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Evaluating Residential Energy, Emissions and Cost Scenarios for Prince George's Official Community Plan: ICEM Approach, Methods and SCEC³ Model Results

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Introduction

This summary explores the Integrated Community Energy Modelling and Mapping (ICEM) approach and its contribution to the development of a consistent method for characterizing energy and emissions in the building stock in communities. It presents final results of analysis of energy and emissions scenarios in the residential housing stock developed in the 2008 to 2012 timeframe in support of Prince George's 2012 Official Community Plan (OCP) update. It describes the overall project approach, key datasets used, integrated modelling and mapping methods developed and findings around the use of visualizations in community energy and emissions planning processes. Results are discussed and recommendations made for potential future research.

Central to this method was the Spatial Community Energy, Cost and Carbon Characterization (SCEC³) model. Developed from 2008 to 2012 by Natural Resources Canada's CanmetENERGY and Vive le Monde Mapping in collaboration with the City of Prince George, the SCEC³ model enabled evaluation of the energy, greenhouse gas and cost implications of specific actions related to energy use and supply in residential buildings. The SCEC³ model was built to provide decision support for community level energy and emission reduction planning initiatives in the City of Prince George BC.

This research will be of interest to anyone developing and implementing energy conservation and GHG emissions mitigation initiatives in buildings and communities including: community energy managers and planners, consultants, academics and students, utilities, professional associations and senior government officials tasked with policy and program development.

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Energy and emissions plans developed by Canadian communities in recent years contain visions that broadly articulate objectives of climate change mitigation, energy security, economic development and a higher quality of life. These plans have been assessed as strong in taking a comprehensive planning approach, setting energy and Greenhouse Gas (GHG) targets and stakeholder consultation. There is room for improvement however in moving from a laundry list of actions to a strategic action plan approach and quantification and economic evaluation of actions (CEA, 2013). Rising energy use and GHG emissions both in communities and nationally suggests that while conducted in earnest, community energy and emissions plans do not always translate to action on the ground. Barriers to implementation include high up front capital costs, legislative barriers and the need for sustained co-ordinated efforts. A related and not insignificant challenge is the estimated $123 billion national infrastructure deficit (Federation of Canadian Municipalities, 2012). Not closing the community energy and emissions 'planning-to-implementation gap' and rapidly accelerating the deployment of integrated community energy solutions will inevitably translate into declining environmental quality and decreased economic stability and quality of life for Canadians.

Understanding that "if it can't be measured it can't be managed," one crucial area of investigation is the characterization or measurement and modelling of energy and emissions in communities and the decision support available to municipal staff, decision makers and enabling organizations. Integrated community energy modelling and mapping (ICEM) approaches can assist with the prioritization of actions, support strategic capital investments and accelerate implementation of Integrated Community Energy Solutions (ICES) by all orders of government and utilities.

Scenarios Developed for the City of Prince George

Four future scenarios developed between 2011 and 2012 assess potential implementation approaches for the residential sector in Prince George, BC to achieve the community-wide emissions target of a 2% reduction in Greenhouse (GHG) emissions from 2002 levels by 2012 articulated in the City's Official Community Plan (OCP). The model was designed to assess what combination of actions would achieve the city's GHG emissions reduction target. This was done on a research basis as municipalities generally do not have access to sophisticated quantitative decision support to set their targets. It was recognized at the outset that timing would not permit the City to make course corrections if the modelling suggested the City's target would not be reached.

The four scenarios, **Business As Usual (BAU), Standard Suburban, Neighbourhood Centres** and **Downtown Infill**, are named to correspond to types of growth patterns. The first two scenarios follow a traditional approach to new construction, the third the nodes and transportation corridors growth pattern in the OCP and fourth the land use approach outlined in the 2009 Downtown Prince George Smart Growth on the Ground Concept Plan. These four scenarios specify retrofits to existing dwellings and renewable energy technologies including solar domestic hot water and connections to the City's downtown district energy system (assumed for the purpose of this study to be biomass-fuelled). Types and rates of retrofits and renewables were guided by local experts and specified as BAU, 'Increased' and 'Intensified'.

The retrofit combinations referred to in the scenario descriptions below are different for each housing archetype as outlined in Table 1.

