
(%)</td></tr>
<tr><td rowspan="2">Year Available
(Year)</td><td>Average Vehicle Kilometres Travelled per capita (small city, medium city, large city)
(km)</td></tr>
<tr><td rowspan="4">Heterogeneity
(Number)</td><td>Energy Consumption and Greenhouse Gas Emissions by Fuel Type for On-road Vehicles
(GJ and tCO_2e)</td></tr>
<tr><td rowspan="2">Year Unavailable
(Year)</td><td rowspan="2">Commercial/ Institutional/Small Industrial Sector</td><td>Share of Floorspace by Building Activity: Wholesale Trade; Retail Trade; Transportation and Warehousing; Information and Cultural Industries; Offices, Educational Services; Healthcare and Social Assistance; Arts, Entertainment and Recreation; Accommodation and Food Services; Other Services
(%)</td></tr>
<tr><td>Energy Consumption and Greenhouse Gas Emissions by Fuel Type for Buildings
(GJ and tCO_2e)</td></tr>
<tr><td>Material Output
(Various)</td><td>Retail Energy Prices</td><td>Retail Energy Prices: Electricity, Natural Gas, Heating Oil, Propane, Wood, Gasoline, Diesel, Ethanol, Biodiesel
($/GJ)</td></tr>
</table>

*All prices are in Canadian Dollars.

3.2. Simulation of Business-As-Usual Forecast

A business-as-usual forecast is a projection of what the future might look like should decision-making behaviour remain unchanged for the duration of the forecast. The accuracy of the forecast depends not only on this assumption, but also on how comprehensively a model captures the options and motivations that influence current decision-making behaviour. Like all forecasts it is not intended to be perfectly accurate since we do not have perfect information about all factors affecting decision-making into the future.

My methodology for developing a plausible BAU forecast for Nanaimo included: (a) creating a community profile for Nanaimo; (b) tailoring user-defined inputs to be Nanaimo-specific and calibrating the CIMS-Community model to historical Nanaimo community data; and (c) applying in-effect climate policies. Each of these stages is described in greater detail below. The section concludes by describing assumptions related to the BAU forecast.

Nanaimo Community Profile

British Columbia has 162 municipalities and 27 regional districts. Regional districts provide a broad range of local government services, from building inspections and solid waste management to land use planning. I selected Nanaimo because it is one of the regional districts that have adopted a regional growth strategy and it was one of the community partners during the *Model Prototyping* phase of CIMS-Community model development.

The community profile of Nanaimo described below provides contextual information that can assist in the interpretation of the plausibility of the BAU forecast, at least for the initial simulation period. The profile includes general trends related to projected population changes, as well as housing and transportation demand.

The Regional District of Nanaimo is situated on the east coast of Vancouver Island, and covers approximately 207,000 hectares of land rich in natural resources. The agriculture and forestry industries have a prominent presence in the region, and its rural areas are characterized by heavy private automobile use (Regional District of Nanaimo, 2013). It is currently the second most populous regional district on Vancouver Island, accounting for approximately 18% of the Island's population (Statistics Canada, 2011; Regional District of Nanaimo, 2012).

Population growth within Nanaimo has been steady at an average annual rate of nearly 3% since 1981, though is projected to slow to an average annual rate of a little over 1.3% for the next decade (BCStatistics, 2014). The demand for housing is expected to follow the population trend over the coming decade. The housing composition currently comprises approximately 68% single detached homes, 15% apartments, and 17% other ground-oriented stock, including attached and mobile homes. The composition of housing stock is expected to shift slightly, with a 1% transfer of market share from single detached units to other ground-oriented stock over the next two decades (Urban Futures, 2007).

The measured GHG emissions associated with Nanaimo were 919,900 tCO_2e in 2007, which equates to approximately 6.6 tCO_2e per capita. This estimate includes emissions from buildings, on-road transportation, and solid waste. This is likely to be an understated total for the region, since CEEI totals do not include estimates from large industrial facilities and the Nanaimo local government does not have access to emissions data for large industrial emitters within their region (BC Ministry of Environment, 2014; Regional District of Nanaimo, 2013).

An examination of current energy and emissions by sector in Nanaimo reveals that while buildings have an energy demand nearly one-fifth greater than vehicles, vehicles contribute roughly two-and-a-half times more emissions than buildings. This can be explained by the fact that the energy demand for buildings in Nanaimo is largely met by electricity, which has lower emissions per unit energy consumed than the gasoline and diesel fuel used by vehicles.

BAU Forecast

The BAU forecast was generated by tailoring user-defined inputs to Nanaimo, calibrating the model to local and historical data, and applying existing climate policies. The simulation assumes that: (1) existing policies will remain at their current value for the duration of the policy run (2010-2050); and (2) the only policies that impact GHG emissions in Nanaimo are those that can be simulated using CIMS-Community. The latter is clearly a false assumption, and the limitations of the CIMS-Community model in this context are discussed in Chapter 5.

User-Defined Inputs and Model Calibration

The model is calibrated to historical data based on the CEEI data up to the present year, as well as historical data provided through user-inputs. In the case of Nanaimo, the calibration step adjusted the model to match the following user-inputs and assumptions:

- Annual rate of population growth: The model's default value is 1.5% annual growth, but after calibration the growth rates were 1.08% (2010-2040) and 1.77% (2040-2050). These new values are based on the Aggressive Growth Scenario outlined in Nanaimo's community energy and emissions plan (Regional District of Nanaimo, 2013)

- People per household: This was set to 2.4 for the duration of the model run from 2010 to 2050 (BCStats, 2014)

- Annual growth rate for residential dwelling units (%/year): The baseline was set at 147m^2 which was the BC average in 2007. The baseline average dwelling size in Nanaimo was assumed to be the same as BC, and the growth rate was set at 0.4% for the duration of the model run (Natural Resources Canada, 2013).

- Dwelling mix: The housing stock shares are predicted to stay constant at their current levels of 68% detached, 14% attached, 15% apartment, and 3% mobile homes.

- Annual growth rate in personal travel: An increase or decrease in the annual rate of personal travel is assumed to be associated with the community shifting to a lower or higher density respectively. In the BAU forecast, this rate does not change from current values.

- Annual growth rate in freight transportation: This rate is based on the region's long-term economic forecast. Since a long-term economic forecast was not available for Nanaimo or BC, the Canadian rate of 1.92% was used.

- Annual growth rate for commercial/institutional buildings: This rate is based on the region's economic forecast, and was set to increase by 0.7% annually for the reasons mentioned above.

