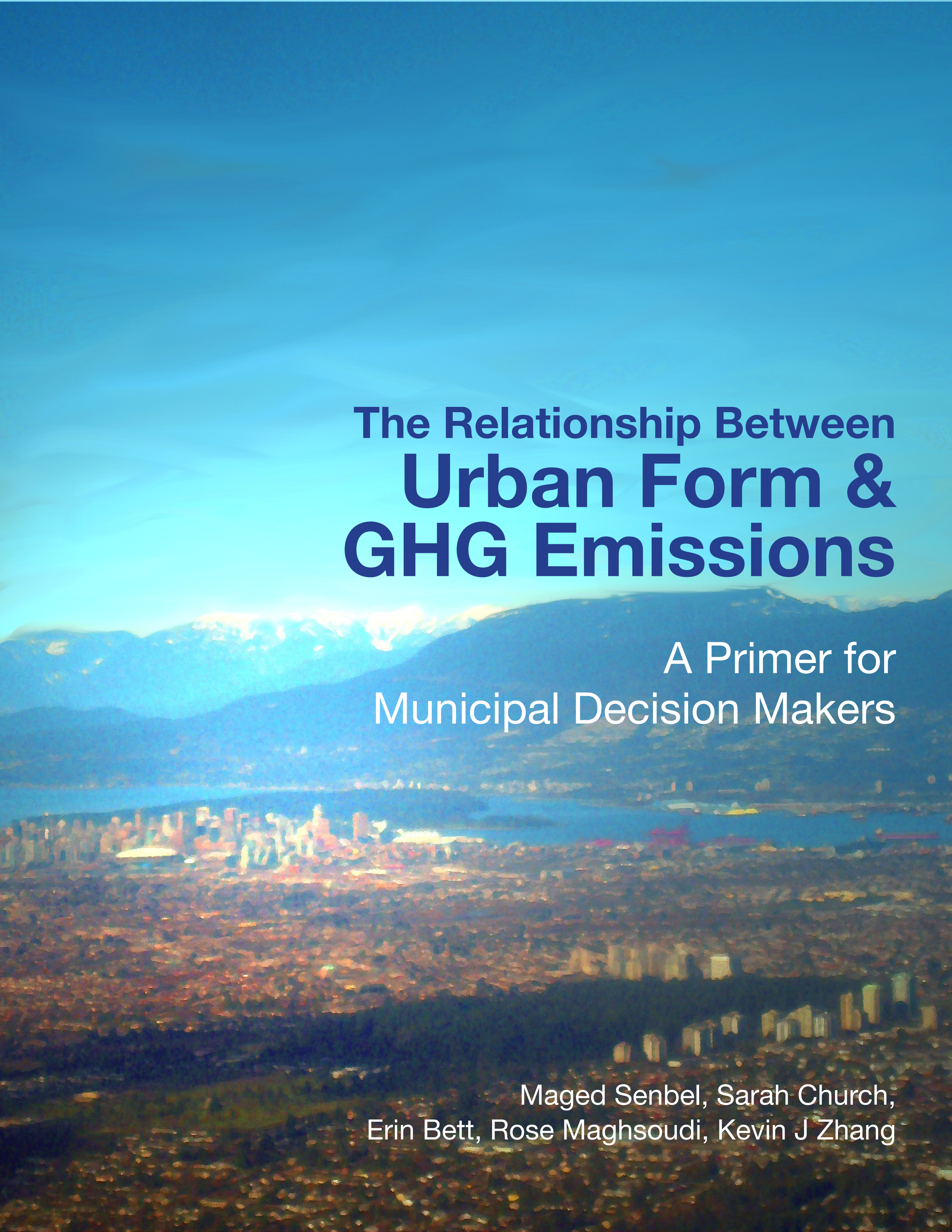

The Relationship Between Urban Form & GHG Emissions

A Primer for Municipal Decision Makers

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EXECUTIVE SUMMARY

The first decade of the twenty first century saw tremendous growth in research and knowledge on climate change. Governments at all levels in Canada began to explore policies, plans and targets that can serve to mitigate climate change and thereby reduce its impacts on communities. At the local level, much focus has been directed towards urban form, specifically compact development that concentrates growth in city centres and around transit nodes in order to reduce vehicle travel – a major source of greenhouse gas emissions – and to promote transit use and active transportation. Local governments have the ability to respond to the challenges posed by climate change through specific planning and development practices.