Table 1 Housing archetypes and retrofit combinations

Archetype	Housing Type	Storeys	Age	Retrofits
SFD1	single family detached	1	1943–1977	Furnace, instantaneous hot water, chimney closure
SFD2	single family detached	1	1978–1996	Furnace, instantaneous hot water, attic insulation upgrade to R56
SFD3	single family detached	2	1978–1996	Furnace, instantaneous hot water, attic insulation upgrade to R56
ROW1	row house	1	1963–1992	Furnace, windows and upgrade of basement insulation to R23
MOBILE1	mobile	1	all ages	Furnace and air source heat pump
APT	Apartment unit in MURB	various	all ages	30% increase in efficiency through renovations to walls, windows, lighting and appliances and other mechanicals

The Business As Usual Scenario anticipates that the majority of the 5500 units of new construction will occur in the suburbs by 2025. Of these new units:

- 49% will be new single family detached (SFD) of which 67% will be built to 2008 BC Building Code (BCBC) and 33% to an EnerGuide for Houses (EGH) 86;
- 45% will be new row houses, all built to the 2008 BC Building Code (BCBC); and
- 6% will be apartments that are also built to the 2008 BCBC.

For existing dwellings, 24% overall will be retrofitted with either:

- a new furnace (26% of SFDs, 6% of row houses); or
- a combination retrofit (13% of SFDs, 6% row houses, 11 % MURBs); and
- 1% of the retrofitted dwellings will be supplied with solar DHW.

The Standard Suburban Scenario uses the same new construction profile as the BAU scenario. For existing dwellings, 37% overall will be retrofitted with either:

- a new furnace (26% of SFDs, 6% of row houses); or
- a combination retrofit (30 % of SFDs, 24% row houses, 20% mobiles, 11 % MURBs)

And of these existing retrofitted dwellings:

- 1% will be supplied with solar DHW.

The Neighbourhood Centres Scenario sees the majority of the 5500 units of new construction in OCP growth priority areas. Of these new units:

- 49% will be SFDs (67% of which built to EGH 86 and 33% built to 2008 BCBC);
- 35% will be row houses built to the 2008 BCBC; and
- 16% will be apartments also built to the 2008 BCBC.

For existing dwellings, 27% overall will be retrofitted with either:

- a new furnace (26% of SFDs, 6% of row houses); or
- a combination retrofit (18% of SFDs, 10% row houses, 11 % MURBs).

And of these existing retrofitted dwellings:

- 25% will be supplied with solar DHW; and
- 5% with solar PV.

The Downtown Infill Scenario sees most new construction in the downtown. Of these new units:

- 47% will be apartments, 600 of which will be heated with biomass-based Downtown District Energy System (DDES);
- 35% will be row houses built to the 2008 BCBC.
- 18% will be SFDs, of which 66% built to EGH 86 and 24% to the 2008 BCBC.

For existing dwellings, 38% overall will be retrofitted with either:

- a new furnace (39% of SFDs, 11% of rows); or
- a combination retrofit (17% of SFDs, 19% rows and 19% MURBs).

For existing retrofitted dwellings:

- 25% will be supplied with solar DHW; and
- 5% with solar PV.

