City of North Vancouver 100 Year Sustainability Vision: GHG Measurement and Mapping

Technical Paper

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This work was carried out as part of the Design Centre for Sustainability's *Sustainability by Design Initiative* (SXD). SXD is a multi-year, multi-project initiative to generate a picture of a sustainable Metro Vancouver region of 4 million in 2050. This initiative recognizes that to achieve a sustainable region, we must employ robust processes and tools to qualitatively and quantitatively evaluate our planning and design options as part of our decision-making process, rather than purely as an evaluation of outcomes. The City of North Vancouver 100 Year Sustainability Vision project was carried out within this context. *The Design Centre for Sustainability* (DCS) is a research centre within the UBC School of Architecture and Landscape Architecture. The mission of the DCS is to promote, support and encourage collaborative research in the broad area of *landscape* with a special emphasis on *"real world"* research as it applies to local and global communities.

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ABSTRACT

The City of North Vancouver 100 Year Sustainability Vision project is one of the first projects in British Columbia to consider at the municipal scale the feasibility of meeting the challenging GHG emission targets established by the 2007 Greenhouse Gas Reduction Targets Act. Like many other municipalities, the City faces this challenge within the context of significant population growth over the next several decades, resulting in potentially a doubling – or tripling – of population in certain areas. Consequently, the project addresses the question of what specific decisions for land use, building form, transportation and infrastructure will contribute to reducing energy consumption and GHG emissions while supporting other environmental, social and economic goals. The potential to achieve the project's GHG emission targets was explored through a public, stakeholder-driven process culminating in a four-day design charrette, during which project participants generated a long-term, low-GHG vision for the City. To evaluate the energy and GHG implications of the urban form decisions made during this process, researchers used a "case" and "development pattern" based methodology integrating building, transportation, infrastructure and technology options to quickly assemble and evaluate scenarios representing baseline 2007 conditions and the 100-year vision developed by stakeholders. GIS analysis was used to generate both quantitative GHG emissions estimates and spatial "GHG maps" of existing and future conditions in the City. Results of this analysis indicate that approximately 31% of the targeted emission reductions, on a per capita basis, can be achieved through urban form decisions alone. With complimentary policy strategies, investment in appropriate technologies and cooperation from the regional, provincial and federal governments, full realization of the targets may be feasible.

1. INTRODUCTION

Globally, the causes and impacts of climate change now have mass consensus. The 2007 Intergovernmental Panel on Climate Change (IPCC) synthesis report offers the strongest evidence to date on human contributions to greenhouse gases (GHGs) in the atmosphere, stating that anthropogenic impacts over the last 30 years have raised average global temperatures, influenced extreme weather events and altered many physical and biological systems. Minimizing the negative effects of climate change is now believed to require between 50% and 85% reductions in GHG emissions from 2000 levels by 2050. Despite substantial challenges, there is agreement among leading experts that significant offsets and reductions in emissions can still be achieved by economically beneficial means worldwide (Bernstein 2007).

Within the Province of British Columbia, GHG emission reduction challenges are being addressed by Provincial legislation and policy such as the Climate Action Plan (2008), the Carbon Tax Act (2008) and the Greenhouse Gas Reduction Targets Act (2007). Achieving the targets set forth in these documents will require increased levels of cooperation between the Province, its regions and its municipalities and will demand both broad planning agendas and negotiated, locally appropriate strategies across a geographically, climatically, economically, demographically and politically variable landscape.

At the regional and municipal level, many of the decisions that will be made to mitigate climate change will necessarily involve land use and urban form. Such decisions on growth, land use, infrastructure, transportation and building form have immense impacts on the energy consumption, energy source opportunities and GHG emissions in communities.

Despite increasing knowledge on the relationship between urban form and environmental issues such as greenhouse gases, there remains a significant gap between planning intentions and development occurring on the ground. The Design Centre for Sustainability (DCS) and its partners seek to shrink this gap through the development of new tools that link neighbourhood and municipal urban form strategies to many aspects of sustainability, including climate change targets and priorities. This paper describes the first attempt to apply the tools developed by the DCS to estimate and visualize the GHG emission implications of urban form decisions within a collaborative, municipal planning process.

The City of North Vancouver 100 Year Sustainability Vision project explored the ability of a BC municipality to reduce annual community GHG emissions 80% from 2007 levels by 2050 and to eliminate community GHG emissions by 2107. The potential to achieve these targets was explored through a public, stakeholder-driven process culminating in a four-day design charrette, during which project participants generated a long-term, low-GHG vision for the City. To evaluate the energy and GHG implications of the urban form decisions made during this process, researchers used a “case” and “development pattern” based methodology integrating building, transportation, infrastructure and technology options to quickly assemble and evaluate scenarios representing baseline 2007 conditions and the 100-year vision developed by stakeholders. Geographic information system (GIS) analysis was used to generate both quantitative GHG emissions estimates and spatial “GHG maps” of existing and future conditions in the City. Results of this analysis indicate that approximately 31% of the necessary emission reductions, on a per capita basis, can be achieved through urban form decisions alone. With complementary policy strategies, investment in appropriate technologies and cooperation from the regional, provincial and federal governments, full realization of the targets may be achievable.

1.1 Context

1.1.1 The City of North Vancouver

The City of North Vancouver (CNV) is a small community located at the base of the North Shore Mountains in the Metro Vancouver region of the Lower Mainland of British Columbia. Bounded to the south by the Burrard Inlet, the City is otherwise bordered by the District of North Vancouver, the largest of the three North Shore municipalities. With a land area of approximately 12 square kilometers, the City supports a population of over 48,000 and provides workspaces for more than 23,000 jobs. It is situated centrally between the two bridges linking the North Shore to Vancouver. CNV is also uniquely connected to downtown Vancouver by the SeaBus, the only passenger ferry route operated by Translink, the public transit authority for southern British Columbia. Due to its central location on the North Shore, relatively high density, transit accessibility and proximity to Vancouver's central business district, CNV functions as a town centre within the Metro Vancouver region.

Throughout the City's development, CNV's limited land base has predetermined a more compact urban form than many municipalities, resulting in higher population and residential densities, a lower proportion of single family homes and one of the lowest rates of automobile use in the region (Alexander and Tomalty 2001). Current CNV planning priorities, as established in the City's Official Community Plan (2002), specifically address issues of sustainability and livability, including prominent energy goals and related initiatives.

In 2004, CNV established the Lonsdale Energy Corporation (LEC), an independent utility owned and regulated by the municipality. This utility provides district energy services to the City through boiler "mini-plants" connected into the LEC system. The system presently supplies heat and hot water to 11 development projects. Supplementing this system is a new installation of 120 rooftop solar hot water panels. By 2010, the City anticipates serving up to 20 developments with the LEC system, totaling over 3 million square feet of building area (City of North Vancouver). In recognition of its achievements in implementing more sustainable development, the City has been presented two Energy Aware Awards from the Community Energy Association (1998, 2005) and the Province's inaugural Green City Award for 2007.

While the City has been successful in achieving many of its planning and sustainability goals, CNV has identified that continued success over the next 20, 50 and 100 years will demand careful consideration. First, as the City's land supply is nearly built out, new development will necessarily be accommodated mainly through infill strategies. Second, energy consumption will increase with population, putting additional demands on the LEC district energy system as well as regional energy infrastructure. As increasing emphasis is placed on greenhouse gases, cleaner energy sources for all uses will be of particular concern. Finally, as in many cities, population increases and new development often challenge essential aspects of sustainability such as affordability and preservation of open space. These and related issues were considered in the City of North Vancouver 100 Year Sustainability Vision project, which is ongoing through December 2008.

1.1.2 100 Year Sustainability Vision project

In November 2007 the City of North Vancouver initiated the 100 Year Sustainability Vision project which sought to combine a long-term, collaborative visioning exercise with explicit considerations of GHG and energy reductions. The 100 Year Sustainability Vision is the fifth case study of the Sustainability by Design (SxD) initiative managed by the University of British Columbia's Design Centre for Sustainability. The project's vision for CNV "to be a vibrant, diverse and highly livable community that provides for the social and economic needs of our community within a carbon neutral environment by the City's 200th birthday in 2107," framed a series of three stakeholder events taking place between April and September 2008. The emphasis on GHG emissions embedded in the project's vision demanded the development of new methods of evaluating and mapping the GHG performance of existing urban forms as well as the urban design decisions resulting from a collaborative design process. Culminating with a multi-day design charrette, findings and outputs from the project are intended to shape future planning initiatives for the City and to bridge between the 20 to 30 year planning work embodied by the Official Community Plan and long-term planning goals.

1.1.3 Project GHG meta-targets

Building on the energy and transportation planning objectives outlined in the City's current Official Community Plan, the Sustainability Vision established two GHG-related project meta-targets:

1) To achieve zero net community GHG emissions by the City's 200th anniversary in 2107

2) To reduce total community GHG emissions 80% from 2007 levels by 2050

The second target was adapted from the Provincial Greenhouse Gas Reduction Targets Act, ratified in November 2007. This act mandates that province-wide GHG emissions will be 33% lower than 2007 levels by 2020 and 80% lower by 2050. In addition, this act calls for annual progress reports on GHG reduction and carbon neutral public sector operations by 2010.

In light of these targets, an important component of the project was to develop a methodology to map and measure the GHG implications of urban form choices made during the course of the project. This method, described below, was used to model the urban form and transportation implications of the 100-year vision resulting from the charrette. In order to provide a consistent comparison to the City's current GHG emissions, the City's present conditions were modeled using the same methodology. This process also provided an opportunity to calibrate the model and method to currently available energy and emission inventories.

1.2 Community GHG Emissions and Urban Form

1.2.1 Community GHG emissions

Local governments must be able to account for the wide variety of GHG emissions that fall within their jurisdiction. According to standard emission inventory protocols, municipal inventories generally cover two specific areas: corporate emissions (emissions resulting from municipal operations) and community emissions (emissions resulting from community-wide activities). Recently, BC's Ministry of the Environment has begun assembling community emission inventories for each of the 185 local governments within the Province. These standardized inventories will play an important role in meeting the requirements of the 2007 Greenhouse Gas Reduction Targets Act by recording and tracking each local government's contributions to GHG emission reductions (Sheltair Group 2007).

Community inventories typically include residential, commercial and industrial emissions from buildings as well as emissions from transportation and solid waste. According to International Council for Local Environmental Initiatives (ICLEI) protocols for GHG analysis (2008), the scope of community GHG emissions includes three distinct areas. First, community inventories account for all direct emission sources located within local boundaries, such as the use of gasoline or natural gas fuels for transportation or heating. Second, community emissions include the indirect emissions resulting from activities occurring within local boundaries, for example, building electricity consumption, where electricity and associated emissions are generated outside of a given municipality. Third, community emissions include any other indirect or embodied emissions resulting from local activities, such as solid waste generation which may result in methane emissions in a landfill outside of local government boundaries. As reflected in the second and third examples, community emission inventories must account for all of the actions and decisions made within a local area, despite where emissions may occur geographically.