Application of In-Effect Climate Policies

Policy selection criteria for the BAU forecast were that: (a) the policy is currently being implemented at the federal, provincial, or municipal level; and (b) the policy can be simulated using the CIMS-Community model. The climate policies met these criteria were: (1) British Columbia Carbon Tax, which was held constant at its post-2012 level of \$30/tCO_2e for the duration of the BAU forecast, since no post-2012 increase has been announced; (2) current BC Building Code specifications for energy efficiency, which are equivalent to an EnerGuide 73-79 rating for residential buildings and a LEED rating for commercial buildings (Natural Resources Canada, 2015); (3) LiveSmart technologies subsidies for residential space and water heating technologies, set to current levels (4) Federal Vehicle Emissions Standard for vehicles, which applies to new vehicle purchases, and stipulates that new light-duty vehicles must have a fleet average emissions intensity of less than 160g CO_2e/km after 2015; (5) Federal MPES regulations for space and water heating technologies in the residential and commercial sectors, set to current levels; and (6) Federal Renewable Content Standards, set to current requirements of a minimum of 5% ethanol by volume in all gasoline transportation fuels.

Assumptions Related to Retail Energy Prices

The following price assumptions apply to both the BAU and two policy scenarios, which are described in the following section. The values are based on projections made by the National Energy Board (2011), and do not include inflation. For each 5-year period, the price represents an average paid by consumers during those five years[7].

Retail Energy Price (2010 $CAD/GJ)	**2015**	**2030**	**2050**
Electricity	23	29	29
Natural Gas	15	17	18
Heating Oil	24	27	29
Propane	28	31	32
Wood	12	12	12
Gasoline	33	36	37
Diesel	28	30	31
Ethanol	57	61	55
Biodiesel	48	49	50

[7] There is a more recent NEB forecast that was published in 2013, but I have used the previous 2011 projections because I was unable to find some of the relevant information for 2013 and CIMS-Community model calibration needed to be completed as soon as possible.

3.2. Simulation of Policy Scenarios

Federal, provincial, and municipal governments can use different compulsory policy instruments to reduce GHG emissions within a particular region. In BC for example, the federal government can implement a regulation for a new fuel-economy standard, the provincial government can increase the carbon tax, and a municipal government can reduce development cost charges for buildings that satisfy specified energy-related criteria.

In this research project I use the CIMS-Community model to develop a policy context for Nanaimo. The goal of my modeling effort is to examine the GHG emissions reduction potential of municipal policies, and determine whether some combination of these policies can help Nanaimo achieve its stated GHG emissions reductions targets. To this end, I will evaluate the two policy scenarios described below. The first policy scenario, *Political Feasibility,* is also referred to as POLICY-Moderate or POL-MOD. The second policy scenario, *Incremental Additions*, is also referred to as POLICY-Extreme or POL-EX.

Scenario 1: Political Feasibility (POL-Moderate or POL-MOD)

The criterion for policy selection under this scenario is political feasibility. Political feasibility typically decreases as policy compulsoriness increases. Compulsory policies under local government control that can be simulated using CIMS-Community are set at the lowest model setting under this scenario, while non-compulsory policies are set at moderate model settings (see Table 3.1 for details). The simulation also assumes that: (1) existing policies that are not under local government jurisdiction (e.g. BC Carbon Tax and Federal Vehicle Emissions Standard) will remain at their current value for the duration of the policy run; and (2) the only policies that impact GHG emissions in Nanaimo are those that can be simulated using CIMS-Community. My hypothesis is that the GHG emissions reductions achievable under this scenario will fall very far short of Nanaimo's stated targets for 2020 and 2050.

Scenario 2: Incremental Additions (POL-Extreme or POL-EX)

This scenario is designed to assess the extent to which Nanaimo can achieve GHG emissions reductions when political feasibility is not a constraint in policy selection and stringency. Policies are run again and again with increasing policy stringency, and the likely GHG emissions reductions are assessed under each stringency setting. My hypothesis is that the GHG emissions reductions achievable under very aggressive policy settings will allow for substantially higher reductions than were possible under Scenario 1, but these policies will still fall short of attaining Nanaimo's stated targets because of limits to their applicability.

Policy Descriptions

BC Carbon Tax

As mentioned in Chapter 2, BC was the first Canadian province to implement a tax on GHG emissions associated with fossil fuel combustion. The tax is revenue neutral in aggregate, but is not revenue neutral at the level of individual businesses or citizens and therefore still provides an incentive for GHG emissions reduction. For the BAU, POL-MOD, and POL-EX scenarios, the stringency of this policy remained at the current tax level of \$30/tCO_2e for the duration of the policy run.

BC Building Code Regulations

The current BC building code requires an energy efficiency equivalent to an EnerGuide 73-79 rating for residential buildings and a LEED rating for commercial buildings. In the EnerGuide rating system, a higher number denotes a more energy efficient building. The scale goes from 0 to 100, where 0 represents a house that has a lot of air leakage, lacks insulation, and has high fuel consumption; 100 represents a house that is air-tight, well insulated, and where the energy used is equal to the energy generated through renewable resources. For the BAU, POL-MOD, and POL-EX scenarios, the energy efficiency requirement was set to current BC code requirements, which is equivalent to an EnerGuide rating of 73-79.

Provincial Subsidies for Residential Technologies

The provincial government offers homeowners rebates to improve the energy efficiency of their space and water heating technologies through the LiveSmart BC program. These rebates depend on the energy efficiency rating of the new technology being purchased. For example in 2013, purchase of an instantaneous condensing gas ENERGY STAR water heater that had an Energy Factor (EF) of 0.90 would qualify for a $300 rebate, while a condensing gas storage type water heater with a Thermal Efficiency of 90% would qualify for a $200 rebate. In 2014, the rebate for upgrading the exterior wall insulation to achieve a minimum of R12+ by adding at least R9 to 100% of the building would qualify for a rebate of $1200[8]. Materials with higher R-values are better able to resist the movement of heat and therefore offer better insulation. For the BAU, POL-MOD and POL-EX scenarios, the subsidies were set to the most recent BC LiveSmart specifications for the duration of the policy run.

Vehicle Operating Charges

Municipal governments can - through means such as congestion fees and road tolls – in effect apply a cost that is directly related to how much an individual uses their personal vehicle. A reasonable operating charge may lie somewhere between $0-0.1/Km. For a vehicle that uses 8 litres per 100 kilometres travelled, a vehicle operating charge of $0.1/Km would translate roughly into a $1.25/litre increase in fuel cost or a

[8] The LiveSmart residential Efficient Incentive Program has formally ended in April 2014. There is now a new energy efficiency incentive program offered by BC Hydro and Fortis BC in partnership with the province. The LiveSmart incentives were included in the modeling scenarios because the CIMS-Community model has not yet been updated to include the newer incentive program. The new program seems to be designed along the same lines as the LiveSmart program. For example, exterior wall sheathing and cavities upgrades with an R-value of R3.8 and R12 respectively qualify for a combined rebate of $1,200 from BC Hydro. Future studies could include an update to the CIMS-Community model in the area of provincial subsidies for residential space and water heating technologies.

$500 carbon tax. No vehicle operating charge was simulated for the BAU forecast, since no such policy currently applies to Nanaimo. For POL-MOD, a charge of $0.05/Km was applied, while for POL-EX the policy runs tested the likely effects of charges of $0.06/Km to $0.1/Km.