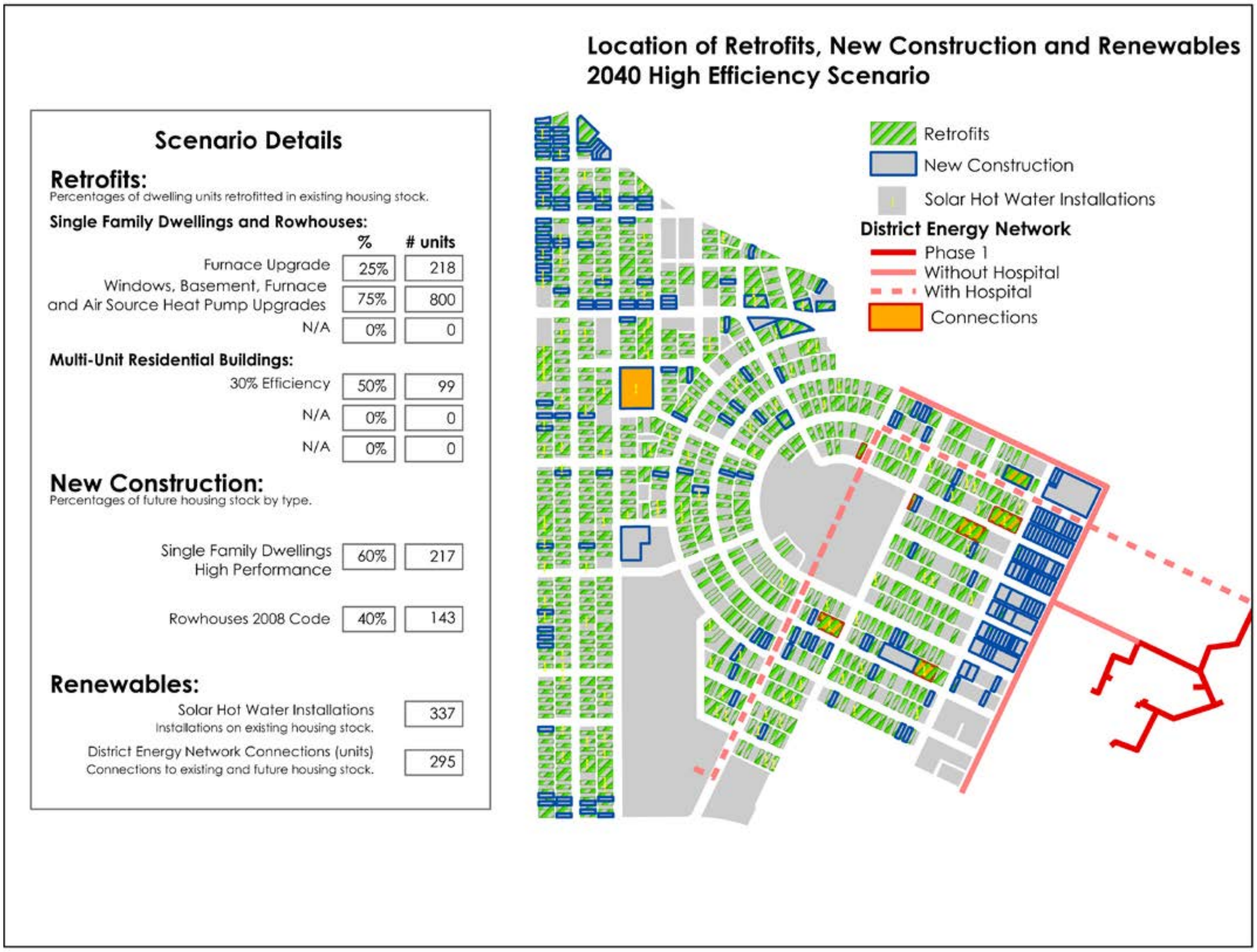
The SCEC[3] model baseline year was 2008, according to the most recent building data available. To enable comparison with the community's GHG target, the scenarios were rolled back to 2002. In other words, buildings built between 2002 and 2007 and their energy use and GHG emissions were subtracted from modelled totals.

Analysis was performed for two time frames:

1. The first target date of 2025 represents the OCP planning horizon; by 2025 the model assumes the retrofit of existing buildings, new construction and integration of renewable energy technology will have been completed.
2. Analysis was also done looking out to 2040 due to high up front capital costs, low electricity rates and associated extended payback periods. This time-frame shows the cumulative cost savings that accrue over a longer timeframe.

Figure 1 illustrates how the SCEC³ model is built at the parcel and building scale. Data on each building in the building stock are augmented with assumptions about retrofits, new construction district and renewable energy technologies assigned to each building and parcel over a planning horizon (in this example, to 2040). Implementation is established on a percentage basis converted into the number of units to which improved performance will be applied. The model randomly allocates the measures to houses and buildings that correspond to certain archetypes. The model does not predict which specific lots will see new construction or which specific buildings will be retrofitted but merely assigns measures to representative properties for the purpose of calculating neighbourhood or community-wide energy and GHG emissions reductions and cost savings.