1.2.2 Areas of municipal control

Local governments face many challenges and limitations in their ability to mitigate community-level GHG emissions. Municipalities have little control over technological innovations such as fuel efficient vehicles or building integrated photovoltaics. Similarly, local governments rarely control energy utilities and so cannot influence efficiencies or fuel switching in terms of energy generation, new pricing structures or other incentives that would affect the GHG intensity of local energy consumption (Betsill 2000). The City of North Vancouver's Lonsdale Energy Corporation is an exception, although it supplies only a fraction of the City's total energy consumption. Many cities are also required to negotiate regionally on transportation investments and decisions, often with dozens of other participating local governments. Additionally, building codes and resulting energy efficiencies at the building scale are generally controlled provincially within British Columbia; the BC building code has just been updated for 2008 to reflect higher standards in energy efficiency (Union of British Columbia Municipalities).

Despite challenges, municipalities also have great potential to mitigate GHG emissions. According to the Province of British Columbia, municipalities may have control over as much as 43% of total GHG emissions (Sheldon 2008). Much of this control lies in the arena of decisions on urban form, land use and infrastructure planning and associated policies. In dealing with building related emissions, local governments have the ability to control building permit approvals as well as influence development processes. In 2008, legislative changes, including the Local Government (Green Communities) Statutes Amendment Act, increased the authority of local governments to mitigate the environmental effects of development projects by establishing specific development permit areas for promoting energy efficiency, reduced GHG emissions and water conservation (Union of British Columbia Municipalities). Local governments can also tie project approvals to specific performance requirements. For example, in the City of North Vancouver, the establishment of the Hydronic Heat Energy Service Bylaw (2004) created a district heating service area with the requirement that all "multi-family residential, commercial, industrial and institutional buildings…apply for, be connected to, and use the [district energy] service."

In terms of transportation related GHG emissions, local government control and influence on land use, infrastructure planning and project approvals can again have significant impacts. Infrastructure choices made by municipalities, especially street patterns and their relative level of connectivity, can impact the feasibility of transportation choices dramatically. Similarly, the densities and land use mixes associated with various patterns of development, for example transit-oriented developments, further increase the viability of transportation alternatives to the automobile and decrease travel distances for many trips.

1.2.3 Urban form impacts on GHG emissions

As recognized in numerous studies (see, for example, Anderson and Kanaroglou 1993; Boarnet 2001; Ewing et al 2008; Newman and Kenworthy 1989; Steemers 2003; and US EPA 2001), the link between urban form, building and transportation energy consumption and GHG emissions is strong. In British Columbia, transportation accounts for approximately 36% of total provincial GHG emissions while commercial and residential buildings contribute approximately 12% (Province of British Columbia 2008). These sectors are responsible for approximately one-third and one-quarter of total provincial energy consumption respectively (Nyboer 2004). The high contribution of the transportation, commercial and residential sectors to energy demand and GHG emissions in British Columbia and elsewhere underscore the importance of urban form in addressing climate change.

Among the characteristics of urban form that have been shown to influence building and transportation energy consumption and GHG emissions, density, or more compact development, may have the greatest impact. In their 2008 report, Ewing and Rong conclude that more compact development could reduce average household energy by as much as 20%. The benefits of compact building forms are also reflected in the BC Hydro Conservation Potential Review which shows that for the Lower Mainland, attached rowhouses and apartment units use significantly less energy for space heating than the average single family house (Figure 1) (Marbek Resource Consulting 2007). The dramatic difference in performance is due both to the heating efficiencies of shared walls and floors between units and also to the smaller average unit sizes for attached and apartment dwellings. Ensuring that residential dwellings perform efficiently for space heating is particularly important, as over 50% of total residential and commercial building energy is used for space heating in British Columbia (Natural Resources Canada).

For transportation, compact development has the potential to reduce vehicle kilometers traveled (VkT) by 20-40% (Ewing et al 2008). Other studies have found that the differences in per capita VkT between central city and suburban locations can vary by as much as a factor of 4 (US EPA 2001). Density has a strong correlation to transportation impacts including reduced vehicle ownership, lower per capita VkT and an increased proportion of travel by walking and transit. Early studies attempting to link density to travel behaviour found that communities with higher residential densities and transit service drove less and that residents of higher density areas were more likely to take public transit even when controlling for factors such as vehicle ownership (US EPA 2001). More recently, Ewing, et al have suggested that the variation in per capita VkT between low and high density communities is as high as 40%, controlling for income and other factors (2008).

Many other characteristics of urban form also have impacts on building and transportation energy demand and emissions. For example, the availability of daylight, solar energy and the potential for natural ventilation to reduce building energy consumption is most affected by urban geometry, or the shape, arrangement and orientation of buildings in the landscape (Ratti et al 2005). For transportation, a high diversity of land uses increases destination accessibility and is associated with reduced travel times (Ewing et al 2008) and creating greater opportunities to walk and cycle to proximate destinations. Pedestrian friendly design, including street connectivity, building orientation and design and landscape features all contribute to relative pedestrian comfort, which can increase the proportion of non-vehicular transit. Locating high density commercial and residential land uses near transit stations can potentially shift mode choice towards increased transit use as well as reduce average automobile ownership (US EPA 2001).

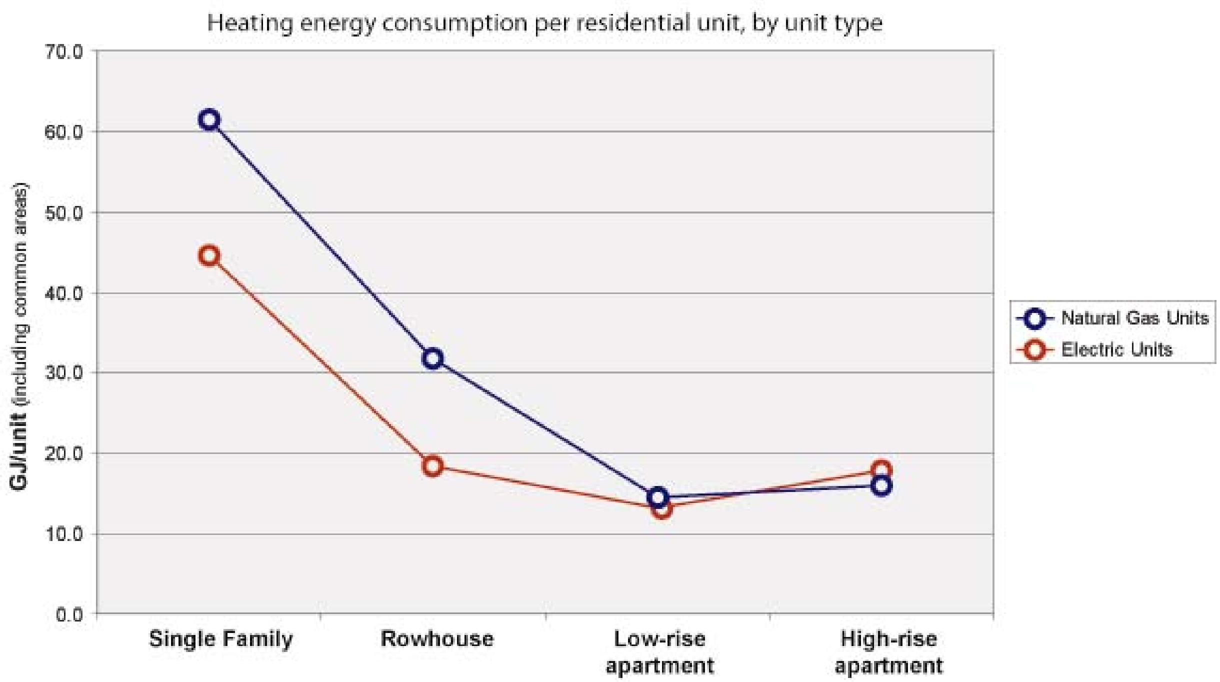

Figure 1: Heating energy consumption per residential unit by unit type, adapted from the BC Hydro Conservation Potential Review, 2007.

2. DATA AND METHODS

2.1 Overview

The development pattern approach, described below, was originally created to facilitate the measurement of urban development scenarios against a range of sustainability indicators within participatory planning processes. This method involves assigning replicable "patterns" of urban development to all areas of the city for a given scenario (current conditions or proposed future conditions). Development patterns are derived from highly specified, parcel-level archetypes that allow for the use of detailed performance models without requiring data for each individual parcel in a city or region - a level of detail that is seldom, if ever, available.

For the CNV project, the range of indicators modeled was expanded to include two simple models of GHG emissions: one for building energy use, the other for transportation associated with residential units. These two models were used calculate GHG contributions for each development pattern and were used to generate "GHG maps" that indicated how the urban form choices of two scenarios influenced the total and relative GHG emissions for different parts of the City.

2.1.1 Development patterns method

The GHG measurement and mapping process used for the 100 Year Sustainability Vision project combined the use of several tools developed or utilized by the Design Centre for Sustainability. Primarily, the process involved the application of "development patterns" across the City using a GIS application, linking building and transportation energy profiles to the development patterns based on selected assumptions and performing a GIS analysis to spatialize the comparative GHG performance of each pattern based on its location in the City.

Development patterns are discrete, replicable units of urban fabric that can be used to "sketch" or approximate a city or region spatially according to existing conditions or future assumptions. Each development pattern represents a shared set of urban form characteristics including land use mix, development densities, street pattern, housing types, building geometries, commercial and residential floor areas and block and parcel configurations. Restated, development patterns can be considered as "packages" of urban form decisions that can facilitate the rapid generation of planning scenarios, enable various types of performance analysis and translate directly into municipal policy decisions.

Beyond representing land use mixes, building types and street configurations, development patterns represent several distinct functions of urban form; namely corridors, nodes and fabric (the areas of land existing between a network of corridors and nodes). The differences between these three functions demands that development patterns are developed both spatially and quantitatively in a variety of appropriate sizes and shapes to reflect the function of the represented urban form. For example, corridor patterns represent long, linear sets of street and land use types, typically one or one-half block wide, while node patterns represent compact areas of land defined by a selected radius (e.g. 100, 200 or 400 meters). Fabric patterns generally represent larger patches of land typically ranging in size from 15-20 ha. Of course, applications of these patterns may vary significantly in land area from the original development pattern; however, the general shape and functional dimensions are maintained.

Development patterns are constructed from information contained in a second tool, the Elements data base, created and maintained by the ElementsLAB research group within the DCS. This database is a comprehensive collection of parcel-scale land use "cases" – case studies representing both built and archetypal examples of streets, open spaces and buildings across a range of densities and forms. Cases vary in land area depending on land use, ranging from a few hundred square meters for small, residential parcels to multiple hectares for large, civic parcels. Each case contains visual and quantitative information including three-dimensional digital models, site plans and data on FAR, floor areas, uses, parcel coverage and number of residential units. These street, open space and building cases can be assembled using spreadsheets, GIS or other spatial modeling platforms such as Google SketchUp to generate development patterns. Variations of patterns can be quickly generated by simply replacing one case for another; for example, a single family house case might be replaced by a duplex case within a pattern to explore intensification potentials. Presently, the generation of development patterns is controlled by urban design researchers and facilitators to ensure a general "fit" to project locations.