Land Use Densification Policies

Municipal governments can – through means such as DCC exemptions and DPA guidelines – alter the composition of new housing stock within a specified region, and provide incentives to reduce residential floorspace. No policy was included in the BAU forecast, since no such policy currently applies to Nanaimo. For POL-MOD, the policy setting that was chosen was a moderate densification scenario. Under this setting in CIMS-Community, approximately 40% of Nanaimo's population growth is accommodated within existing developed areas. For POL-EX, between 40% and 100% of new development is accommodated within existing development areas. Residential floorspace and intra-community transportation demand also decrease under the policy scenarios relative to BAU.

Under POL-MOD, approximately 40% of Nanaimo's population growth is accommodated within existing developed areas. Under the highest stringency setting in POL-EX, 100% of Nanaimo's population growth is accommodated in existing developed areas. Under this aggressive POL-EX setting, the model also simulates higher mixed-use areas (i.e. where residential and commercial buildings both exist in proximity to each other), and shifts the building type in low density residential areas in the direction of attached homes and apartments and away from detached homes. Residential floorspace also decreases under policy scenarios relative to BAU.

Building Standards

Municipal governments can use DCC exemptions and DPA guidelines to incentivize developments that exceed the current provincial code specifications for residential and commercial buildings. For residential buildings, this would require developers building to EnerGuide ratings above 73-79. For commercial buildings, this would require developers building to specifications above ASHRAE 90.1-2004 standard developed by the American Society of Heating, Refrigerating, and Air Conditioning Engineers. Developers may use the prescriptive path – in which all building components exceed the 90.1 specified standards – or the performance path in which building energy simulations are used to show how the proposed building design will use less energy than an archetypical building built to 90.1 standards. For the BAU forecast, residential and commercial building standards were held at the current BC building code specifications of EnerGuide 73-79 and ASHRAE 90.1 respectively. For POL-MOD, the residential building standard was set to be 14% above the current code from 2025, which is equivalent to an EnerGuide rating of 80-90. The commercial building standard was set to ASHRAE 90.1+3% from 2026, which represents a 3% increase over the current code for the duration of the policy run. For POL-EX, the following residential building standards were simulated in an attempt to evaluate the likely impacts of changing the stringency and timing of this policy: (1) 14% above the current BC residential building code from 2020; (2) 14% above the current BC residential building code from 2015 and 40% above the current residential building code from 2040; (3) 40% above the current residential building code from 2015; (4) 3% above the current commercial building code from 2021; (5) 19% above the current commercial building code from 2016 and 34% above the current commercial building code from 2026; and (6) 34% above the current commercial building code from 2016. The first policy run of 14% above code from 2020 was included in the final POL-EX package.

Development Cost Charge Exemptions

These subsidies may be offered to developers by municipal governments if they exceed the energy efficiency requirements specified in the current BC building code.

For the BAU forecast no DCC exemptions were applied since no such subsidies are currently applicable to Nanaimo. For POL-MOD, a rebate equivalent to 5% of the capital costs was applied to residential buildings that met or exceeded EnerGuide 80-90 beginning in 2025. For commercial buildings, a rebate equivalent to 5% of the capital costs was applied to commercial buildings that met or exceeded ASHRAE 90.1-2004 + 3% beginning in 2026. For POL-EX, DCC the following rebates for residential and commercial buildings were applied in different policy runs: (1) 15% rebate for 14% above residential code from 2016; (2) 20% rebate for 14% above residential code from 2026; (3) 20% rebate for 14% above residential code from 2016; (4) 5% rebate for 3% above commercial code from 2016; (5) 15% for 19% above commercial code from 2021; (6) 20% rebate for 34% above commercial code from 2021; and (7) 20% rebate for 40% above commercial code from 2026.

Federal Regulations for Residential and Commercial Technologies

The federal government specifies minimum efficiency performance standards (MPES) for space and water heating technologies. The BAU forecast and the two policy scenarios used the most recent MPES standards specified by the federal government for the duration of the policy run.

Federal Vehicle Emissions Standard

The federal government has committed to a new regulation beginning in 2016 that will require new light-duty vehicles purchased after this date to have a vehicle emissions intensity of less than 160gCO_2e/Km. This policy setting was applied to the BAU forecast and the two policy scenarios for the duration of the policy run.

Federal Renewable Content Standard

The federal government currently requires personal vehicles to use gasoline that has a minimum of 5% ethanol by volume. This policy setting was applied to the BAU forecast and the two policy runs for the duration of the policy run.

The following table summarizes the policy instruments applied in the BAU forecast and two policy scenarios. The stringency level of a particular instrument only differs from BAU in the case of policies that are under municipal influence. These stringency settings are indicated for municipal policies under POL-MOD and POL-EX. Policies included in a particular scenario are denoted by a check mark.

Table 3.5. Simulation of Policy Scenarios

Policy Instrument & Description	**BAU Forecast**	**POL-MOD**	**POL-EX**
Carbon Tax	√	√	√
Already exists at a rate of \$30/tCO_2e. Tax applies to direct emissions from fossil fuel combustion. This policy is under provincial jurisdiction and applies to all sectors.	**Stringency:** Remains at post-2012 value of \$30/tCO_2e for the duration of the policy run (2013-2050).	**Stringency:** Same as under BAU.	**Stringency:** Same as under BAU.

Building Code Regulations Regulation applies to all new construction and major retrofits. Improved Efficiency measure is an approximation of the space heating demand relative to single family homes. Assumed compliance rate of 90%. This policy is under provincial jurisdiction and applies to the residential and commercial sectors.	√ **Stringency:** Set to the level of the current BC Building Code. **Start Date:** 2011	√ **Stringency:** Same as under BAU.	√ **Stringency:** Same as Under BAU.
Subsidies for Space and Water Heating Technologies New product purchases for residential or commercial use (e.g. heat pumps, high efficiency furnaces) are eligible for subsidy. This policy is under provincial jurisdiction and applies to the residential and commercial sectors.	√ **Stringency:** Residential: Existing LiveSmart subsidy continues unchanged for the duration of the policy run (2011 – 2050). No Commercial subsidy since none currently exists.	√ **Stringency:** Same as under BAU.	√ **Stringency:** Same as under BAU.

Vehicle Operating Charge Applies to personal vehicles. Can be in the form or congestion charges, increased parking rates, etc. This policy is under provincial & municipal jurisdictions and applies to the transportation sector.		√ **Stringency:** User-defined charge value ($/Km). A reasonable operating charge is <$0.1/km.	√ **Stringency:** User-defined charge value ($/Km). Test effects of higher and higher vehicle operating charges on GHG emissions reductions.
Land Use Densification (Zoning Regulations & Financial Incentives) User defines housing stock composition, residential floorspace demand and transportation demand relative to BAU. This policy is under municipal jurisdiction and applies to the residential sector.		√ **Stringency:** Moderate densification policy in which roughly 40% of population growth is restricted to brownfield sites. Start Date: 2016	√ **Stringency:** Test effects of higher and higher % brownfield population growth on GHG emissions reductions. Start Date: 2016
Building Standards (Regulations) Local governments can use DPA guidelines and Zoning regulations to specify the energy efficiency of new buildings. This policy is under municipal jurisdiction and applies to the residential and commercial sectors.	√ **Stringency:** Energy efficiency requirements set to level of current BC Building Code or higher.	√ **Stringency:** Energy efficiency requirements set to EnerGuide 80-90 (14% more efficient than current building code) beginning in 2025.	√ **Stringency:** Test effects of increasing energy efficiency requirements, up to EnerGuide 91-100 (40% more efficient than current building code), beginning in 2016.