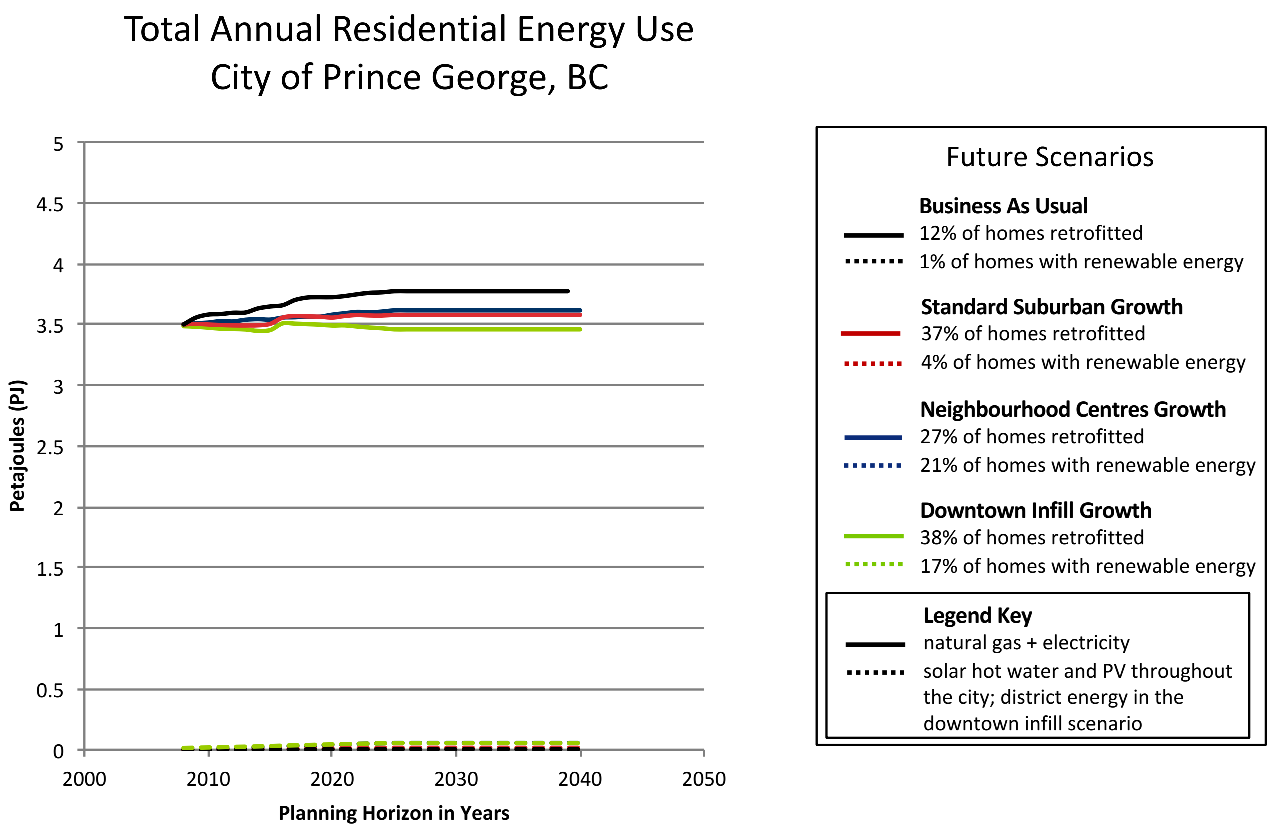
Figure 1 Map showing SCEC³ model allocation of energy efficiency and technology measures



Modelling Results

Results suggest that the Downtown Infill Scenario, where a suite of energy end-use and supply measures are implemented in an integrated step-wise manner, is overwhelmingly the most effective choice for conserving energy, reducing emissions and increasing cumulative cost-savings for Prince George residents over the long term. Even an ambitious approach to new construction, retrofits and integration as established in the Downtown Infill Scenario will result in a reduction of less than .5 petajoules annually. See Figure 2 for an illustration of the relative contribution of energy efficiency and renewable energy technology measures. Particularly striking is the gap to net zero energy.

Figure 2 Total annual residential energy use in Prince George, BC under four scenarios



Source: NRCan, Vive le Monde Mapping; results derived from the Spatial Community Energy Carbon and Cost Characterization Model (SCEC[3]).