Strategies such as densification and mixed-use development, reduced distances between housing and employment, and improved transit, bicycle and pedestrian infrastructure all play a role in reducing GHG emissions. Current research on the relationship between urban form and GHG emissions indicates that:

- Higher densities provide a foundation for urban form characteristics that together reduce a community's GHG emissions by capitalizing on:
    1. A critical mass of passengers to support frequent and reliable transit.
    2. Shorter distances to travel destinations, which enables walking and cycling as mode choices.
    3. A critical mass of customers to support local businesses.
    4. Clustered buildings for efficient heating.
    5. Clustered buildings for efficient use of municipal infrastructure and service networks (water, sewer, power and waste/recycling).
- Density is directly related to energy consumption and GHG emissions through its influence on transportation behaviour, space heating efficiency and construction efficiency.
- Residential density reduces vehicle ownership and vehicle kilometres traveled (VKT).
- High-density developments result in lower GHG emissions per capita for transportation, building maintenance and operation.
- Densification of the employment district, along with improvements to the pedestrian environment, may serve to increase the viability of transit service and increase the likelihood of non-vehicle travel to and from work.

- Residents of mixed high-density development make shorter vehicle trips and spend less time driving.
- Residents experiencing high levels of street connectivity on their commuting route are much more likely to walk or cycle to work.
- Shorter distances to commercial destinations and community amenities within neighbourhoods are more likely to encourage walking, if the neighbourhoods are deliberately designed to be walkable.
- Improved cycling infrastructure, including designating safe and well-networked routes, and end-of-trip facilities, increases the use of cycling as a transportation option.
- A small home in a multi-unit building consumes less energy and produces fewer emissions than a large detached home.
- Local energy sources can impact GHG emissions by reducing the need for large-scale infrastructure and increase energy security and community resilience.
- District energy systems can be more cost effective and efficient than individual building heating systems, can be converted to renewable fuels and can benefit local economic development.

Local governments have begun to use an array of policy instruments, including provincial legislation, to reduce their GHG emissions. Communities are setting specific reduction targets, which creates the foundation for more specific policies that address buildings, land use, transportation and energy. The community plans and actions considered within this report incorporate land-use planning principles that strive toward reducing energy consumption and promoting alternative modes of transportation. Some communities are utilizing specific frameworks, such as Smart Growth or the Natural Step, to develop strong, integrated sustainability plans; others are focusing on urban design and other land-use planning measures, such as urban containment boundaries, transit-oriented development, and mixed-use developments.

While there are many challenges facing communities as they attempt to shift to more sustainable planning and development approaches, the research and examples in this report represent viable and effective opportunities for change. Compact, high-density, mixed-use development supported by transportation options will reduce our overall GHG emissions. Communities must therefore work quickly to develop strategies that capitalize on the relationships between GHG emissions and built form in order to reduce our reliance on conventional energy sources, create resilient communities and help reduce the negative impacts of climate change.

1

INTRODUCTION

The design of our cities and towns has a direct impact on our greenhouse gas (GHG) emissions. The configuration of land use, density, transportation networks and other relationships between buildings, roads, and infrastructure directly influence how much energy and materials we use to live, work, shop, and play. This report synthesizes research demonstrating the direct link between urban form and levels of energy consumption, with their resultant GHG emissions, and provides a number of examples of community responses to the challenge of reducing GHG emissions. The examples cover a number of Canadian communities, with a focus on B.C.

Municipal and local governments have the ability to considerably reduce GHG emissions through appropriate planning and urban design. The two main contributors of GHG emissions in urban regions, and significant contributors in rural areas, are vehicle travel and the heating and cooling of buildings. Both of these sources can be diminished by reinforcing some basic community planning and design principles. For example, travel behaviour is directly related to the distribution of services, amenities and employment opportunities, as well as to transit access: closer destination proximities and greater available travel options therefore result in lower GHG emissions per capita. In addition, such forms of compact development also enable efficiencies in heating buildings: shared walls reduce overall surface areas exposed to the elements, thereby reducing demand for heat, while clustered buildings allow for the provision of district heating.