Exemption of DCCs (Subsidy) Applies to new buildings. DCC exemption for buildings that meet a specified energy efficiency standard. User defines DCC exemption as a percentage of total development capital costs. This policy is under municipal jurisdiction and applies to the residential and commercial sectors.		√ **Stringency:** Energy efficiency requirements set to EnerGuide 80-90. For buildings that meet this standard, apply a reduction equivalent to 5% of total development capital costs. Start Date: 2016.	√ **Stringency:** Energy efficiency requirements set to EnerGuide 80-90 or better. Test effects of greater and greater capital cost reductions on GHG emissions reductions. Start Date: 2016.
Federal Standards for Space and Water Heating Technologies Energy performance standards apply to all new water and space heating technologies. This policy is under federal jurisdiction and applies to the residential and commercial sectors.	√ **Stringency:** Energy performance of water and space heating technologies set at current Federal MPES levels for the duration of the policy run (2011-2050).	√ **Stringency:** Same as under BAU.	√ **Stringency:** Same as under BAU.

Federal Vehicle Emissions Standards Applies to new vehicle purchases. This policy is under federal jurisdiction and applies to the transportation sector.	√ **Stringency:** Existing vehicle emissions intensity standard for light-duty vehicles:160gCO_2e/Km **Start Date**: 2016	√ **Stringency:** Same as under BAU.	√ **Stringency:** Same as Under BAU.
Renewable Content Standards Applies to personal vehicles. This policy is under federal jurisdiction and applies to the transportation sector.	√ **Stringency:** Existing standard (minimum 5% ethanol by volume in all gasoline transportation fuels) for duration of policy run (2015-2050).	√ **Stringency:** Same as under BAU.	√ **Stringency:** Same as under BAU.

Despite the limitations of the CIMS-Community model, the results of the two policy scenario simulations described in the table above may help decision-makers in Nanaimo better understand the feasibility of their stated GHG emissions reduction targets and the kinds of actions that will be necessary to achieve them. Simulation results are discussed in the following chapter.

4. Results and Discussion

My BAU simulation forecasts the likely energy consumption and GHG emissions for Nanaimo under current federal and provincial climate policies. In 2007, which is considered the baseline year for Nanaimo's stated GHG reduction targets, regional emissions were estimated to be roughly 920 ktCO_2e. Nanaimo's 2020 GHG emissions under BAU will be 727 ktCO_2e, which is 113 ktCO_2e above Nanaimo's stated GHG emissions target. By 2050 Nanaimo's BAU emissions climb to 849 ktCO_2e, which is 665 ktCO_2e above Nanaimo's stated target. In this section, I explore how, and to what extent, local government policies can help to bridge this shortfall between Nanaimo's stated targets and the regional GHG emissions forecasted in the absence of such municipal intervention.

Table 4.1 summarizes the overall emissions trends under BAU and each of the policy scenarios. For the POL-EX scenario, the policy stringency level included in the package was the one that resulted in the greatest GHG emissions reductions in 2050. For example, in the case of the vehicle operating charge policy, the setting of $0.09/Km resulted in the most GHG emissions reductions in 2050, as compared with the other policy runs for charges of $0.06/Km, $0.07/Km and $0.08/Km. For a list of the different stringency settings under *Incremental Additions* simulations for each municipal policy, please see Chapter 3.

The results presented in Table 4.1 indicate that even in the presence of municipal intervention at levels deemed to be politically infeasible (POL-EX scenario), Nanaimo would still be reliant upon additional municipal, provincial and/or federal climate policies in order to meet its stated emissions reduction targets. The findings of each policy simulation are discussed in greater detail in the sections that follow.

The trend in the BAU forecast - where total GHG emissions decrease from 2015 levels in 2020 and 2030 but increase above 2015 levels by 2050 – can be explained by considering the opposing effects of higher energy efficiency and increasing population on GHG emissions. On the one hand, there is a shift toward more efficient technologies such as furnaces (for space heating) and motors (for transportation) that occurs under BAU independently of policies, as older and more energy- and GHG-intensive technologies are retired and replaced with new stock[9]. For example, there are new high-efficiency furnaces being added for each five-year modeling period from 2010 to 2050 under BAU, but no new low-efficiency furnaces are added after 2020. As a result, the total stock of furnaces continues to become more energy efficient under BAU. The same trend of increasing energy efficiency is seen in the total stock of new motors for cars and trucks under the BAU forecast. On the other hand, the total population for Nanaimo keeps increasing, and the GHG emissions associated with this increase in population eventually offsets and overtakes the GHG reductions caused by improving energy efficiency of technologies under BAU.

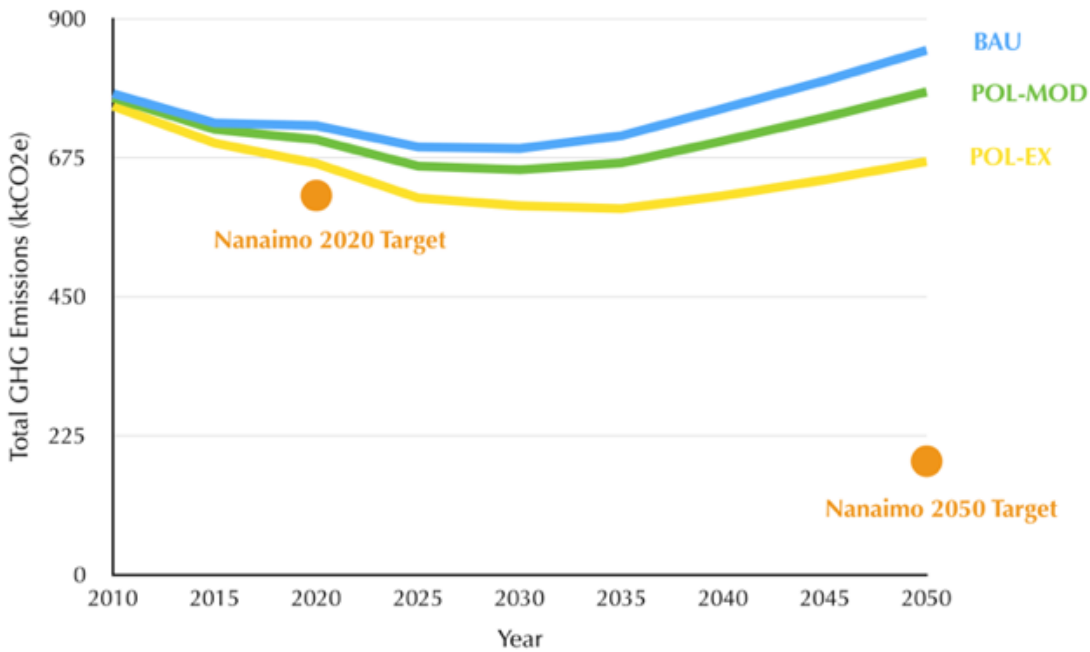
[9] Most community energy and emissions models do not capture this effect, and simply create a BAU forecast using a linear relationship between population and emissions. The ability of CIMS-Community to incorporate the energy efficiency gains associated with technologies in the absence of any policy is a strength of the model.