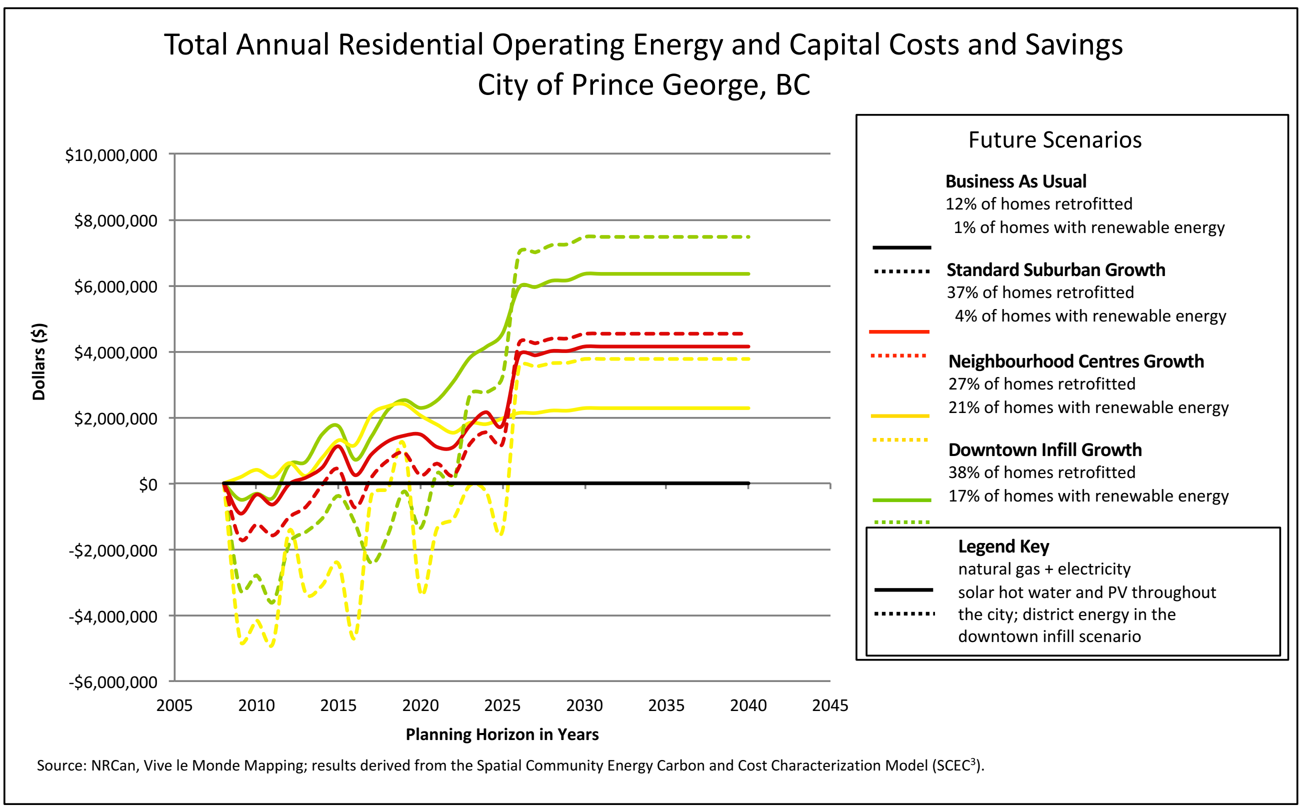
Results suggest that it will be challenging for the residential sector in Prince George to "do its part" to meet the community-wide GHG reduction target. Even an ambitious program of retrofits to 38% of the existing housing stock under the Downtown Infill Scenario, will see only a 2.3% reduction in GHG emissions when all measures have been implemented in 2025. Given that Prince George is a slow growth community, model results for both energy and GHG emissions have implications for communities that are growing rapidly, where it will be significantly more challenging to achieve net zero energy or reach ambitious emission reduction targets.

Interestingly, while energy conservation and GHG emissions reduction may have been the original motivation for the study, long term costs savings may actually provide a more compelling justification for action. When the financial implications of Standard Suburban, Neighbourhood Centres and Downtown Infill Scenarios are compared to a Business As Usual approach for the seventeen year OCP timeframe from 2008 to 2025, savings by residents could total as much as $30 million dollars. Cumulative savings for the most common single family dwelling could reach $6,000 dollars, depending on the combination of retrofit and renewable energy technology measures pursued.