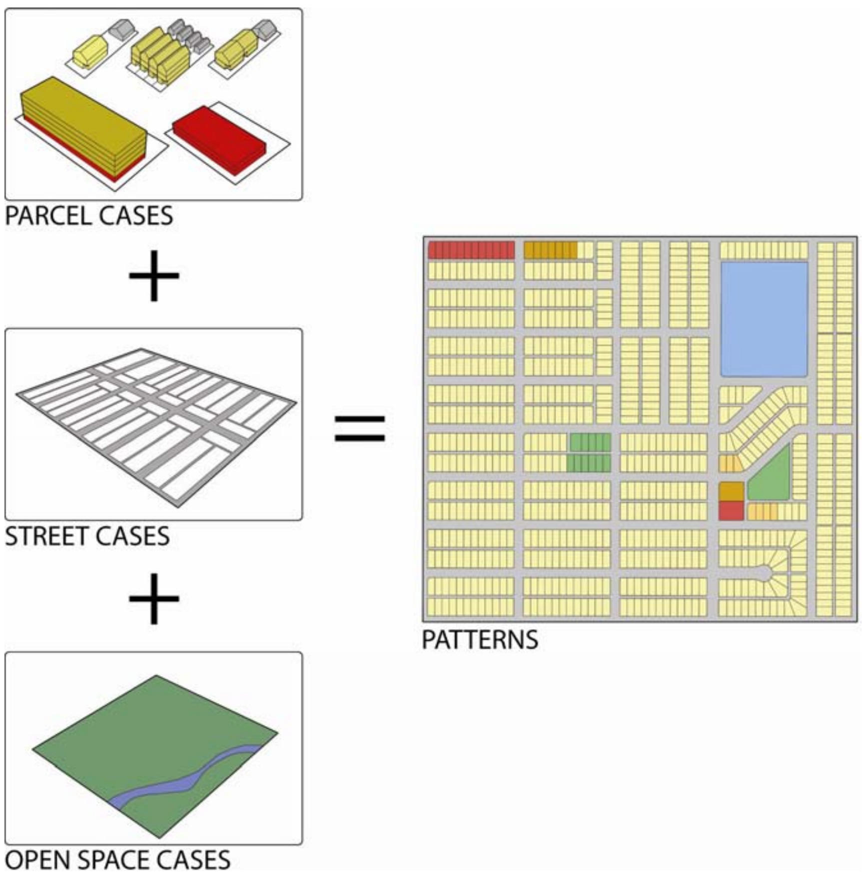

Figure 2: Parcel, Street and Open Space cases are assembled into development patterns.

Because development patterns are assembled from sets of data-rich cases, the resulting patterns contain a range of information that can be analyzed in a variety of ways. Inherent to the patterns' construction are performance attributes such as residential unit mix, average density, land use diversity and commercial floor space. In addition to physical measures, the overlay of locally specific characteristics such as average household sizes and employment densities enable the estimation of population and jobs within a pattern as well as their respective spatial allocations. The addition of building energy and transportation demand profiles to development patterns, as discussed below, has expanded analysis potential to include greenhouse gas emissions. Future projects anticipate using more detailed data at the case-level to assess additional factors such as effective impervious area and renewable energy potential.

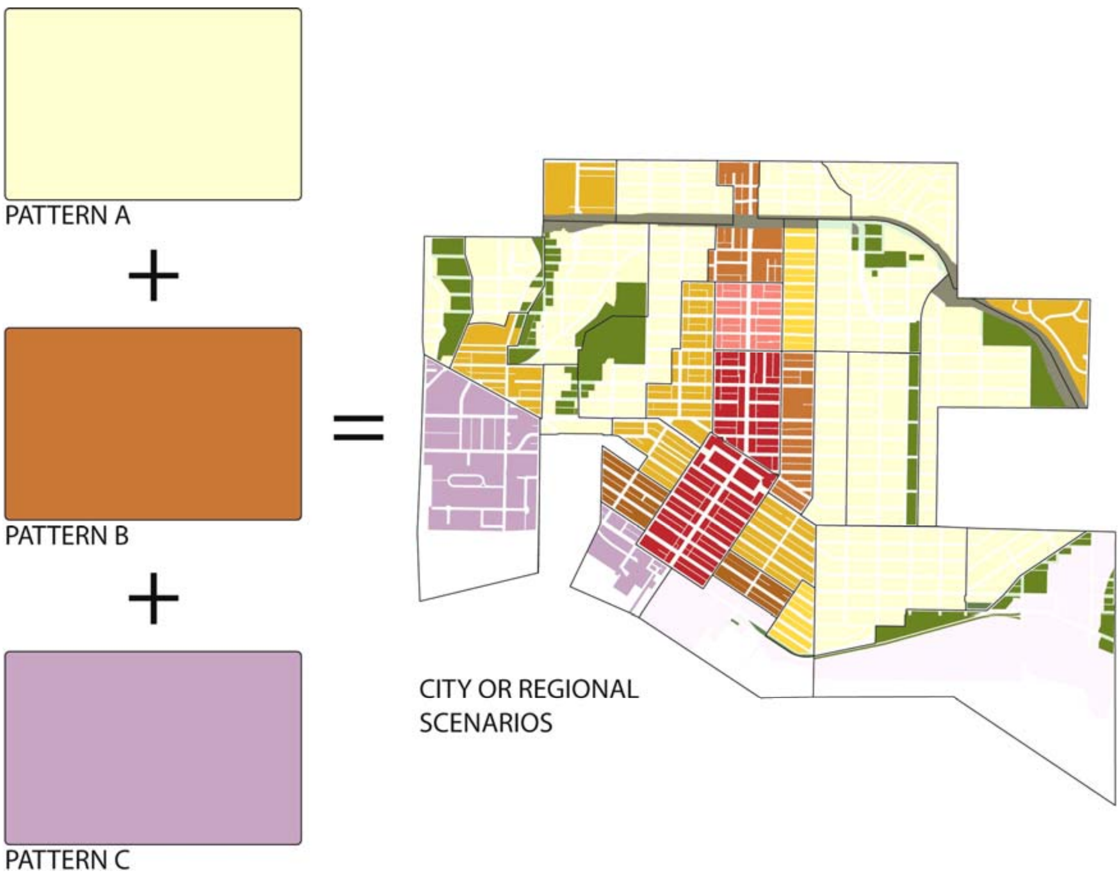

Figure 3: Assembling the development patterns into scenarios.

As development patterns are applied to scenarios using GIS, more complex analyses involving spatial relationships can be calculated in addition to simple additive measures. While at present these analyses are limited to proximity calculations (such as housing diversity, proximity of people and jobs to transit infrastructure, proximity to district heating systems and the allocation of open space), future models will incorporate the full range of GIS-supported spatial analyses.

For the CNV project, development patterns were used to model the charrette's resulting 100 Year Sustainability Vision scenario. The development patterns were used as inputs to the two models that measured the scenario's GHG outputs: the building energy model and the transportation model. In order to calibrate the models, and to provide a benchmark that was modeled using the same methodology, the current conditions (based on 2007) for the City of North Vancouver were also modeled.

2.1.2 Building energy demand model

In order to model the energy demand from buildings in the scenarios, building energy profiles for various categories of buildings were created. These profiles are quantitative descriptions of energy consumption by end use and energy source for each building type represented in the development patterns. Currently, the development patterns are comprised of the following building types: single family detached, duplexes, rowhouses, low-rise apartments, high-rise apartments, commercial buildings, institutional buildings and industrial buildings. Energy profiles were derived based on current aggregate figures for the Lower Mainland region (see section 2.2.3). Future demand was discounted according to a variety of assumptions, including changes in building technologies, energy source and changes in occupant behaviour. Total energy demand for each pattern was derived by using per unit (for residential buildings) or per square meter (for other building types) annual energy demand estimates.

2.1.3 Transportation demand model

For the purposes of the CNV project, a coarse transportation model was also used. Transportation related GHG calculations were limited to trips beginning or ending at a residential unit within the project area. While this definition does not capture all transportation GHG emissions (in particular, it neglects the considerable GHG emissions of people traveling from external locations into the project area to shop or work), it was deemed suitable for the purposes of the charette process, which targeted the ability of the local government to mitigate resident-based emissions.

The transportation-related GHG emissions for each development pattern were modeled as a product of the types of units (different unit types generate different numbers of trips per day, with attached units generating fewer trips than larger, single-family units), total trip length, vehicle efficiency and fuel assumptions and mode split. Absent a compelling way to model changing trip lengths within the scope of the project, both average trip length and vehicle efficiencies were assumed to be constant between baseline and future scenarios and were derived from the existing local inventories. The significant variables affected by the development patterns were the number of trips generated (as a function of unit size) and mode split (studies have shown that areas with high densities of residences and commercial space have significant mode shifts away from private automobiles). In this model, only emissions from private vehicle trips were accounted for.

The model also recognized that mode split is affected by proximity to major transit. As the development patterns do not contain information about the location of significant transportation infrastructure, this information was modeled separately in GIS and intersected with the GIS map of development patterns.

2.2 Applying the Methods to the City of North Vancouver

2.2.1 Spatial data

Spatial data utilized for the CNV project was mainly supplied by the City of North Vancouver as GIS layers. The City provided the following types of information:

Municipal boundaries
Neighbourhood boundaries
Legal parcels
Municipal zoning
2002 OCP information
2007 air photo
Building footprints
Roads
Cycling, truck and transit routes
Rail lines
Environmentally sensitive areas
Parks and trails
Hydrological features
Topography

One issue that made classifying the City's current conditions into development patterns more complex is that the City contains a significant number of parcels that have been rezoned as "comprehensive developments" from standard land use zoning designations. To determine the actual use of these parcels for the purposes of the project, actual use codes provided by the BC Assessment Authority for 2007 were integrated into the baseline spatial model of the City. Actual use codes, as defined by the Assessment Authority, identify "the primary purpose or activity for which a property is being held or used." The codes, assigned to each parcel, are three-digit numeric tags organized into six main groups: residential, farm, commercial, industrial, transportation/communication/utility and civic/institutional/recreational.

Further clarification and refinement of the parcel-level land use model required visual surveys of land use and built form within the City using Google Earth. In addition, the baseline land use model was calibrated using population, employment, household and dwelling type data from Statistics Canada, as collected and summarized in the *2004 Community Profile* prepared by the City. This report references 2001 National Census data for both the whole City – the Census Subdivision or CSD – and for each of the City's nine neighbourhoods, for which customized census data was obtained.

2.2.2 Energy and emission inventories

Two independently produced energy and emission inventories for the City were available for comparison to and calibration of the methodology applied during the project. First, the City of North Vancouver prepared a GHG inventory report in conjunction with its participation in the Partners for Climate Protection (PCP) program. This program guides municipalities through a five milestone process towards the reduction of greenhouse gas emissions. Performing a GHG analysis internally for municipal operations and community-wide is Milestone One in the PCP program. The City's inventory quantified both corporate and community emissions and tracked both total and per capita emissions for each inventory year.

In addition to the City's data, the BC Ministry of the Environment's Community Energy and Emissions Inventory (CEEI) initiative has developed preliminary Community Energy and Greenhouse Gas Emissions Inventories for each local government within BC for 2005 in conjunction with the establishment of a provincial database of community GHG emissions data. The preliminary inventories follow Federation of Canadian Municipalities (FCM) and PCP protocols for quantifying community GHG emissions, including buildings, community transportation and municipal waste. These inventories do not quantify corporate emissions. The CEEI inventories, the included sectors and the protocols for measurement are expected to evolve over time as the knowledge and rigour of reporting methods increases.