Climate Change

Climate change is an unprecedented challenge for governments and communities around the world. While some GHGs are produced in nature, climate change is the result of dramatic increases in GHGs produced through human activity.[1] Human-induced climate change is caused by the increase in the atmosphere of several greenhouse gases, the most prevalent being carbon dioxide (CO2), as shown in Figure 1.[i] GHGs are most commonly reported in tonnes of CO2 equivalent (CO2 eq) which includes the converted equivalents of other greenhouse gases. Increased atmospheric CO2 traps heat from solar radiation that would otherwise escape into space. This raises the average global temperature, which in turn can cause sea level rise, ecosystem changes, and increased storm intensity. By far the largest percentage of human-produced CO2 is from the burning of fossil fuels for transportation and electricity.

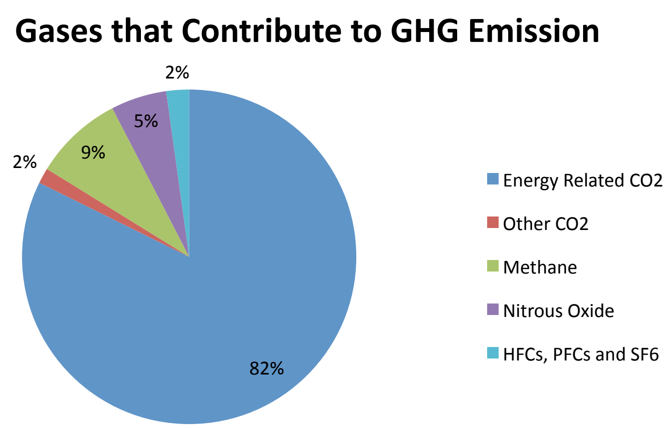

Figure 1 – The gases that contribute to GHG emissions

i There are a number of other gases that contribute to the green house effect including water vapour, methane, nitrous oxide (N2O) and other industrially produced gases such as hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF6)

The effects of climate change are already being felt around the world, and are especially evident in resource communities. Changes in ecosystems, water, agriculture, fisheries, and forests are affecting everything from employment to human health. As climate change progresses, the most noticeable effects will be: changes in levels and timing of precipitation; frequency and intensity of storms and droughts; insect infestations; and rising sea levels. Communities will become more vulnerable to natural forces outside of their control, and mitigating the effects of climate change requires urgent global and local strategies to reduce GHG emissions.

Every category of human consumption contributes to GHG emissions, from resource extraction, processing, transportation and manufacturing, to the construction and basic environmental control of buildings. In British Columbia, cars, trucks and buildings make up 47% of GHG emissions.[2] Local governments have direct influence over emissions from these sectors through land use planning and development control. At the provincial level, B.C. has committed to reducing GHG emissions by 33% by 2020. This policy commitment acknowledges the kinds of institutional, societal and economic changes required in all economic sectors in order to minimize the threats of climate change.

Greenhouse Gases

Environment Canada publishes an annual national inventory of GHG emissions and monitors changes by sector from year to year.[3] While some annual fluctuations in emissions exist due to changes in the mixture of fuel sources, changes in the level of petroleum extraction activities and changes in the severity of winter, long-term trends show considerable increases in emissions. In 2007, total GHG emissions were 4.0% higher than the 2006 levels. In 2008, total GHG emissions were 2.1% lower than the 2007 levels; however, this is still 24% above Canada's Kyoto target. Environment Canada reports that the long-term trends