Over a thirty-two year time frame from 2008 to 2040 in comparison to a BAU approach, under the Downtown Infill Scenario the residential sector could see cumulative cost savings of $98 million dollars after capital costs have been repaid. For the most common single family dwelling, this could represent potential cumulative savings of up to $27,000 dollars.

Figure 3 shows that after the capital costs of retrofits and renewable energy technologies have been repaid by the end of the planning horizon, all three future scenarios will produce annual operating energy cost savings. The position of the lines in relation to the $0 axis represents years when the capital cost of retrofits and operating costs are either in a deficit or surplus in comparison to the BAU Scenario. Solid lines represent scenarios involving only energy efficiency measures in new and existing houses; dotted lines represent scenarios that incorporate both efficiency and renewable energy technologies. According to the model up until 2025, the year by which all the retrofits and renewable energy technologies are installed, some of these lines initially show a deficit. There is more money expended during these years due to the high capital cost of installation than saved through lower operating energy costs. When these initial capital costs are paid off, energy savings translate into operating energy cost savings. Although scenarios involving renewable energy technologies are more costly in the short term, they save money in the long-term. Future savings are exemplified in the graph past the year 2025. Solid lines represent the energy efficiency aspect of the scenarios without renewable energy sources. Dotted lines represent combined cost savings from energy efficiency and renewable energy components of the scenarios. It can be concluded that taking an integrated approach combining energy efficiency and renewable energy technologies is more advantageous from a future cost savings perspective. These savings represent dollars that can be retained in Prince George's local economy.

Figure 3 Total annual residential operating energy and capital costs and savings for BAU and three alternate future energy scenarios



Looking at energy use in future scenarios, the Standard Suburban scenario sees an increase of 10.1% in comparison to the SCEC[3] model 2002 values (as a proxy for the 2002 Prince George inventory). Even under the Downtown Infill Scenario an increase in energy use of 1.1% in comparison to a 2002 modelled baseline is anticipated.

Modelling results for GHG emissions tell a similar story. In comparison to the 2002 baseline referenced in the City of Prince George's community-wide GHG target, the change in emissions ranges from an increase of 8.1% under the Standard Suburban Scenario to a decrease of 2.3% under the Downtown Infill Scenario. This projection implies that the residential sector will only surpass the community-wide target by 0.3% under the Downtown Infill Scenario.

Action on energy and emissions in Prince George's residential housing stock should therefore not only be motivated by environmental considerations when the economic benefit may in fact be larger. Implementing energy efficiency and renewable energy technology measures in new and existing dwellings can be thought of as planting a forest of money trees that will grow cost savings for Prince George residents over the long term. To achieve implementation of the Downtown Infill Scenario, long-term vision, innovation in municipal and provincial policy and creative financing are required to make the business case for energy efficiency and renewable energy technologies when low utility rates and high upfront capital costs are taken into account. Taking a strategic, long-term approach to energy planning is not unlike planting seedlings today that will grow into a forest that yields economic benefits in years to come.

Recommendations for Prince George and Other Municipalities

Compact, complete land use patterns lay the foundation for communities that are energy efficient and economically efficient. Energy savings are optimized when higher density new construction is emphasized; however to achieve even modest energy conservation and emissions reductions, the approach to retrofits must be aggressive. Renewable energy technologies are essential for reducing GHG emissions – and may be crucial for the city to achieve targets on a going-forward basis – however financial solutions are also required to help mitigate high up front capital costs.

Modelling results indicate Prince George can establish inherent energy efficient land use patterns and new construction by following planning objectives laid out in the 2009 Smart Growth in the Ground Downtown Concept Plan and the Nodes and Corridors land use pattern laid out in the OCP. Encouraging new construction that is higher density and mixed-use with passive design features and energy efficient mechanical systems will lead to higher building energy performance. Consideration of building orientation supports energy efficiency and also improves feasibility for solar renewable energy applications. Design guidelines and development permit areas are policy options within local government jurisdiction that can support energy efficient new construction.

Although it is recognized that local governments have little influence over energy performance in the existing housing stock, a concerted effort around retrofitting existing dwellings is nevertheless required if residents wish to see long-term economic benefit from energy efficiency measures.. Voluntary communication and educational measures could involve cross-promotion of conservation demand management programs led by utilities or other levels of government, promotion of home energy evaluations and availability of retrofit financing schemes.