The preliminary inventory conducted by CEEI for the City of North Vancouver has several important differences in comparison to the City-generated inventory. First, although the City and Provincial inventories both included building energy consumption data from local utilities (BC Hydro for electricity consumption data and Terasen Gas, Inc. for natural gas consumption data), the Province used data aggregated at the scale of six-digit postal codes, while the City used data aggregated at the FSA code (3-digit postal code) level. Because the FSA areas extend well beyond the City's municipal boundaries, estimates from this data may be less accurate. In addition, the City's inventory excluded emissions from the industrial port lands located along the City's waterfront, as the City does not have jurisdiction over port operations. Second, the City and Provincial estimates for GHG emissions from both transportation and solid waste use different methodologies and data sources to estimate the number of vehicles and tonnage of solid waste within the City respectively. Both inventories also use different emission factors from different sources for electricity, natural gas, gasoline, diesel and solid waste. The differences in methods and data sources between the two inventories result in statistically significant variations in GHG totals and are mainly related to varying sources of data. These discrepancies warrant further consideration; however, both inventories were used as points of comparison during the course of this project.

2.2.3 Building data

General building-level data was constructed using parcel-scale, land use "cases" as described above. These cases, derived from real-world case studies of built form from North America and abroad, represent the physical dimensions of a spectrum of parcels, building forms and uses. Data from these cases include:

- Average parcel areas
- Average FAR
- Building form (attached, detached, stacked)
- Gross and net floor areas by use (residential, commercial and/or industrial)
- Number of residential units
- Assumed residential unit sizes
- Population accommodated
- Assumed household sizes by unit type
- Number of jobs accommodated
- Assumed employment densities (square meters per employee) by job type
- Average density (residential units, population and jobs per hectare)

For the 100 Year Vision project, a total of 30 representative cases covering residential, commercial and industrial land uses was used.

Because the land use cases assembled for the project were required to represent not only future conditions but also the existing 2007 conditions of the City, selected land use cases were calibrated to specific City of North Vancouver conditions using the City's Official Community Plan, Zoning Bylaw and census data. These references ensured that the core set of land use cases reflected the building forms and densities currently built or planned within the City and that residential unit sizes and average household sizes were consistent with the local context. Additional land use cases representing new building forms, mixes of use and densities were also included for use in the construction of future scenarios.

In addition to data regarding the physical dimensions of buildings and parcels within the City, data on the potential energy performance of the land use cases was also collected. Data for the energy performance of residential buildings was based on BC Hydro's 2007 Conservation Potential Review (CPR), which reviews the potential for electricity savings from 2006 to 2026 for the residential, commercial and industrial sectors in British Columbia. The residential sector component of the CPR report establishes a baseline year of 2006 to illustrate both how and where electricity is currently used within the Province based on actual electricity sales data. This data is also disaggregated by region (including Lower Mainland data) and by residential unit type (single family detached and duplex, rowhouse, low-rise apartment and high-rise apartment). The equivalent level of data for natural gas consumption was not available directly from Terasen Gas; for this reason, BC Hydro's data on net space heating and cooling loads, which incorporated space heating load research and actual sales data from Terasen Gas, was used to estimate natural gas consumption.

For commercial, institutional and industrial buildings, the Conservation Potential Review was also considered as a data source, but was eventually dismissed. For commercial buildings, the CPR provides detailed energy use simulations for 15 large and medium commercial/institutional building types (e.g. retail, hotels, hospitals and warehouses) calibrated to reflect actual utility sales data. Energy use data is provided in the report as units of electric and natural gas energy consumed per square meter of commercial space. However, when these profiles were assigned to the reported commercial building area within the CNV, resulting energy consumption, particularly in terms of natural gas for heating and hot water, was dramatically different than the energy consumption reported in both CNV energy and emission inventories. Potentially, the small and relatively distinct areas of commercial land use located within the CNV are too specialized for the CPR's average energy profiles, although such discrepancies require further investigation. For the purposes of the project, energy use per square meter for commercial, institutional and industrial space was taken to be the total energy consumed, as reported in the CNV inventories, divided by the reported commercial, institutional and industrial building area within the City. This method was assumed to utilize the most specific and locally relevant data available during the course of the project.

Because the 100 Year Sustainability Vision project involved developing future scenarios that could be assessed for their relative reductions in GHG emissions, a variety of long-term future assumptions about potentials for emission reductions, particularly in terms of technological advances and applications, were required. For this purpose, the project looked to several reports that have considered such questions. Foremost among them, the project relied on assumptions from "Kyoto and Beyond," published by the David Suzuki Foundation. This report describes the potentials of Canada to reduce total national emissions by 50% by the year 2030 by modeling an "end-use oriented, technology-based simulation of the Canadian energy economy" (2002). The report covers multiple GHG emission sectors including residential, commercial and institutional buildings, passenger and freight transportation, industrial production, non-energy emission sources, the oil and gas industries and electricity production. Although the CNV scenarios required assumptions for 2050 and 2107, at least 20 years later than the timeline posed by the Suzuki Foundation report, the 2030 GHG reduction potentials were considered "conservative" estimates for the 2050 CNV scenario. For 2107 scenario assumptions, no data or models were available; for this timeframe, project researchers used educated judgment to account for so distant a time horizon. For example, the 2107 scenario assumed that all residential buildings by 2107 would be replaced or retrofitted at energy efficiency levels equivalent to the best, currently available design practices. Potentially, such assumptions cannot be prescriptive as specific future conditions, but do enable scenarios to illustrate the intensity and type of changes required to meet long-term GHG reduction targets.

2.2.4 Transportation data

The transportation model was calibrated using data from a number of sources. These included local sources (such as the City's municipal inventory, the City's CEEI inventory and summaries of Translink's 2004 Trip Diary Survey) as well as more generic information (e.g. trip generation rates from the Institute of Transportation Engineers' *Trip Generation, 6th Edition*, the Suzuki Foundation's *Kyoto and Beyond* report and Census Canada data.)

One major complication of measuring the transportation-related GHG implications of the CNV scenarios was that the only available local inventory data pertaining to transportation was aggregated at a municipal scale, while the scale of decision-making at the charrette was at a much finer scale. This mismatched scale of calibration data means that the some significant assumptions about trip length and mode splits had to be made that might not necessarily be supported by other data. In particular, detailed trip diary data (which provides information on trip origin and destinations, as well as mode split) was not available in time for the charrette and model runs. Therefore, current transportation model assumptions should be treated as indicative of magnitude and direction of change only.

The mode split assumptions that were used for both scenarios are described in Table 1.

Table 1: Mode Split Assumptions

Land Use	% of Trips by Alternative Modes of Transportation
Within 400m of significant transit	50%
Land use density > 150 jobs + residents/ha	50%
Land use density > 150 jobs + residents /ha AND within 400m of significant transit	75%
Rest of City	18%

While these numbers might seem high, they do reflect current conditions within the city (50% of trips in the dense Lower Lonsdale area are transit, walking or biking) and a conservative trajectory of mode shifts over the next 50 years.

2.2.5 Generation of development patterns

A palette of nine "existing" 2007 patterns was developed specifically for this project, along with 8 "future" patterns. The 2007 patterns were applied to the baseline scenario, while the future pattern set was used to model the 2107 scenarios (see below).

To develop the 2007 patterns, the City was first divided into 33 zones using the boundaries of the City's nine neighbourhoods and according to a visual survey of pattern changes within the urban fabric, such as variations in building type or street configuration. For each of the 33 zones, land use data was statistically compared. Zones containing statistically similar land use mixes were grouped, with the mean for each land use taken as that pattern's land use mix. For this analysis, 11 land uses were considered:

Residential, single family detached
Residential, duplex
Residential, rowhouse
Residential, apartment, 5 stories or less
Residential, apartment, more than 5 stories
Commercial
Mixed use, residential and commercial
Industrial
Civic
Street right of way
Park and other designated open space

The nine resulting 2007 development patterns were further refined through the assignment of one or more parcel-scale cases to each land use, representing a greater level of detail about building forms and densities.

The future development patterns were generated by replacing cases within each pattern with new cases reflecting changes in land use or density. Changes to each pattern were directed by stakeholder input from project workshops. Land use mixes were also shifted as needed; however, the amount of land dedicated to street rights of way was held constant in recognition of the existing gridded street system that was unlikely to change substantially over time. Similarly, the amount of open space and civic land in each pattern was either held constant or, for one pattern, increased, reflecting the desire of stakeholders to preserve and enhance public, park and natural areas. At the design charrette, project participants further revised and applied seven "future" patterns resulting in the final 100 Year Sustainability Vision plan. The resulting seven future development patterns, and their key statistics, are described in Table 2.

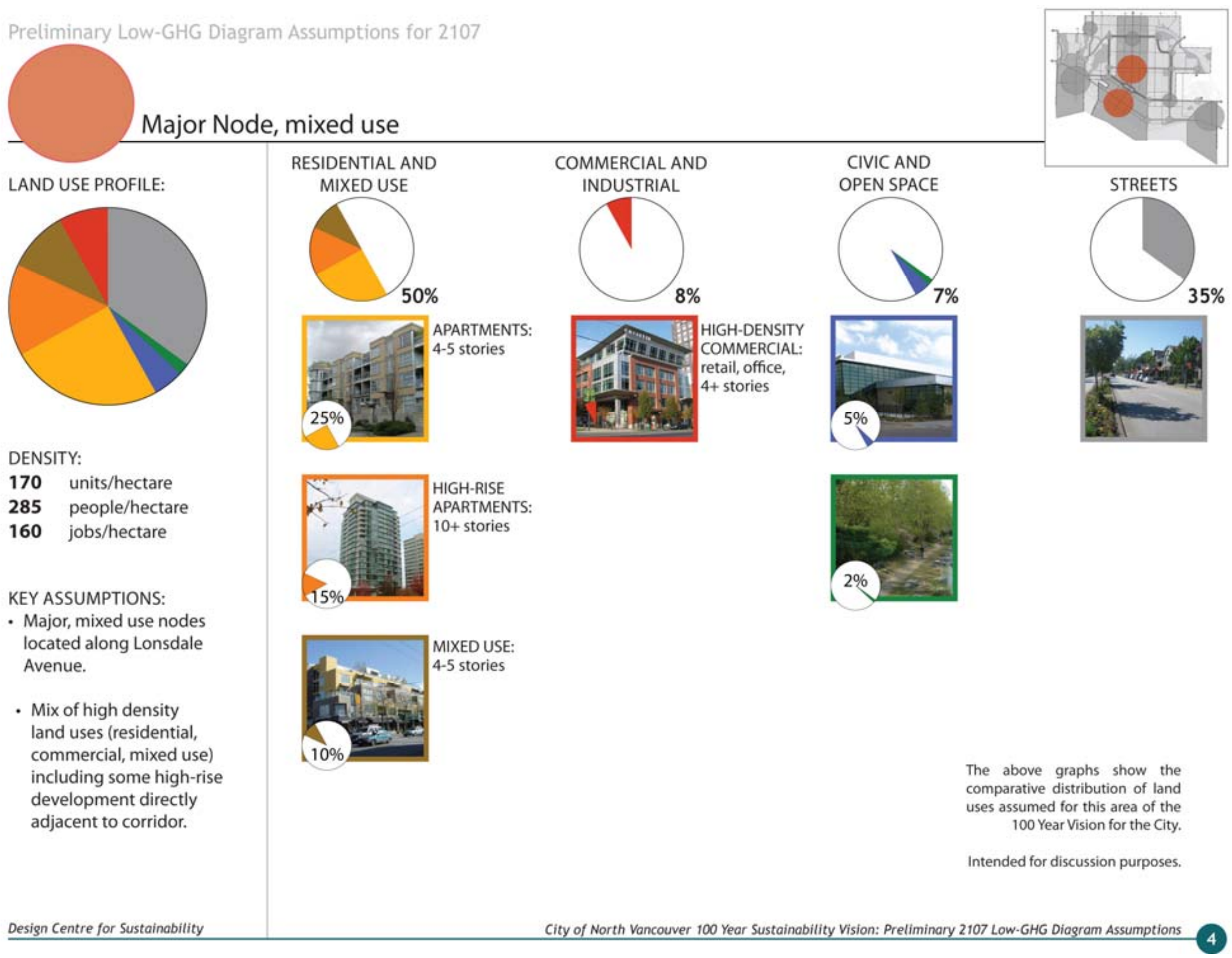

Figure 4: Example of a development pattern as presented to charrette participants.