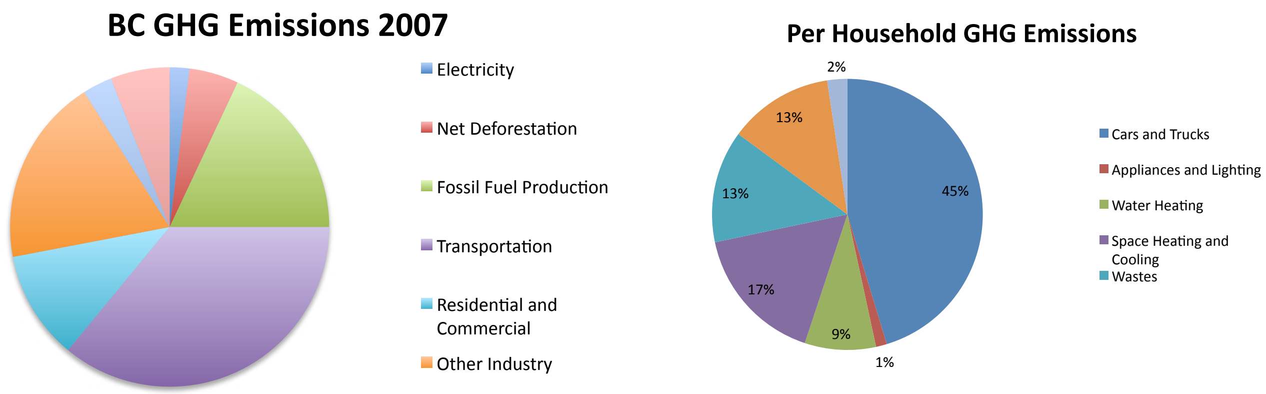

Figure 2 – Greenhouse gases by source in BC, from LiveSmart B.C.[5]

show emissions levels that are 33.8% in excess of Canada's Kyoto target.[4]

The charts above indicate B.C. provincial and household GHG emissions by sector.

Lifecycle Analysis

An important aspect of calculating GHG emissions is determining not only the amount of energy used during the operation of buildings, water and sewage systems, and other components of built form, but also taking into account the entire lifecycle of urban development. This includes the energy expended in the construction and maintenance of roads, buildings, and urban services. These hidden energy costs are sometimes referred to as embodied energy. A lifecycle calculation of urban infrastructure would include elements such as: mining, logging, and processing of materials; energy used in transportation, assembly and construction of the infrastructure; the lifetime operation and maintenance of the infrastructure; and the ultimate disassembly or removal of the infrastructure to a landfill.

For residential developments, lifecycle costs include calculations for buildings as well as water, sewer, power, and transportation infrastructure. The network of energy and materials is complex, and it is difficult to attribute exact amounts of energy per resident or per household for shared resources such as roads, underground services, and transit systems. As a result, most methods produce conservative estimates of lifecycle costs. Variations between different ways of calculating lifecycle costs can arise from assumptions about the type of energy used in the manufacturing of specific materials. For example, a steel manufacturing plant that uses coal-generated electricity generates significantly more GHG emissions than a plant operating on hydroelectric power. Lifecycle-based cost-benefit analyses must include long-term costs and benefits so that long-term savings in energy consumption and emissions are weighed against the short-term costs of construction. Despite these difficulties, lifecycle accounting is an important parallel measurement that should be considered when making land use and infrastructure decisions.

Peak Oil

An issue that will have far reaching consequences for our society is the decline of global petroleum supplies as we reach the peak in available global reserves. Known as "peak oil," this acknowledgement of the finite nature of fossil fuels has broad implications for societies and economies. Energy experts from around the world acknowledge that we are fast approaching the point where oil extraction is at its peak.[6,7] Beyond the peak, world oil production will occur at lower levels every year, and as supply fails to keep up with the increasing demands of a growing population and a growing economy, the price of oil will continue to climb. There will be some upward swings along this path of supply decline, such as increased exploration and extraction from marginal sources as the price increases, and drops in price with economic slowdowns, but the long run trend will be increasing fuel prices and decreasing availability for individual purchasers. Higher fuel prices will affect most areas of the economy that require electricity, transportation, fertilizers, plastics and synthetic fabrics. Communities can respond to the uncertainty peak oil poses by thinking of the long-term impacts of their current planning and building infrastructure in order to best prepare for the future.