Table 4.1. GHG Emissions by Simulation (ktCO2e)

Simulation	**2015**	**2020**	**2030**	**2050**
BAU	731	727	690	849
POL-MOD	721	704	655	782
POL-EX	699	666	597	669
Nanaimo's Stated GHG Emissions Targets		614		184
Difference between BAU and Target		113		665
Difference between POL-MOD and Target		90		598
Difference between POL-EX and Target		52		485

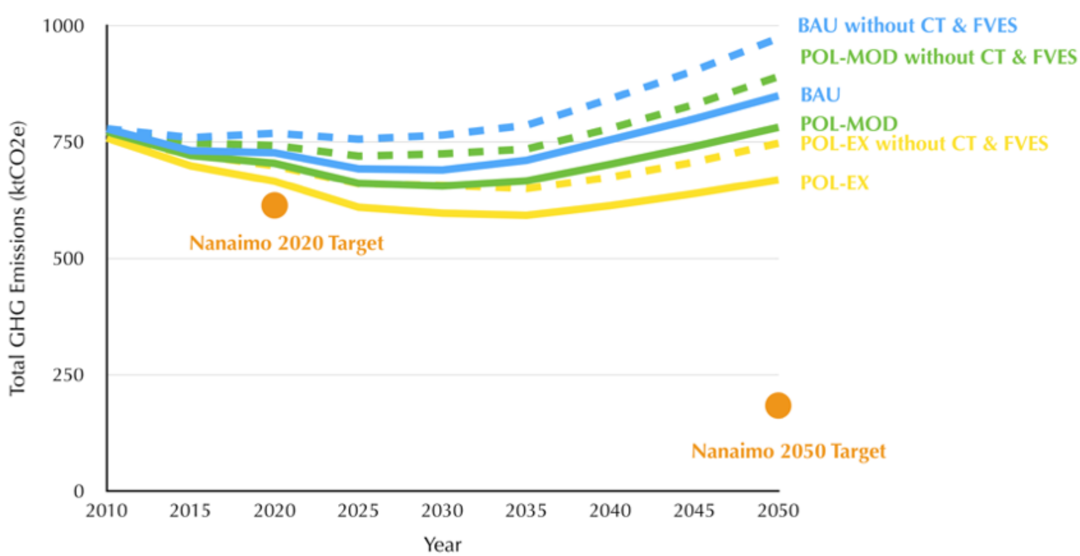
Figure 4.1 shows GHG emissions under BAU and policy scenarios for the duration of the policy run from 2015 to 2050. The figure also includes Nanaimo's stated GHG emissions targets for 2020 and 2050.

Figure 4.1. GHG Emissions Under BAU and Policy Scenarios (ktCO2e)



While the figure above suggests Nanaimo will be unable to meet its targets by implementing policies under municipal jurisdiction, even these results overemphasize Nanaimo's ability to influence regional GHG emissions. When the impacts from some existing federal and provincial climate policies are removed, namely the *BC Carbon Tax* and federal *Fuel Economy Standards*, the gap between Nanaimo's stated targets and regional GHG emissions is increased significantly as shown in Figure 4.2. The results show that it will be difficult for municipal governments to achieve deep GHG reductions on their own, and even more so without existing policies from provincial and federal governments.

Figure 4.2. GHG Emissions Under BAU in the Absence of BC Carbon Tax and Federal Vehicle Emissions Standard



In quantitative terms, if the provincial and federal governments choose to withdraw the existing BC Carbon Tax and Federal Fuel Economy Standard policies, regional emissions in Nanaimo under the various simulation scenarios would increase by the amounts shown in Table 4.2. Limitations in the CIMS-Community model that may lead to an underestimation of Nanaimo's actual GHG reduction potential are described in Chapter 5 and should be taken into consideration when evaluating the estimates provided in the table below.

Table 4.2. Impact of Provincial Carbon Tax and Federal Vehicle Emissions Standards on GHG Emissions (ktCO2e)

Simulation	2020	2050
BAU without CT & FFES	769	973
POL-MOD without CT & FFES	743	890
POL-EX without CT & FFES	699	748
Increased Shortfall from BAU with CT & FFES	42	124
Increased Shortfall from POL-MOD with CT & FFES	39	109
Increased Shortfall from POL-EX with CT & FFES	33	79

Despite the apparent limited ability of Nanaimo to influence GHG emissions within its regional boundaries, it may be useful for local government decision-makers to know which policies under municipal control are relatively more effective, and at what stringency levels. Effectiveness of municipal policies is evaluated in three main areas: vehicle operating charges, land use densification, and improvements to building energy efficiency.

Vehicle Operating Charges

Within the CIMS-Community model, vehicle operating charges are represented as an additional fixed annual intangible cost. In terms of the sector-specific impacts of this policy, as expected the impacts are restricted to the personal transportation sector. While the total fuel consumption associated with personal transportation decreases in the policy scenarios, there is no shifting from one fuel type to another. This is logically consistent with the design of the vehicle operating charge policy, which applies a standard charge to all personal vehicles irrespective of which fuel type is being used. In other words, there is no incentive for individuals to use less GHG-intensive fuels under this policy, they are simply incentivized to use their personal vehicles less. This is a significant shortcoming of the CIMS-Community model, since this is one of the levers that is available to municipal governments that can be applied creatively to parking availability and costs, personal VKT, and other factors that will influence mode shift to less GHG-intensive modes of travel such as public transit.

As modeling, in the shorter term vehicle operating charges were able to achieve the greatest GHG emissions reductions in 2020 as compared to land use densification, building standards, and development cost charge exemption policies. Of the four areas of municipal influence that were simulated, only land use densification policies had a greater effect on GHG emissions in 2050. Table 4.3 shows how GHG emissions change under different vehicle operating charges. The POL-EX scenario was run under five different vehicle operating charges, ranging from \$0.06/Km to \$0.1/Km with a \$0.01/Km increase for each subsequent run. Each incremental addition of \$0.01/Km resulted in a decrease of approximately 3 ktCO_2e in 2030 and 2050. For example, the simulated GHG emissions within the personal transportation sector for 2050 under vehicle operating charges of \$0.08/Km and \$0.09/Km were 309 ktCO_2e and 306 ktCO_2e respectively.