Table 2: List of CNV Charrette Development Patterns

Description	Units/ha	Population/ha	Jobs/ha	Net FAR
Low Density Residential	25.6	55.8	10.1	0.8
Attached Residential	37.0	78.8	19.2	1.0
Low Rise Residential	118.9	206.7	52.9	2.3
Mid Rise Mixed Use (Residential/Commercial)	151.0	245.3	297.7	3.5
Corridor Mixed Use (Residential/Commercial)	155.3	273.4	111.3	2.2
Industrial/Commercial Mixed Use	83.4	144.5	329.5	2.3
High Density Industrial/Commercial Mixed Use	98.0	159.9	639.1	3.5

2.2.6 Scenarios

In all, four scenarios were generated and modeled for the CNV project: a 2007 baseline scenario, a preliminary 2050 scenario, a preliminary 2107 scenario and a scenario that modeled the charrette results. The first three scenarios were modeled prior the charrette.

The creation of the 2007 baseline scenario enabled GHG measurements to be calibrated to the available inventories for 2005 and confirmed that the proposed methods produced results in accordance with the inventory evaluations. The baseline scenario additionally served to describe the existing conditions of the City in a way that was comparable methodologically to other scenarios developed within the project and enabled the visual comparison between the City's current conditions and future alternatives through the creation of GHG maps.

Long range targets, such as those established for the City in terms of population, employment and GHG emissions over a 100 year timeframe, are often set in the absence of knowledge regarding the feasibility of such targets, the magnitude of action or change necessary to meet them and the consequences of their realization. In order to understand the feasibility of these targets, and to help frame discussion at the charrette, preliminary scenarios were developed for 2050 and 2107. Prior to the charrette, stakeholders provided direction regarding high-level urban form conditions and the spatial arrangement of those future conditions. This direction was interpreted by project researchers and used to generate preliminary development-pattern based scenarios for 2050 and 2107 from which population, employment and GHG consequences could be estimated. These scenarios were used to examine whether or not the charrette targets (80% reduction in GHG by 2050, 100% reduction by 2107) were attainable, to identify the types of strategies that would be necessary to attain such targets and to help create the future development patterns used during the charrette.

The 2050 preliminary scenario was created as a midpoint between the baseline and the 2107 scenarios and applied the 2107 strategies at a lesser degree of completion. Land use, population and emissions data from the baseline and preliminary scenarios, as estimated using the development pattern model, can be found in Tables 3 through 5.

At the charrette, revised development patterns were applied by workshop participants through facilitated drawing exercises to create the 100 Year Sustainability Vision (Figure 5). Participants sketched new boundaries for where future patterns should be assigned, including the identification of new corridors and nodes and the selection of residential fabric for various levels of intensification. These areas were color-coded according to pattern, and the final plan digitally photographed for importing into GIS (Figure 6). Once in GIS, by linking to relational databases containing information on the patterns, assigned cases and applied building energy and transportation demand profiles, charrette participants could be informed – during the course of the charrette – about their progress toward meeting population, employment, housing and GHG targets.

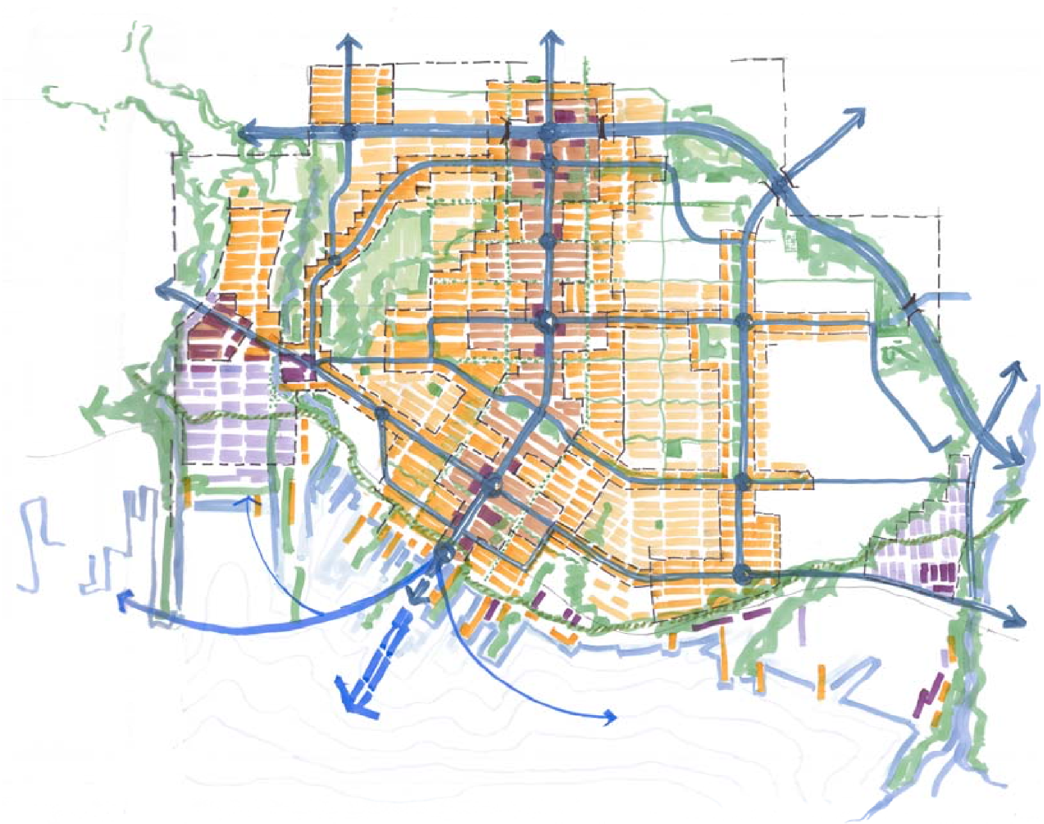

Figure 5: Initial sketch (drawn during charrette) that was digitized to form the GIS development pattern map (Figure 6).

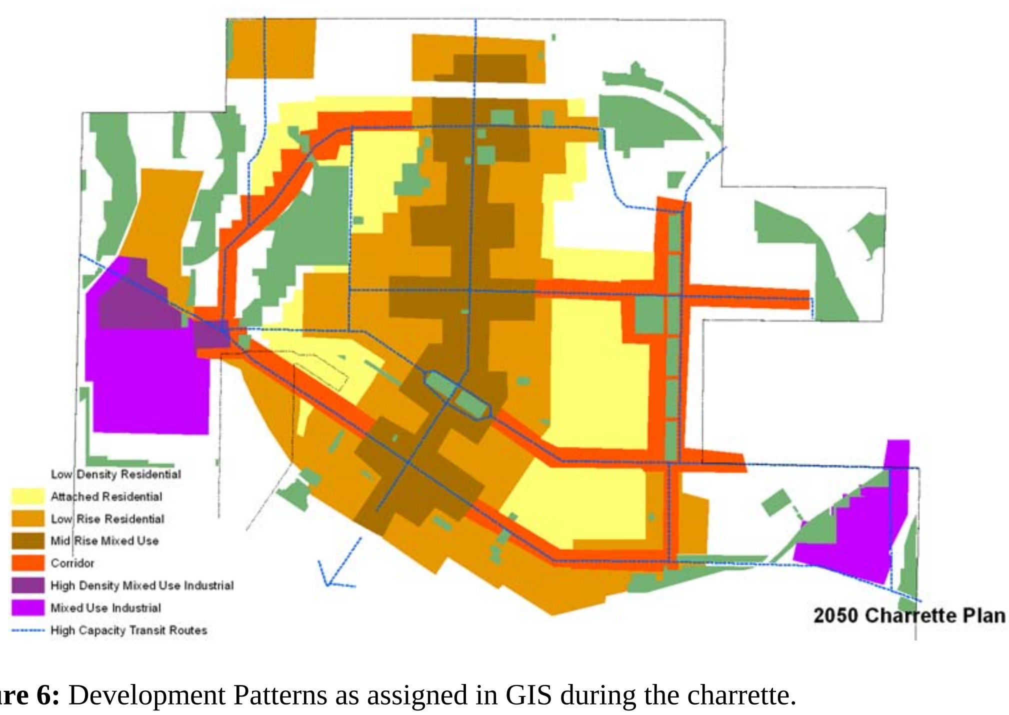

Figure 6: Development Patterns as assigned in GIS during the charrette.

Table 3: Population and Employment – Baseline, Preliminary and Charrette Scenarios

Population Statistics	**2007 Baseline**	**Preliminary 2050 Scenario**	**Preliminary 2107 Scenario**	**Charrette 2107 Scenario**
Population	46311	72294	138302	141270
Employment Population	31760	46660	77697	94490
Population Density (persons/hectare)	39	61	117	119
Total Households	22098	34322	75139	79563
Residential Density (units/hectare)	19	29	63	67
Assumed Annual Growth Rate (%) (2007 – Target Date)	n/a	1.1	1.1	1.1

Table 4: Residential Dwellings – Baseline, Preliminary and Charrette Scenarios

Residential Dwellings	**2007 Baseline**			**Preliminary 2050 Scenario**			**Preliminary 2107 Scenario**			**Charrette 2107 Scenario**		
	# units	% of total	% change	# units	% of total	% change	# units	% of total	% change	# units	% of total	% change
Detached Single Family	4927	22	n/a	2774	8	-44	1295	2	-74	762	1	-85
Attached Duplex	914	4	n/a	457	1	-50	182	0	-80	0	0	-100
Attached Rowhouse	1360	6	n/a	2528	7	86	5752	8	323	3575	4	163
Apartment <5 stories	10261	46	n/a	20277	59	98	50017	67	387	45223	57	341
Apartment >5 stories	4636	21	n/a	8286	24	79	17893	24	286	30005	38	547
Total	***22,098***	*100*		***34,322***	*100*	***55***	***75,139***	*100*	***240***	***79,565***	*100*	***260***

Table 5: Building Energy and Emissions Summary – Baseline and Preliminary Scenarios

Energy and Emissions	**2007 Baseline**			**2050 Preliminary Scenario**				**2107 Preliminary Scenario**			
	energy, electricity (GJ)	energy, natural gas (GJ)	emissions (t)	energy, electricity (GJ)	energy, natural gas (GJ)	energy, renewable (GJ)	emissions (t)	energy, electricity (GJ)	energy, natural gas (GJ)	energy, renewable (GJ)	emissions (t)
Residential	652,769	567,139	33,772	276,902	128,143	247,100	8,816	496,556	1,500	189,471	73
Single Family/Duplex	*256965*	*380614*	*21005*	*67884*	*105185*	*0*	*5776*	*52412*	*0*	*0*	*0*
Rowhouse	*58565*	*20309*	*1532*	*41299*	*3574*	*40852*	*553*	*93394*	*0*	*65227*	*0*
Apartment, <5 stories	*199713*	*94684*	*6470*	*167719*	*19384*	*118417*	*2487*	*350750*	*1500*	*45515*	*73*
Apartment, >5 stories	*137526*	*71532*	*4765*	*0*	*0*	*87831*	*0*	*0*	*0*	*78729*	*0*
Commercial	489,772	707,932	39,151	276,688	75,454	293,433	6,233	416,370	0	89,215	0
Institutional	209,316	194,350	11,441	60,839	11,318	45,272	1,112	44,713	0	7,890	0
Industrial	50,984	178,430	9,210	18,647	0	60,599	170	14,491	0	29	0
Total	***1,402,841***	***1,647,851***	***93,574***	***633,076***	***214,915***	***646,404***	***16,331***	***972,130***	***1,500***	***286,605***	***73***

3. RESULTS

3.1 Calibration to Existing Inventories

As described above, the baseline scenario was primarily used to calibrate the overall methodology with existing GHG inventories. Generally, energy and GHG emission quantities resulting from the development pattern methodology tended to fall between quantities as estimated by the City and Provincial energy and emission inventories. Consistency of results is due in large part to overlapping data sources between the three GHG estimate methodologies, including some reliance on the inventories themselves as data inputs as discussed in Section 2.2. Results comparing the existing emission inventories to the results of the development pattern methodology are summarized in Table 6.