Despite the high up front cost for solar energy technologies it would also be important to explore mechanisms to support their adoption by Prince George residents. For the residential sector at the time of the study, solar DWH was found to be more attractive due to the high cost of solar PV. Solar PV was deemed more appropriate for commercial and institutional buildings. Due to falling prices for solar panels and inverters, residential solar PV installations may now also be financially viable. Other technology options such as geothermal hold promise but were not evaluated as a part of this study. Renewable energy technologies may also be explored as an area of economic development for Prince George.

In summary, results of this analysis suggest that pursuing a Business As Usual Scenario means potentially foregoing tens of millions of dollars in operating energy cost savings by the residents of Prince George by 2040. While it does represent a short term cost to taxpayers, allocating modest resources for city staff to facilitate implementation of energy and emissions actions already laid out in the plans will save Prince George residents in the long run. Establishing an energy advisory committee is a complementary low cost measure that has proven highly effective in other jurisdictions.

Discussion on ICEM, an Innovative Integrated Decision Support Approach

Further to the project approach and results obtained, this summary also describes the integrated community energy modelling and mapping (ICEM) approach and associated technical methods developed in the course of the research. Innovative methods in the areas of data, modelling and visualization were used to create the SCEC^3 model. The communication of interim project results generated interest among others undertaking community energy modelling and mapping initiatives as they were tackling similar themes of data, modelling, scenario development and visualization and communication.

Data

Existing datasets can be used for integrated community energy modelling and mapping. BC Assessment property assessment records enable identification of local housing archetypes and contain floor area data required to distribute energy intensity factors. The ecoENERGY retrofit audit records identify typical retrofits and local geometric and mechanical characteristics to develop accurate housing energy simulations. LiDAR data may be re-purposed for analysis of rooftops suitable for solar photovoltaic (PV) and Domestic Hot Water (DHW) panel placement. Expert opinion and local knowledge informs assumptions around growth rates and local retrofit and technology costs. Data gaps include: audit records for multi-unit residential buildings, and household-level measured electrical and natural gas data by archetype not utility rate class.

Modelling

The ICEM parcel data method (ICEM-PDM) enables integration of data at the parcel and building scales; the use of a Geographic Information System (GIS) enables aggregation to any level of geography. Local housing and building archetype identification and characterization leverages both GIS and HOT2000 housing energy simulation to develop locally-relevant housing energy information. Remote sensing is used to assess the general technical potential of solar PV and solar DHW.

Designed to run on mainstream software packages used by local governments, the SCEC^3 model is developed in Excel and ArcGIS in parallel. The Excel Dashboard enables planners to quickly assess which scenarios are worth exploring in more detail with GIS analysts using the ArcGIS application.

Scenario Development

Actions in the SCEC^3 model are explored in three major areas: new construction, retrofits and the introduction of renewable and district energy technologies. A model user specifies the number and type of each of these actions. The choice of baseline year and end of the planning horizon is flexible; within this timeframe it is possible to define when a specific new construction, retrofit or renewable energy action will take place.

Visualization and Communication

Graphic and map outputs are best planned with the audience and decision context in mind. To facilitate understanding of trade-offs associated with different scenarios, results should be presented at building, neighbourhood and community-wide scales for energy, GHG emissions and costs. Information at the household scale is that to which people can most directly relate. Photographs of housing archetypes and Sankey diagrams were found to be effective. While GIS based decision support would seem to lead naturally to showing maps, other common graphic types including bar graphs, line graphs are often more effective and appropriate.

Communication and Technology Transfer

The ICEM methodology and SCEC^3 model results have informed community energy modelling and mapping efforts across Canada via numerous projects and initiatives including:

- Tract and Neighbourhood Data Modelling (TaNDM) project, BC
- the BC Community Energy and Emissions Modelling community of practice
- Victoria's Climate Action Navigator
- BC Hydro's Policy Impact Estimator
- Alberta's C3 and the Energy Mapping in Alberta's Industrial Heartland project
- a Manitoba Hydro-supported University of Manitoba Master's thesis project focused on the Ebby-Wentworth neighbourhood in the City of Winnipeg
- the Integrated Community Energy Mapping for Ontario Communities (IEMOC) project
- Horizon Utilities' Energy Mapping for Conservation Demand Management project.