Table 4.3. Incremental Impact of Vehicle Operating Charge on GHG Emissions

Total GHG Emissions in Personal Transportation Sector (ktCO2e)	**2020**	**2030**	**2050**
BAU (No VOC)	387	329	380
POL-MOD (VOC: \$0.05/Km)	365	296	318
POL-EX (VOC: \$0.1/Km)	356	282	303

We can examine the total GHG emissions associated with the personal transportation sector to put these reductions in context. In 2050, the total GHG emissions from personal transportation under the different *Incremental Additions* policy settings ranged from 315 ktCO_2e at a vehicle operating charge of \$0.06/Km to 303

$ktCO_2e$ at a vehicle operating charge of \$0.1/Km. Each incremental addition of \$0.01/Km therefore resulted in a further reduction of approximately 1% of GHG emissions associated with the personal transportation sector in 2050. A vehicle operating charge greater than \$0.1/Km was not modeled because it was deemed to be unrealistic for the policy period of 2010 to 2050.

Figure 4.3 below shows the effect of vehicle operating charges on GHG emissions in the personal transportation sector. The figure shows that as incremental vehicle charges continue to increase by \$0.01/Km, the gains in terms of GHG reductions remain fairly constant at approximately 3 ktCO2e in 2030 and 2050. One possible reason for the fact that higher vehicle operating costs do not result in correspondingly greater and greater emissions abatement is that really deep emissions reductions will require electrification or a switch to hydrogen or biofuels within the personal transportation sector. The vehicle operating charge policy penalizes driving in general, rather than the driving of combustion vehicles specifically, and therefore does nto incentivize the shift to near-zero and zero-emission vehicles. If a vehicle operating charge could specifically be applied to fossil fuel combustion vehicles within the personal transportation sector – which municipal governments could implement through differential parking costs for different vehicle types for example – the policy would likely be capable of deeper emissions reductions than we see in the current POL-EX simulations.

Figure 4.3. Incremental Impact of Vehicle Operating Charge on Personal Transportation Emissions

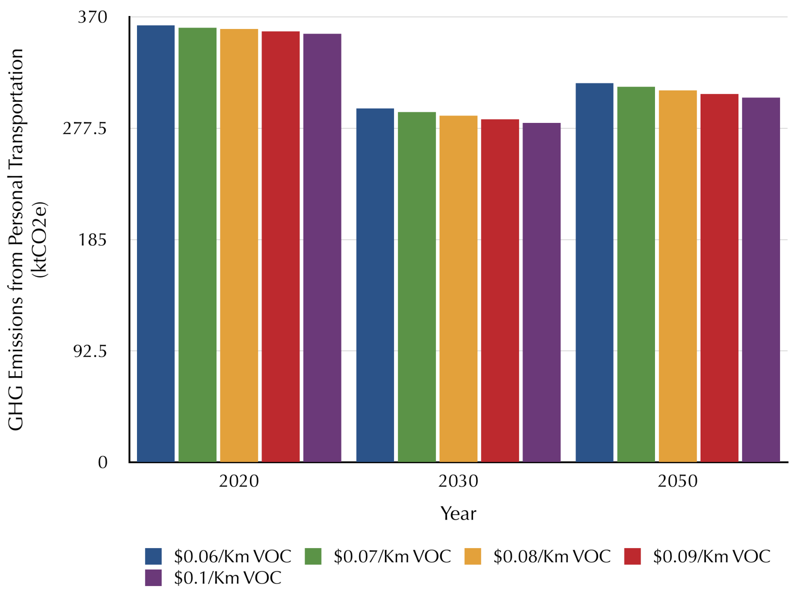
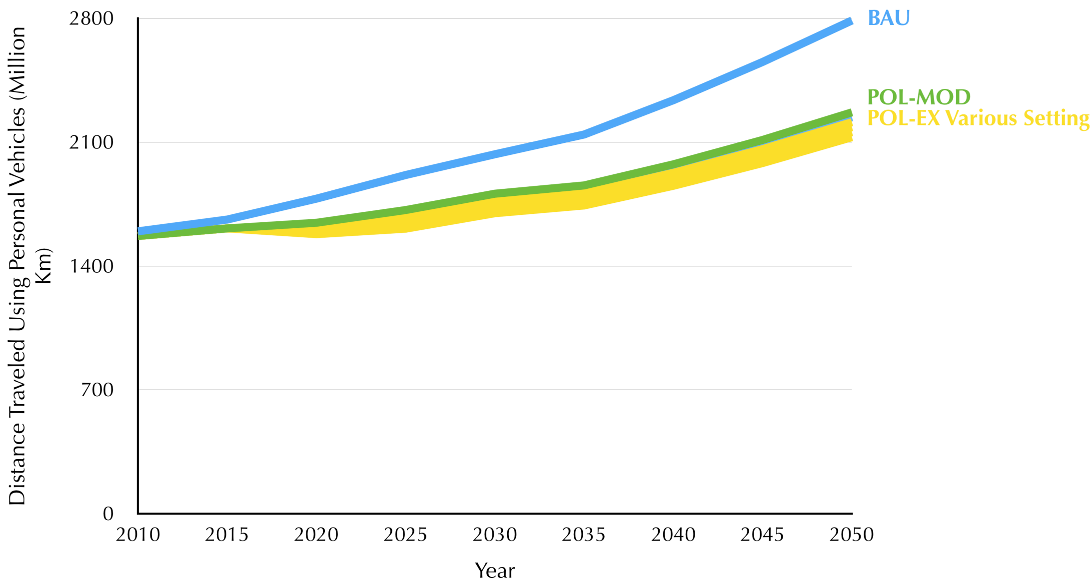


Figure 4.4 shows how the distance travelled using personal vehicles declines under the different simulations. Person kilometers traveled does not change between BAU and policy scenarios since this is an exogenous, population-driven estimate for the region.