For transportation, as the transportation model only considers residential transportation (trips to or from a residence by a vehicle registered in the City of North Vancouver), only values for passenger and light duty vehicles were used from the City inventory. These vehicle categories account for 94% of the City's emissions from locally registered vehicles.

Table 6: Energy and Emission Calibration Results

	Development Patterns (Baseline Scenario)	City Inventory (2005 condition)	CEEI Inventory (2005 condition)
Buildings			
Energy, electricity (GJ)	1,400,000	1,380,000	1,530,000
Energy, natural gas (GJ)	1,650,000	1,580,000	1,860,000
GHG emissions (tonnes)	*93,600*	*89,400*	*105,300*
Transportation			
Energy (GJ)	1,504,000	1,506,000	1,504,000
GHG emissions (tonnes)	*109,600*	*108,500*	*108,300*
Total Emissions	***203,200***	***197,900***	***213,600***

3.2 Results of the 2107 Scenarios

The scenario that resulted from the charrette was essentially a refinement of the preliminary 2107 scenario discussed in section 2.2.6. This is not surprising, as the preliminary scenario was provided to the charrette participants as an input; participants were asked to critique and improve the scenario. The spatial arrangement of the development patterns was modified slightly to reflect local knowledge and concerns. In addition, the patterns were themselves adjusted to reflect local sensibilities with respect to land use, density and building height.

3.2.1 Land use and building types

The charrette scenario maintained the general structure of the City by concentrating the highest level of densification along the central corridor. Density along this corridor averaged approximately 3.5 FAR, with the highest overall densities and greatest amounts of office and commercial space occurring at two major centres located in Lower and Central Lonsdale respectively. Major, high density, mixed use employment nodes were developed in areas of previously low density commercial and industrial use on the southeast and southwest edges of the City. Throughout low-density residential areas, transit routes were intensified with apartment and townhome housing types and commercial services, and higher density, mixed use neighbourhood nodes were located at transit intersections. Residential areas closest to the central corridor were infilled to densities supportive of an expansion of the district energy system while remaining residential areas were assumed to double in density through new attached housing types and secondary suites.

Unlike most municipalities in the Metro Vancouver region, CNV housing stock is primarily composed of multi-family units including attached homes and apartments. Approximately 20% of housing units are single family detached dwellings – one of the lowest percentages in the region; however, single family units consume over two-thirds of residential land within the City. The charrette scenario assumed that the majority of these units would be redeveloped over the next 100 years to rowhouse and apartment-style units. Despite these changes, the number of ground-oriented units (generally regarded as suitable for families) only declined slightly from 2007 to 2107, with additional growth in residential units met by higher density housing types. The majority of ground-oriented units were proposed as attached forms (duplexes or rowhouses). This shift in housing stock reflects expected demographic changes over this time period towards a substantial increase in elderly and childless households. The scenario maintains the current street network and increased the total amount of land area dedicated to civic and open space. The changes in residential dwellings and population are summarized in tables 4 and 3 respectively.

Employment areas for the 2107 charrette scenario were primarily located along Lonsdale Avenue as well as the southeast and southwest edges of the City where employment centres were assumed to accommodate a mix of mid to high density commercial and industrial uses. In addition to these three areas, smaller scale retail and service locations were located at key transit intersections and along transit corridors throughout the City's residential areas, bringing employment opportunities and daily shopping and service needs closer to most residents. The scenario envisioned substantial increases in office type employment and in mixed use buildings containing both residential and commercial uses. Employment figures, as estimated using development patterns, are summarized in Table 3 above.

3.2.2 Building emissions summary

Because the charrette participants were unable to come to consensus during the workshop on specific technologies or strategies at the building scale, only a partial energy and GHG analysis of the charrette scenario was completed. Full energy and emissions analysis, such as was conducted for the preliminary scenarios, would have required additional assumptions to be made regarding building retrofits, construction standards, energy sources, technology and policy implementation. The land use and building type decisions that were made during the charrette, however, were found to have a significant impact on the City's resulting energy use and GHG emissions. By concentrating population and jobs in dense building forms, there was a substantial reduction in energy required for space heating. Without assuming any changes to construction methods or sources of low-GHG energy, it is estimated that the shift to more compact and energy-efficient unit types (while maintaining 2007 unit sizes) would reduce the average energy use per unit by over 20%.

As illustrated in Table 5, building GHG emissions from the preliminary scenarios were estimated to decrease by 82% by 2050 and to be eliminated by 2107. The preliminary scenarios illustrate that to achieve these reductions, intensive building retrofits and substantially more efficient new construction must take place, reducing average building energy consumption by roughly 50% by 2050 and 70-90% by 2107 depending on building type. Additionally, the preliminary scenarios require a move to new, zero-carbon, renewable energy sources, primarily for heating energy by 2050, but for all energy needs by 2107. These renewable energy needs are assumed to be met in the preliminary scenarios through intensive expansion of the City's district energy system, eventually powered by renewable fuel sources, and supplemented by building integrated technologies such as photovoltaics for electricity.

Considering that the building form and land use changes resulting from the charrette were more aggressive than anticipated in the preliminary scenarios, it is expected that results similar to the 2107 preliminary scenario would be achievable if additional design and technology strategies, similar to those prescribed by the preliminary 2107 scenario, were adopted by the City. The assumptions utilized in the preliminary 2107 scenario are described in Table 8.

3.2.3 Transportation emissions summary

Reductions in transportation emissions for the charrette scenario result from a shift to more transit-friendly development. The charrette scenario assumed a substantial investment in transit infrastructure, including a significant increase in light-rail lines throughout the City. This results in 95% of the population being within a maximum of 400 meters of a high speed, high capacity transit line. As a result of the mode shifts described in Table 1, and assuming that non-automobile trips, 100 years in the future, are completely powered by GHG-neutral energy sources, the GHG reductions are substantial. Further reductions would require that passenger and commercial vehicles be powered by GHG neutral energy sources.

3.2.4 Energy and GHG summary

The wedge diagrams (Figure 7) express graphically the changes in both energy demand and supply that are required to meet the project's GHG emission reduction targets. The preliminary scenarios, which are depicted in the wedge diagrams, demonstrate that the targets are achievable, but require substantial changes in urban form, building technology and energy sources.

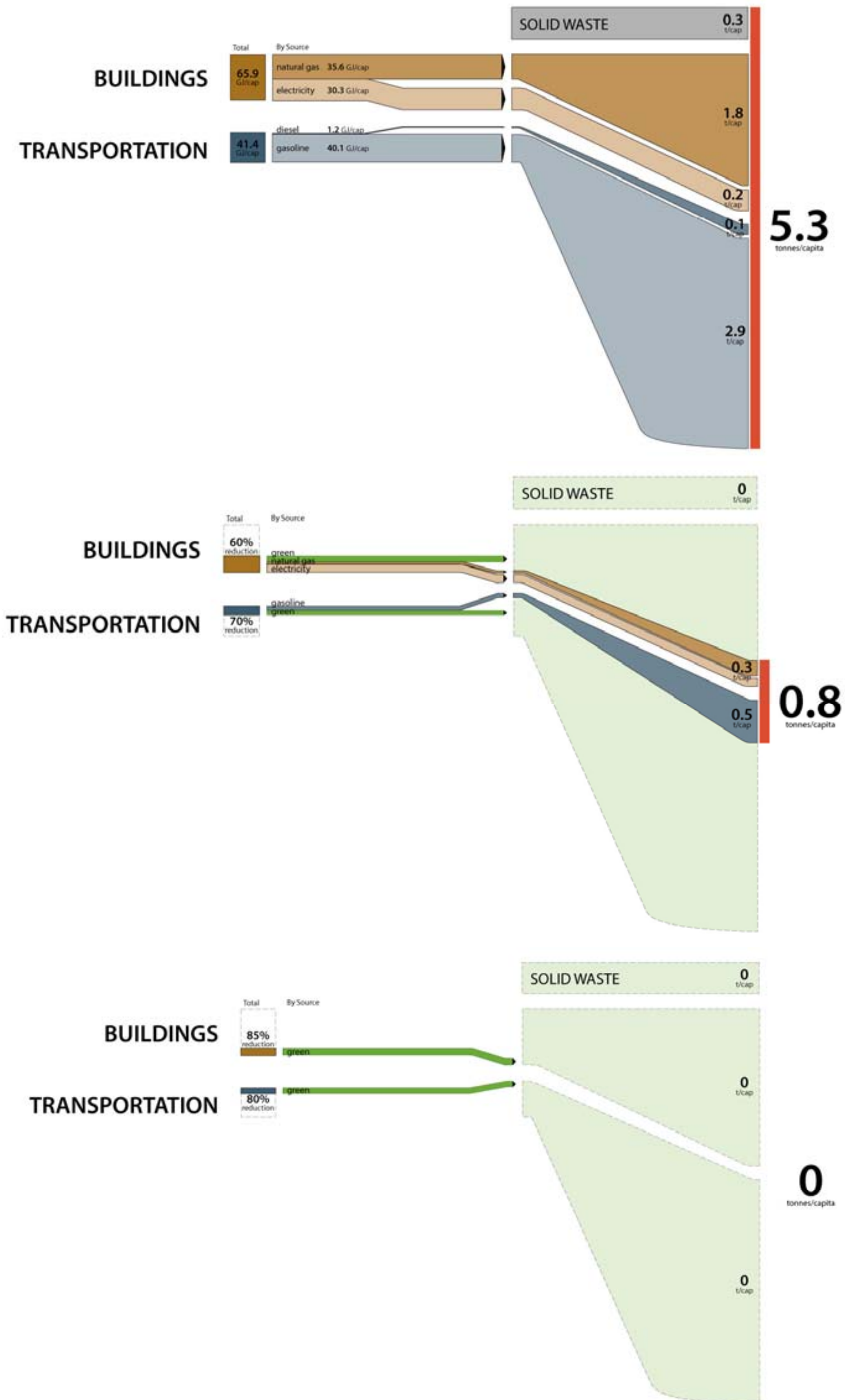

Figure 7: Energy and emission wedge diagrams for the baseline 2007 (top), preliminary 2050 (center) and preliminary 2107 scenarios (bottom). Diagrams represent: per capita energy demand (left), energy source (center) and resulting emissions (right), respectively.