Building Resilient Communities

Scientific evidence points to an accelerating pace of climate change that will have dramatic and potentially devastating impacts on the global environment.[8] The timing and severity of climate change are difficult to predict, as are the impacts of the change across different geographic regions. However, the inevitability of climate change means that all communities across Canada will be profoundly affected, while the continued increase in human-generated GHG emissions means that the change and the severity of its impacts are accelerating.[9]

Communities must therefore develop mitigation strategies that attempt to both delay the onset of climate change and reduce its intensity, as well as adaptation strategies that guard against the damage that climate change is expected to bring. One of the major influences on how much fossil fuel we consume is the way in which we design and build our communities. The location and types of buildings, roads, water, and waste systems all interact to influence household and per capita energy consumption. This report examines these relationships through community examples that help us better understand the relative influence of different aspects of built form on GHG emissions. As the following sections reveal, compact, high-density, mixed-use development generally reduces overall demand on fuel consumption, and builds resiliency in local communities in the face of climate change and peak oil.

Recent Legislation in B.C.

The 2007 Greenhouse Gas Reduction Act committed the BC government to reduce provincial GHG emissions to 33% below 2007 levels by 2020. This legislation set in motion the first official steps towards addressing climate change in British Columbia. In 2008, in order to support this commitment, the provincial government enacted two pieces of legislation that would amend the local government and housing statues in British Columbia. The Green Communities Act (Bill 27) and Housing Statues Act (Bill 10) give municipal governments new powers and responsibilities in relation to GHG reductions.

***Green Communities (Bill 27)*[10]**

Under Bill 27, municipalities and regional districts are required to establish targets, policies and actions to reduce GHG emissions in their Official Community Plans (OCPs) by May 31, 2010, and in their Regional Growth Strategies by May 31, 2011.

This legislation also gives local governments tools to implement strategies for reducing GHG emissions. Increased development permit authority, including flexibility with parking requirements and Development Cost Charges (DCCs)[ii], allows local governments to use a system of incentives and disincentives to guide development towards an overall reduction in emissions.

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ii DCCs are fees imposed by municipalities on developers to recover the capital costs of infrastructure required to service new development.

A parallel voluntary initiative asks local governments to sign onto the British Columbia Climate Action Charter. By doing so, B.C. communities make their own explicit commitment to reducing GHG emissions by 2012. As of January 2010, 178 local governments had signed the Charter.

BC is supporting municipalities by providing GHG baseline data sets, through the Community Energy and Emissions Inventory Initiative (CEEI), and offering a set of technical tools to evaluate the commitment and progress of each community.[11] In addition, the province is developing an incentive system intended to recognize and reward the success of local governments for action on climate change. [iii]

Development Cost Charges
Under Bill 27, local governments have the ability to waive DCCs for some housing initiatives that help reduce energy and water use. Governments can also charge developers on a variable scale depending on the anticipated GHG impacts of their proposed developments. The legislation does not require communities to waive DCCs. Instead, it gives communities the option of waiving these charges to encourage the building of denser, more sustainable and affordable developments: for example, the exemption of DCCs on units smaller than 29m2 is expected to encourage developers to build smaller and therefore more affordable residential units. Currently there are very few units of this size being built in B.C. communities, and this new legislation creates an incentive for builders to do so.

Development Permit Areas
Under Bill 27, new flexibility with Development Permit Areas (DPAs) allows local governments to create environmental and emissions standards for DPAs in their communities. Performance targets such as solar orientation and permeable surface area can be required for a DPA for the purpose of energy and water conservation. It should be noted that DPA legislation does not give local governments power to enact more stringent building code requirements.

Parking Requirements
Bill 27 also allows communities more flexibility in parking policies and funds. Local governments may vary or exempt off-street parking requirements for development based on activities or circumstances related to transportation. For example, development located closer to transit or mixed-use developments could have lower parking requirements because transportation options are accessible. Similarly, cash in-lieu provided by developers for off-street parking under this legislation can be placed into a reserve fund for the purposes of providing alternative transportation infrastructure. For example, local governments can use these funds to build bike paths or invest in public transportation. Under previous legislation parking reserve funds could only be used for alternative off-street parking.