Figure 4.4. Impact of Vehicle Operating Charge on Personal Transportation

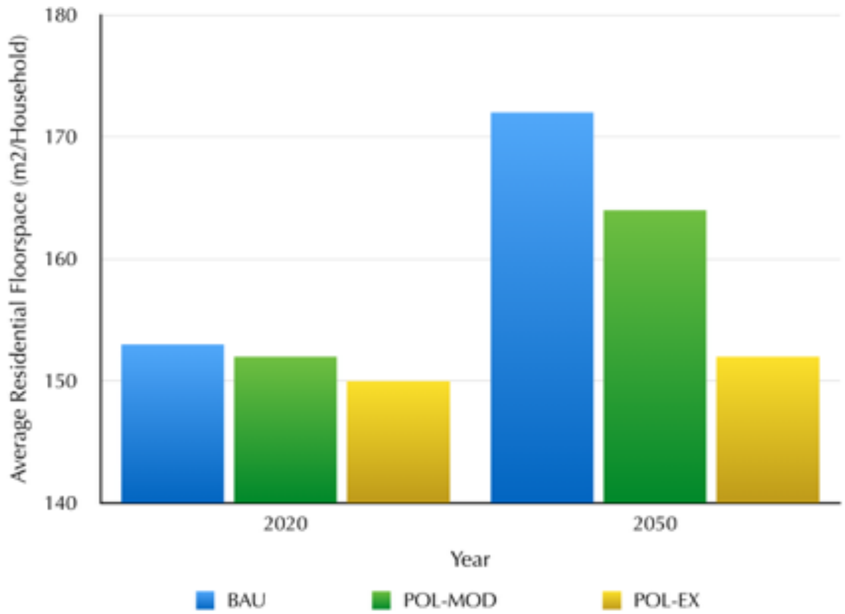


Land Use Densification

Results from the Quite Useful Ecosystem Scenario Tool (QUEST) modeling projects informs how land use densification policies are modeled in CIMS-Community. Using QUEST results for city size archetypes and policy strengths, CIMS-Community simulations change the size and type of buildings and the amount of transportation within the community under different policy scenarios. Under POL-MOD, approximately 40% of Nanaimo's population growth is accommodated within existing developed areas. Under the highest stringency setting in POL-EX, 100% of Nanaimo's population growth is accommodated in existing developed areas. Under this aggressive POL -EX setting, the model also simulates higher mixed-use areas (i.e. where residential and commercial buildings both exist in proximity to each other), and shifts the building type in low density residential areas in the direction of attached homes and apartments and away from detached homes. Residential floorspace also decreases under policy scenarios relative to BAU.

The policy simulation scenarios show that, as expected, this policy only has an impact on the residential and building transportation sectors. In terms of total GHG emissions in 2050, there is a decrease of 67 ktCO2e from BAU under the POL-MOD scenario of 40% brownfield growth and 153 ktCO2e from BAU under the most aggressive setting of the POL-EX scenario in which there is 100% brownfield growth. In terms of average residential floorspace, it decreases from approximately 172m^2 under BAU to 164m^2 and 152m^2 under the *Political Feasibility* and *Incremental Additions* scenarios respectively by 2050. It is interesting to note that while the residential floorspace decreases as the stringency of the land use densification policy increases, there is an overall increase in the average residential floorspace per household from 2020 to 2050 under BAU and each of the policy scenarios. These averages are based on exogenous forecasts, but it is interesting to see that the average floorspace under the most aggressive 100% brownfield growth scenario has approximately the same floorspace of 152m^2/household in 2050 as does the BAU forecast in 2020. A decrease in average floorspace affects GHG emissions mainly through changes in the energy consumption of space heating and lighting technologies in the residential sector. The effect of the land use densification policy on residential floorspace is shown in Figure 4.5.

Figure 4.5. Impact of Land Use Densification on Residential Floorspace



Reductions in floorspace are accompanied by a gradual shift from detached homes to apartments, which under the *Incremental Additional* scenario, reaches a maximum of 22% more apartments than detached homes by 2050. The proportion of attached and mobile homes remains fairly constant across the policy period.

Within the personal transportation sector, there is less intra-community driving as densification increases, which is consistent with increasing mixed-use developments under the policy scenarios. This policy does not shift the mode share of personal transportation vehicles (single occupancy, high occupancy, transit, walking, and cycling); rather, mobility decreases for each mode with increasing densification. Usually, an increase in the cost of car mobility in models that use the CIMS methodology leads to both a decline in mobility (mobility demand elasticity) as well as a shift in travel mode away from vehicular travel to public transit, walking and cycling. The CIMS-Community model does not capture the change in mode share in response to increasing densification (example a switch to more walking trips), which is a limitation of the current version of the model.

The two other areas of municipal influence – building standards and development cost charge exemptions – affect energy consumption within Nanaimo but policy stringency does not have a significant impact on GHG emissions within the region. This is partly because the building policies simulated in this project were based on energy performance rather than being prescriptive in terms of technology or fuel specifications. Performance standards tend to have the advantage of being more economically efficient because they are more flexible as policy instruments, but designing DCC and DPA policies using fuel specification constraints rather than energy efficiency standards would likely have resulted in greater GHG emissions reductions for these policies. As described below, it is possible for municipal governments to incentivize the use of cleaner fuels for building technologies, though this is difficult to simulate using the current version of the CIMS-Community model.

Building Energy Efficiency

Municipal decision-makers can require that new residential and commercial buildings meet energy efficiency specifications that exceed those stipulated in the current BC Building Code through the use of development permit area guidelines and development cost charge exemptions. The CIMS-Community model simulates the effect of increased energy efficiency standards for building envelops by constraining the market share available to lower efficiency building types. In the simulations run in this research project, DPA guidelines and DCC exemptions were not designed to incentivize the use of lower-intensity fuels for the specified reductions in energy consumption. Adding an incentive for cleaner fuels would likely result in greater GHG emissions reductions associated with building energy efficiency policies. For example, local governments could in theory specify that only residential buildings that were built to energy efficiency standards 14% above the current BC building code would qualify for a DCC exemption equivalent to 5% of the building's capital costs, provided the developer uses fuels that have a GHG-intensity lower than that natural gas or heating oil. As mentioned above, simulating the fuel constraint is not straightforward within the current version of the CIMS-Community model.

The effect of building standards on energy consumption within the Residential and Commercial sectors is shown in Figure 4.6, while the effects of DCC exemptions are shown in Figure 4.7. Irrespective of the policy stringency setting, these policies have only a minor impact on regional GHG emissions, particularly in the Residential sector. This can be partially explained through the rationale above, namely that the policies in this project were designed to reduce energy consumption of buildings rather than GHG emissions. It is likely that deep GHG reductions will be achievable only through fuel switching, with reduced energy consumption and improved energy efficiency only contributing marginal GHG reductions. The other factor that could help explain these results is the fact that the new buildings with improved energy efficiency only account for a small percentage of the total building stock. Given the very slow turnover of building stock due to retirement, retrofitting and replacement with new stock, any policies that aim to improve the energy efficiency or switch to building fuels with lower GHG-intensities will be very slow acting.