As mentioned above, due to timing issues, charrette participants were unable to achieve consensus on detailed building standards and energy sources. Primarily, participants focused on urban form changes and coarse transit system improvements. In order to explore the broadest implications of their work, the charrette scenario was modeled with two sets of assumptions: using current energy demand profiles (as used in the 2007 baseline scenario) and using the building energy demand reduction assumptions from the 2107 preliminary scenario (Table 8).

Table 7: Energy Demand Results for the 2007 Baseline and 2107 Charrette Scenarios

Energy Demand	2007 Baseline Scenario	2107 Charrette Scenario (urban form changes only)	2107 Charrette Scenario (urban form + aggressive building technology changes)
Per Capita Building Energy Demand (GJ)	26.3	20.8 *(-21%)*	6.4 *(-76%)*
Per Capita Transportation Demand (Residents Only) (GJ)	41.4	25.7 *(-38%)*	25.7 *(-38%)*
Total Per Capita Energy Demand (GJ)	**67.7**	**46.5** ***(-31%)***	**32.1** ***(-53%)***

The results, described in Table 7, indicate that by simply changing the kinds and locations of urban development, the City of North Vancouver could achieve a per capita energy reduction of 31%. By implementing aggressive technologies and construction methods for further reducing building energy, the per capita energy demand could be reduced by 53%. While further reductions in building energy demand may be possible, it is likely that most of the remaining energy and GHG emission reductions would need to be addressed by GHG-neutral energy sources, significant vehicle efficiency improvements and by encouraging additional shifts away from private vehicles.

The maps in Figure 8 spatialize these results by development pattern. These maps depict the areas of the City with considerably lower energy demand in dark green and reflect that inhabitants are living in higher density units and have a mode split that focuses on transit, cycling and walking trips rather than private automobile.

Figure 8: Maps that spatialize the per unit energy demand for 2007 baseline and the 2107 charrette scenario .

Table 8: 2107 Preliminary Scenario Assumptions

Residential Buildings
Residential densities significantly increase, particularly in areas designated for district energy and in identified nodes and corridors
Most single family homes add secondary suites
Residential areas are densified in such a way that additional land is made available for increased open space and green infrastructure
Residential units/buildings built before 2050 are retrofitted or replaced
Single family and attached units use on average 66% less energy for heating and ventilation (based on average 2007 performance)
Low and high rise apartments use on average 95% less energy for heating and ventilation (based on average 2007 performance)
Household hot water requirements are reduced 50%
Mechanical space cooling is eliminated
Appliances are high-efficiency, and reduce household appliance energy consumption 50%
Lighting consumes 66% less energy
Residential units located within designated district energy areas (70% of attached and low-rise apartment units and 100% of high-rise apartment units) are connected to the system for heating , hot water and electricity
Residential units located outside of district energy areas utilize passive heating strategies with supplemental heat and electricity from low-GHG sources
Commercial, Institutional, Industrial Buildings
Commercial densities significantly increase, particularly in areas designated for district energy and in identified nodes and corridors
Commercial, institutional and industrial buildings built before 2050 are retrofitted or replaced
Commercial and industrial buildings use on average 70% less electricity and 95% less heating energy (based on average 2007 performance)
Institutional buildings use on average 75% less electricity and 95% less heating energy (based on average 2007 performance)
Commercial, institutional and industrial buildings are connected to the district energy system for heating, hot water and electricity
Commercial, institutional and industrial buildings located outside district energy areas generate or purchase energy from low-GHG sources
Energy Systems
District energy systems, located in designated areas throughout the City, co-generate electricity using a diversity of low-GHG sources
Low-GHG energy is generated throughout the City where feasible and appropriate through a variety of technologies
Locally generated energy is supplemented by Regional and Provincial low-GHG energy supplies

Table 8 continued: 2107 Preliminary Scenario Assumptions

Transportation
Average vehicle energy efficiency improves 60% from 2007 levels
Per capita vehicle kilometers traveled are reduced 50% from 2007 levels, particularly for commuting and shopping trips which are accommodated by walking, cycling and transit
Public transit replaces fossil fuels with a diversity of low-GHG energy sources
All energy for personal vehicles is supplied by low-GHG sources
Waste
Emissions from solid waste are eliminated through a combination of strategies, including waste avoidance, recycling, composting and waste to energy systems

4. DISCUSSION

4.1 Summary and Conclusions

The City of North Vancouver 100 Year Sustainability Vision project is one of the first projects in British Columbia to consider at the municipal scale the feasibility of meeting the challenging GHG emission targets established by the 2007 Greenhouse Gas Reduction Targets Act. Like many other municipalities, the City faces this challenge within the context of significant population growth over the next several decades, resulting in potentially a doubling – or tripling – of population in certain areas. Moreover, the project addresses the question of what specific decisions for land use, building form, transportation and infrastructure will contribute to reducing energy consumption and GHG emissions while supporting other environmental, social and economic goals.

The urban design choices and associated quantified GHG estimates arising from the CNV 100 Year Sustainability Vision project indicate that Provincial targets may be achievable, at least for the City of North Vancouver. The City has several unique advantages which facilitate beneficial urban form decisions, including a small, constrained municipal boundary, highly interconnected street infrastructure, greater than average residential densities, geography facilitating solar orientation and a municipal energy utility servicing the central core. How urban form choices may play out in other locations within British Columbia, particularly those without the advantages of CNV, will require further investigation. Results from the project also call attention to the inability to meet an 80%, or 100%, GHG reduction target entirely within municipal jurisdictions. Rough estimates indicate that perhaps 31% of the necessary emission reductions, on a per capita basis, could result from land-use and transportation related decisions made at the municipal level, such as increased density, mixed use zoning, infrastructure investments and other negotiated development requirements. Remaining reductions for the 2050 and 2107 CNV scenarios depend on the availability of developing technologies, aggressive construction standards and clean, renewable energy supplies that would necessitate the cooperation and support of the public, the region and the Province.

The development pattern methodology developed for the CNV project proved successful as a way to quickly estimate the performance of urban form conditions during a public process. Quantitative results from the development pattern-based 2007 baseline scenario were typically within 5-10% of results reported in the energy and emission inventories prepared by the City and Province. While this level of accuracy may not be appropriate for all purposes, it was sufficient to elevate the effects of urban form on GHG emissions during the project and for making comparisons between scenarios. Most importantly, the development pattern method of quantifying and spatialising GHG emissions enabled a standardized and consistent means of measuring scenarios with significantly different levels of detail and information, namely a current condition for which a wide variety of data existed and a 100-year future, for which relatively little could be known. Rather than expecting stakeholders to make parcel-by-parcel design decisions for a long-term future or requiring a consistent level of detail for decisions made across the study area, stakeholders were able to assign “packages” of general design choices across the City, while adding greater amounts of detail to sensitive or otherwise important areas.

The methods of GHG estimation and mapping also illustrate how municipal GHG inventories, and the CEEI inventories in particular, can be interpreted spatially and linked to the daily and long-term urban form decisions made by municipal governments. This will become increasingly important as all municipalities across British Columbia begin receiving their annual CEEI reports in tandem with requirements to make decisions that meaningfully impact those inventoried GHG emissions. Further improvements to the CEEI inventories, including refined methodologies and more detailed energy and emission data, such as residential emissions per unit type, will improve future spatial translations of this quantitative data.

The quantitative and design-based results of the project suggest that a development pattern-based methodology has significant potential to inform decision-making on urban form and GHG emission reductions during a fast-paced, collaborative planning process. Using development patterns as a mean to discuss and evaluate urban form decisions during the design charrette provided opportunities for “live” feedback from researchers on performance issues such as population and job targets so that adjustments could be made during the four-day charrette in subsequent iterations of the 100 Year Vision. Because development patterns are conceived to function with the types of data sets commonly available to local governments, the products of the charrette, and particularly the characteristics and allocation of development patterns across the City, are readily translatable to the City’s policy and implementation processes.

The CNV 100 Year Sustainability Vision project represents only a first attempt to cohesively address the complex issues of GHG emissions accounting and reductions, urban design, long-term decision making, land use and transportation planning and collaborative planning processes. Certainly, the successes of the CNV project suggest that there is substantial potential for infusing public processes with new tools, methods and expertise to bring information together in meaningful ways. The development pattern-based method described in this paper links urban form decisions to GHG consequences, facilitates the generation of GHG-relevant future scenarios and provides fast, quantitative and visual feedback that can support municipal policy and decision making. While the results of this project are encouraging, significant additional research, development, and tests through project applications will be required to improve the overall methodology. Methodological refinements sought through ongoing and future work are described in detail below.

4.2 Additional Data

Like so many projects, continued work on the development pattern-based GHG estimation and mapping methodology described in this paper would benefit greatly from access to more detailed, accurate and spatially explicit data. Presently, most available data (for transportation, energy, etc.) is aggregated and summarized prior to being made available for use. Such summaries limit the potential to incorporate data accurately and efficiently in ways meaningful to development patterns and urban form decisions.

More detailed spatial information disaggregated by small, consistent geographical units such as postal codes or census tracts could expedite the generation of representative, locally relevant development patterns. Specifically, data on transportation as well as residential and commercial floor areas by type have been lacking, requiring researchers to make broad assumptions. More disaggregated transportation and building energy data, made available by postal code, would help to clarify the relationships between travel behaviour, building energy consumption and varying patterns of development.

A list of additional disaggregate data desirable for future projects is summarized in Table 9. It can be noted that this list reflects an idealized data set, and not a minimum requirement to create meaningful estimates and maps of municipal GHG emissions; the City of North Vancouver project, for example, did not have access to any of the data listed below. Although some of this small-scale data may be available by request or purchase from various agencies including Statistics Canada, energy utilities, the BC Assessment Authority and the Insurance Corporation of British Columbia (ICBC), certain data sets may require other agencies, such as the Province, to facilitate acquisition. While not all of this data is explicitly important to the calculation of GHG emissions, these data sets are valuable to municipalities, who understandably seek to make decisions that simultaneously reduce emissions and meet other environmental, social and economic goals.

Table 9: Desired Disaggregate Data for Project Area

Small Scale Data (e.g. 6-digit postal code)
Building unit counts and floor area by type
Population, by building type
Employment, by building type
Building energy consumption by building type
Total vehicle kilometers traveled
Transportation mode splits

4.3 Refinement of Methods

As suggested, the development pattern approach applied to the CNV project illustrates the potential for a simple, spatially explicit modeling method to be a robust and replicable tool for considering GHG emissions in municipal and regional planning processes. While this overall framework is essentially complete, several components of the method require further refinement.

4.3.1 Modeling refinements

First, estimations of building energy performance for the CNV project depended primarily on average regional data provided by BC energy utilities. While this data is useful for calibration, it did not differentiate between building forms beyond simple categories such as attached, detached or apartment buildings. These categories cannot take into account variations in location, building design, vintage, mechanical systems or potential energy technologies. Additionally, the development patterns do not currently take into account building orientation, shading and other block or pattern-scale conditions that may further affect building energy consumption and potentials for renewable energy generation. Future iterations of development patterns and building energy profiles will incorporate additional building and neighbourhood scale energy modeling to account for these effects.