Green Buildings Act (Bill 10)[12]
Bill 10 enables local governments to develop bylaws that promote greater energy and water conservation measures, GHG emissions reductions, and improved accessibility for persons with disabilities. Under this legislation, professional associations will also have the ability to create specialist certifications in areas related to improved building performance, and to determine the levels of training and knowledge required for such certification. The BC government also amended the building code to require more energy efficiency measures in new construction.[iv] This will have the dual effect of developing local expertise in technologies that emit fewer GHGs, while helping communities meet their reduction targets.

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iii A Q&A discussion of Bill 27 can be found on the Community Energy Association website http://www.communityenergy.bc.ca/resources-introduction/bill-27-tatiana-robertson-presentation-to-cea-agm-june-9-2008

iv Greening the B.C. Building Code http://www.housing.gov.bc.ca/building/green/index.htm

2

ELEMENTS OF BUILT FORM

Density provides a foundation for enabling essential urban form characteristics that together reduce a community's GHG emissions.

As Canadian communities move towards reducing GHG emissions, they will find it increasingly important to examine the role that the form and spatial distribution of buildings has on emissions. A number of interrelated factors contribute to the distribution, functioning, and energy performance of the built areas of our communities. Any urban design feature that affects people's movement, or the energy performance of buildings, is a factor in GHG emissions. For example, higher housing density creates a foundation that enables a host of services and amenities that together reduce a community's GHG emissions. Without higher densities, viable commercial nodes become a challenge; transit is not sufficiently supported to be frequent or reliable; walking and cycling distances are too great to create a feasible alternative to driving; and individual housing units and urban infrastructure are so distributed that they are less energy efficient.

However, higher density alone is not enough to reduce GHG emissions. Density must be coupled with viable transit and a mixture of amenities. As Richard Kuzmyak states, "A number of researchers have noted that density by itself is not the operative ingredient in determining travel behaviour. One can build a group of townhouses on a farm out beyond the suburbs and few will walk, because there is nothing to walk to. Similarly, few will use transit, since there will be little or none available"[13]. Other factors, such as the mix of land uses, the quality of pedestrian amenities, and the distances to job centres all play an important role in changing travel behaviour and creating opportunities for greater energy efficiency. The sections that follow summarize key research findings on the importance of each of these elements of urban form.

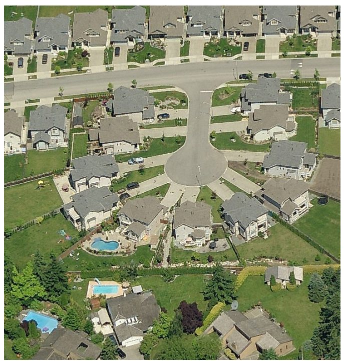
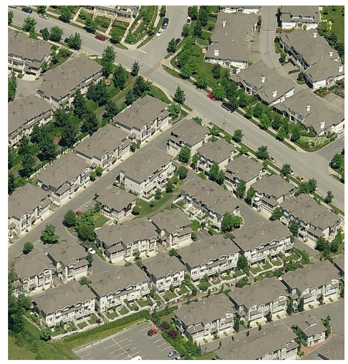
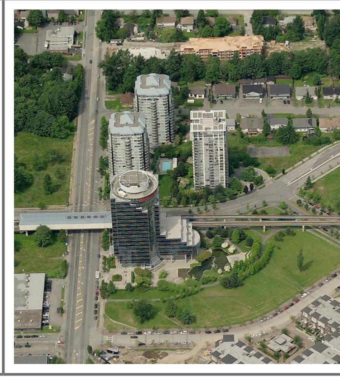
	Low-density	**Medium-density**	**High-density**
Dwelling units/hectare	2.5 -– 15	30 - 40	More than 60
Housing Type	Detached single family houses	Row houses, townhouses, low rise apartments	Multiple story condominium and apartment buildings
Examples from Surrey, B.C. (images courtesy of Bing Maps)			

Table 1 – Urban Residential Density Measures

2.1 Residential Density

Urban residential density is a measure of the concentration of residential development per unit of land.[i] Although the precise definitions of low, medium, and high-density vary depending on the local context, in urban settings low-density residential development generally refers to areas dominated by detached single family homes (2.5-15 dwelling units/hectare), medium-density refers to areas predominately made up of row houses, townhouses, and low rise apartment buildings (30-40 units/hectare) and high-density refers primarily to apartment buildings and condominiums that are multiple stories high (greater than 60 units/hectare), as outlined in Table 1.[ii] These varying levels of density directly relate to energy consumption and GHG emissions through transportation behaviour, space heating efficiency and construction efficiency.