Figure 4.6. Impact of Building Standards on Total Energy Consumption

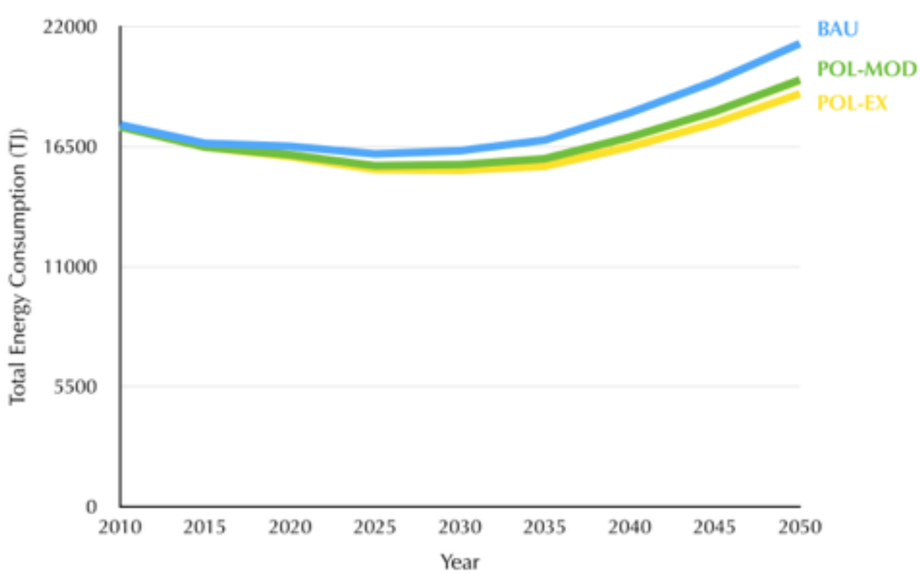
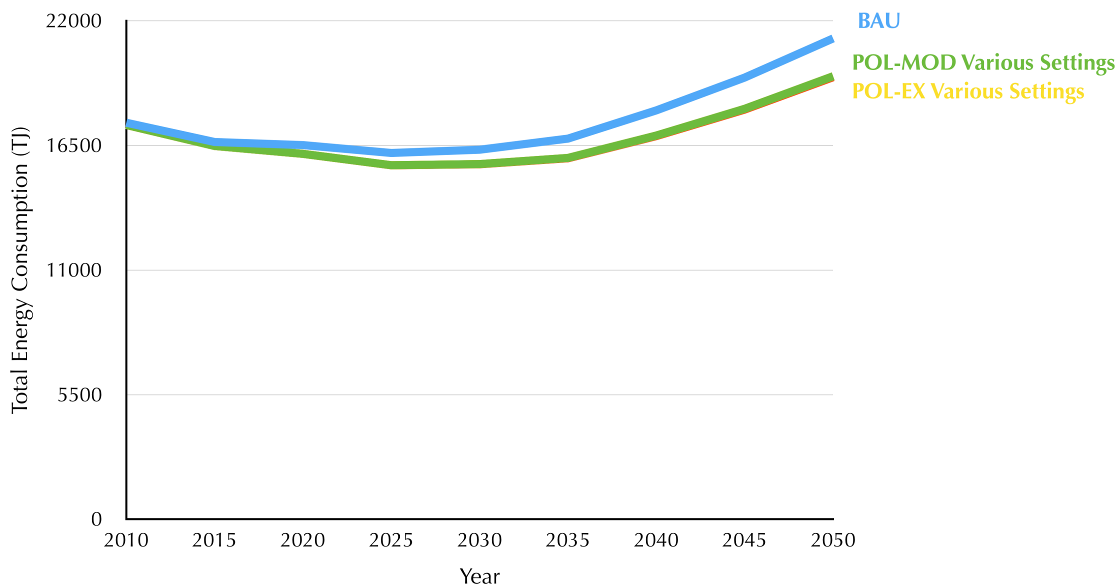


Figure 4.7. Impact of DCC Exemptions on Total Energy Consumption



The following chapter concludes with some recommendations for Nanaimo decision-makers based on the results from this project, and considers how this work could be built upon through future studies.

5. Conclusion

Municipalities are no longer seen as simply the providers of services and utilities, but are increasingly being looked upon as loci for action on climate change. The suite of climate policies implemented by municipalities will be influenced by criteria used in this project, such as jurisdictional reach and likely political feasibility and environmental effectiveness of each policy. This research project helped to develop and experimentally apply the CIMS-Community model to demonstrate its utility as a tool to guide decision-making at the local government level.

Utility of CIMS-Community Model

Local governments can use CIMS-Community as a policy assessment tool in the areas of target setting, policy design, and policy evaluation. In this project, the effectiveness of municipal policies was evaluated in three main areas: vehicle operating charges, land use densification, and improvements to building energy efficiency.

Realistic Target Setting

The per capita GHG emissions achievable by 2050 under the most aggressive POL-EX simulations were found to be 1.5 ktCO_2e/person greater than Nanaimo's stated target. While CIMS-Community is not comprehensive in its coverage of the GHG abatement policies under Nanaimo's influence - for example it does not cover emissions from liquid waste, agriculture, or livestock - incorporating emissions reductions from these additional sectors is unlikely to make up the shortfall and achieve Nanaimo's stated GHG emissions reduction targets. CIMS-Community can be therefore be used by local governments as a "reality check" to help them set targets that may be less ambitious, but more likely to be achieved.

Directed Policy Design

Improving the energy efficiency associated with building standards is within the legislative jurisdiction of municipal governments and can be implemented through policy instruments such as DCC exemption subsidies for more energy efficient buildings. The results from CIMS-Community simulations in this project suggest that while these policy instruments do indeed result in lower energy consumption for Nanaimo, they only negligibly lower the GHG emissions of the region. Based on these results, local governments could improve upon this policy design by tying subsidies for energy efficiency gains with a specification of fuel restrictions. In other words, local governments could choose to implement a policy that incentivizes the use of cleaner fuels in more energy efficient building technologies.

Policy Evaluation

The utility of CIMS-Community can also be illustrated through a comparison of Nanaimo's current community profile and BAU. Vehicle use is currently the major contributor to greenhouse gas emissions across all Nanaimo jurisdictions. It is therefore unsurprising that one of the goals of Nanaimo's community energy and emissions plan is to reduce emissions associated with personal vehicles. One policy instrument currently being employed to achieve this goal is the use of financial incentives to promote the adoption of low emission vehicles (Nanaimo, 2013). Policy makers could consider dropping, reducing, or delaying the use of these incentives when confronted with CIMS-Community's BAU forecast, since the forecast shows the adoption they are trying to promote as occurring even in the absence of such incentives. This suggests at the very least that Nanaimo's incentive-based policy will be economically inefficient, since it is targeting some adopters who would have transitioned to low emissions vehicles even in the absence of the incentive.

My overall assessment of the likely impacts of GHG emissions abatement policies under Nanaimo's control suggest their stated emissions reduction targets are very ambitious and unlikely to be achievable in the desired timeframes. However, if emissions reduction targets are viewed more as a means of working towards a desirable societal shift – as opposed to an end in themselves – these ambitious targets might hold some value in impressing upon citizens the urgency for local action against climate change.

Recommendations for Future Studies

Three potential areas for development of the CIMS-Community model are improvements to the model's comprehensiveness, analysis capabilities, and utility as a policy assessment tool for local governments.

Comprehensiveness

Including GHG emissions associated with sectors such as agriculture/livestock and liquid waste would broaden sector coverage. Data availability at the local government level will determine the timing for building and populating these sectors within the model. The inclusion of emissions associated with a community's upstream energy would also improve the model's comprehensiveness, though this requires both data availability and the ability to meaningfully standardize the diversity of upstream energy sources that feed communities across BC.

Analysis

Improvements to the resolution at which the model operates are already underway with the proposed development of a neighbourhood version of the model. Future updates could support analysis at even higher resolutions including block, building, and parcel level analysis. This would depend on relevant data availability and/or development of robust data disaggregation assumptions.

Utility

The inclusion of additional model outputs, such as capital and operating costs, will significantly enhance the utility of CIMS-Community as a policy assessment tool. Costs can currently be exogenous calculated, but this is not user-friendly and requires a good understanding of CIMS methodology.

These developments to CIMS-Community would help improve a model that already scores well against the majority of ideal model attributes.

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