Second, the transportation model used for this project was intended as quick proof of concept. Currently, it uses coarse assumptions about the impacts of urban form and proximity to transit routes on mode split and makes very general assumptions about trip generation and length. While acceptable for a proof of concept model, the model is not sophisticated enough to work at the same detailed scale as the building energy model, and does not take advantage of the development pattern approach's detailed dataset.

A better transportation model needs to be developed or adopted that reflects the local and regional spatial patterns, as well as available transportation infrastructure. The City of North Vancouver, owing to its particular geography, has very restricted access to the rest of the region's transportation network. While the current model assumes that sufficient transit capacity exists to accommodate the very high levels of demand suggested by the charrette scenario, it is plausible that the charrette scenario does not provide enough transit capacity to accommodate the future, transit-intensive mode split. Congestion and travel time differences resulting from the restricted capacity (of both the road and transit networks) could have a large impact on residents' choice of transportation mode and should be reflected in a subsequent model.

Fortunately, the development pattern approach provides a very high level of disaggregate data with respect to population and job figures. This offers significant possibilities for integrating the approach with existing state of the art transportation models. Such models would allow researchers to more accurately model the impacts of the different scenarios on energy use resulting from transportation choices.

Third, the CNV development patterns were not able to account for the capacity of particular patterns to accommodate renewable energy strategies. While specific technologies may not be feasible or desirable to address within the context of unknowable futures, the aspects of urban form that broadly support or encumber such technologies are. Future development patterns will explore characteristics such as density, orientation, available roof and wall surfaces, solar access, and building depths as a proxy for renewable energy potential.

Fourth, the development pattern method as applied in the CNV project depended on a high level of manual inputs and analysis, resulting in additional labor, greater opportunities for error and a reduced ability to capture and evaluate decisions made by stakeholders during the charrette process. While this is to be expected in the early stages of tool development, future development of modeling processes will increase automation, allowing for greater efficiency, improved accuracy and faster turn-around during charrette events.

4.3.2 Representation issues

In mapping GHG emissions across the City for each scenario, several methodological issues arose regarding how emissions are best represented visually to enhance the understanding of the relationship between urban form and greenhouse gases. First, the GHG mapping for the 2007 baseline scenario was completed both at a parcel scale, showing GHG performance variation for each property, and at the development pattern scale, showing the relative GHG performance of each of the 33 subdivided areas of the City to which development patterns were applied. The parcel-scale GHG map illustrated clearly the high level of variance among different building uses and types and also highlighted the diversity of GHG emissions contributions that can exist within a single pattern of development. The pattern-scale map more clearly reflected the holistic performance of a package of land use decisions. The choice between parcel and pattern-scale mapping becomes less relevant for the generation of future scenarios, when compiling parcel-scale urban design decisions may become prohibitive. For this reason, pattern scale mapping, which maintained a consistent level of detail throughout the project, was selected for the CNV scenarios.

Second, the units of measurement selected for the purposes of mapping GHGs significantly impact the visual results. As illustrated by mapping exercises conducted by the Center for Neighborhood Technology, maps representing total emissions by area illustrate very different information than maps representing emissions per capita. This issue significantly impacts GHG mapping by development pattern, as the patterns with the highest density will generate more total emissions, but fewer per household, resident or job. Additionally, per capita emissions are typically measured by residential density (people or households); therefore, commercial areas with low residential numbers tend to be shown as high-GHG per capita areas, even if their location, building form and proximity to transit are energy and GHG efficient. For City GHG maps, emissions were represented by kilogram of GHGs per resident or job to account for the effects of commercial areas, although this method did not reflect provincial or project mandates for reductions in total, rather than per capita, emissions. All of the issues considered in this section require further investigation in order to maximize the effectiveness of the information presented.

4.3.3 Engagement process refinements

As with any collaborative engagement process, the acceptance, comprehension and meaningful application of information are dependent on complete, effective communication. Energy and GHG emissions, the relationships between GHG emissions, urban form and other aspects of sustainability, and the DCS development pattern methodology are all complex, information intensive and often unfamiliar topics. Each of these areas warrants significant additional effort towards improvements in explanations, graphics and other resources. Development patterns as a design tool, in particular, have not yet been successfully presented; participants at the CNV charrette had many questions about their use and implications. Future work in the presentation of development patterns will move beyond the basic data provided to CNV stakeholders (illustrated previously in Figure 4) to include additional visualizations, more explicit information on performance tradeoffs and examples of how patterns can be applied to scenarios. Similarly, improved graphic representation of the GHG “maps,” such as those generated for the CNV scenarios, requires further investigation; some of the representation questions raised by GHG mapping have been discussed previously in section 4.3.2.

The overall CNV engagement process, encompassing two stakeholder workshops and the design charrette, closely followed the standard DCS program for participatory events. This choreography of events has proved highly successful for a variety of projects completed by the DCS over several years; however, the added complexity of energy and GHG emission planning posed particular challenges. Namely, to fully address and estimate the impacts of the 100 Year

Sustainability Vision on GHG targets required not only urban form decisions – the typical output of a charrette event – but also consensus on assumptions such as future energy efficiency standards, technology applications and energy sources to fully describe the 100 Year Sustainability Vision scenario. Although such assumptions are too far into the future to be prescriptive, these conversations were intended to enable participants to explore the extent, direction and magnitude of changes that would be required to meet GHG targets. This level of resolution was found not to be achievable within the demands and time constraints of the CNV events. Several new projects applying the development pattern methodology in other BC municipalities are anticipated over the next three years. These projects will develop and test adapted engagement strategies and events to better incorporate energy and GHG emissions into urban form decision making.

4.3.4 Development pattern refinements

For the City of North Vancouver project, development patterns were created only for the specific conditions found within that municipality. Due to the constrained size, compactness and other unique characteristics of the City, the resulting development patterns do not reflect the wider diversity of urban forms present in the Vancouver region or the Province and are insufficient for future projects. To extend the applicability of the development pattern methodology, a broader framework of patterns must be generated. This library of patterns will reflect the range structural characteristics (street networks, densities, land use mixes and building types) found over a larger geographic area, while allowing "customization" for locally specific conditions through the overlay of more detailed data such as building form, household characteristics and regional or local energy sources.

Additionally, further research, generation and modeling of innovative "future" patterns, representing North American and international best practices in terms of energy and GHG emissions, are required to fully consider the opportunities of urban form in relation to climate change. Modeling and representing such patterns, and examining how innovative development patterns may fit into the existing landscape, will assist in fostering new ideas, urban design strategies and policy decisions as BC communities begin to address climate change in regional and municipal policies.

References

Alexander, Don and Ray Tomalty. "BC Sprawl Report 2001." Smart Growth BC, 2001.

Anderson, W. and Kanaroglou, P. "Urban Form, Energy and the Environment, A Review of Issues, Evidence and Analytical Approaches." Hamilton, Ontario: McMaster University Institute for Energy Studies, 1993.

Bernstein, Lenny, et al. "Climate Change 2007 Synthesis Report." Intergovernmental Panel on Climate Change, 2007.

Betsill, Michele M. "Localizing Global Climate Change: Controlling Greenhouse Gas Emissions in U.S. Cities." Belfer Center for Science and International Affairs, 2000.

Boarnet, Marlon G. and Randall Crane. Travel by Design: The Influence of Urban Form on Travel. New York: Oxford University Press, 2001.

Center for Neighborhood Technology. Regional CO2 Emissions Maps. Available online at http://www.cnt.org/publications?keyword=emissions&issue=&submit=Go&submitted=1

City of North Vancouver. "Draft GHG Inventory Report." Unpublished. 2006.

City of North Vancouver Hydronic Heat Energy Service Bylaw, 2004 (Bylaw No. 7575). City of North Vancouver, Third Reading.

City of North Vancouver. "Lonsdale Energy Corporation." Accessed 15 November 2008. http://www.cnv.org//server.aspx?c=2&1=98

City of North Vancouver. "Official Community Plan." 2002.

Design Centre for Sustainability. Sustainability by Design: A Vision for A Region of 4 Million. Vancouver, BC: Design Centre for Sustainability at the University of British Columbia, 2006.

Ewing, Reid, et al. Growing Cooler: The Evidence on Urban Development and Climate Change. Washington, DC: Urban Land Institute, 2008.

Ewing, Reid and Fang Rong. "The Impact of Urban Form on U.S. Residential Energy Use." Housing Policy Debate 19.1 (2008): 1-30.

Federation of Canadian Municipalities. "About Partners for Climate Protection." Accessed 26 October 2008. http://www.sustainablecommunities.fcm.ca/partners-for-climate-protection/

Greenhouse Gas Reduction Targets Act, 2007 (Bill 44). Province of British Columbia, Third Reading.

Hyla Environmental Services, Ltd. "North Vancouver City Preliminary Community Energy & Greenhouse Gas Emissions Inventory: 2005." Prepared for the Province of British Columbia, Ministry of the Environment, 2008.

International Council for Local Environmental Initiatives. “International Local Government GHG Emissions Analysis Protocol, Release Version 1.0. 2008.

Local Government (Green Communities) Statutes Amendment Act, 2008 (Bill 27). Province of British Columbia, Third Reading.

Marbek Resource Consultants. “2007 Conservation Potential Review: The Potential for Electricity Savings, 2006-2026.” BC Hydro, 2007.

Ministry of the Environment. “BC Community Energy and Emissions Inventory Initiative.” Accessed 27 October 2008. http://www.env.gov.bc.ca/epd/climate/reduce-ghg/ceei-reports.htm

Mitchell, Gordon. "Urban Development, Form and Energy Use in Buildings: A Review for the SOLUTIONS Project." EPSRC SUE SOLUTIONS Consortium 2005. Draft paper

Natural Resources Canada. “Comprehensive Energy Use Database.” Accessed 29 October 2008. http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/comprehensive_tables/index.cfm?attr=0

Newman, Peter W. G. and Jeffrey R. Kenworthy. Cities and Auto Dependency: A Sourcebook. Aldershot, UK: Gower Publishing Co., 1989.

Nyboer, John, et al. “Energy Consumption and Supply in British Columbia: A Summary and Review, Final Report.” Canadian Industrial Energy End-Use Data and Analysis Centre, 2004.

Province of British Columbia. "Climate Action Plan." 2008.

Ratti, Carlo, Nick Baker and Koen Steemers. "Energy consumption and urban texture." Energy and Buildings 37 (2005): 762-776.

Sheldon, Ted. “Community Energy and Emissions Inventory (CEEI) Initiative.” Powerpoint presentation. 2 April 2008.

The Sheltair Group. “Energy and Greenhouse Gas Inventories by Local Governments in BC: Implications for the CEEI Initiative.” Province of British Columbia, Ministry of the Environment, Community Energy and Emissions Inventory Working Group, 2007.

Steemers, Koen. "Energy and the city: density, buildings and transport." Energy and Buildings 35 (2003): 3-14.

Union of British Columbia Municipalities. “BC Climate Action Toolkit.” Accessed 1 November 2008. http://www.toolkit.bc.ca/

U.S. Environmental Protection Agency. "Our Built and Natural Environments: A Technical Review of the Interactions between Land Use, Transportation, and Environmental Quality." Washington, DC: U.S. Environmental Protection Agency, Development, Community and Environment Division, 2001.