Strategies for increasing residential densities include increasing zoning density caps, establishing minimum densities, reducing minimum lot sizes, offering density transfers and offering density bonuses to developments that meet other desirable walkability and mixed-use targets. Density can also be increased through disincentives such as charging impact fees for developments that encourage

Density enables:

1. Critical mass of passengers to support frequent and reliable transit
2. Short enough distance to travel destinations to enable walking and cycling as mode choices
3. Critical mass of customers for viable commercial businesses
4. Clustered buildings for efficient heating
5. Clustered buildings for efficient use of municipal service networks (water, sewer, power and waste)

i Residential density is measured in a number of ways including people per hectare/acre, dwelling units per hectare/acre, and floor space ratio (FSR) or floor area ratio (FAR). FSR and FAR are a measurement of the ratio of a building's floor area to the area of the lot on which the building is built.

ii A good summary on different measures of density can be found at "Measuring Density: Working Definitions for Residential Density and Building Intensity" www.housinginitiative.org/pdfs/from_MDC_Website/db9.pdf

Density Threshold Per Hectare	Impact on Transportation	Study
Above 12 households	Daily driving decreases by 38%	Dunphy and Fisher, 1996
Above 17 households	Household transit trips jump from 0.3 to 1.3 per day	Holtzclaw, 2002
Above 20 to 30 persons	Vehicle dependent land uses decline	Newman and Kenworthy, 1989
Jumping from 20 to 105 units	VKT reduced by 54%	Newman and Kenworthy, 1989
Above 32 households	Mode choice changes away from vehicle-dependence	Frank and Pivo, 1994
Above 74 households	Household walking trips jump from 0.6 to 1.4 per day	Holtzclaw, 2002
Above 295 households	Household walking trips jump to 1.5 per day	Holtzclaw, 2002

Table 2 – Summary of density thresholds at which travel patterns are affected

auto dependence. The creation of urban growth boundaries and urban service limits can help contain the spread of sprawl.[14]

Density and Transportation

Numerous studies have shown that people who live in neighbourhoods with higher residential density own fewer vehicles and drive fewer kilometres[iii], which results in lower overall energy expenditure for those residential developments. As Table 2 indicates, higher residential densities make higher frequency public transit more cost effective and reliable, thereby increasing its competitiveness with private vehicles. Similarly, higher density residential areas close to a city's core employment areas make walking and cycling a more viable transportation option for more residents.[15]

Vehicle use is the largest contributor to household energy use for both high-density and low-density development. However, transportation energy consumption causes much higher emissions in low-density developments because of the distances and number of vehicular trips that low-density residents make.[16] Research examining density and travel behaviour in several metropolitan regions shows that increasing density beyond the single family home threshold reduces household vehicle ownership and vehicle kilometres travelled (VKT): in Chicago, shifting from single family home density reduced vehicle ownership by approximately 33% and VKT[iv] by 32%; in Los Angeles by 35% and 35%; and in San Francisco by 40% and 43% respectively.[17] An earlier study found similar results where increasing density correlated strongly with a decline in vehicle ownership,[18] while a 2010 study of Hamilton, Ontario, found that concentrating future population growth projections in the urban centre would result in a 25% reduction in emissions compared to continued sprawl in 2031.[19] A New Zealand study examining the impact of density in relation to peak oil projections found the risks posed to necessary and

iii Most transportation related research uses Vehicle Kilometres Traveled (VKT) or Vehicle Miles Traveled (VMT) as a standard measure of the total distance a person or household travels by car in a certain period of time (usually per annum).

iv VKT figures relate directly to GHG emissions and are used to estimate GHGs. This report refers to both VMT and VKT as VKT.

essential trips to be significantly higher in a business-as-usual growth scenario versus a concetrated growth scenario.[20]

Different measures of density can also point to different relationships between urban form characteristics. For example, by measuring density as the number of households in areas designated for residential development,[v] a stronger correlation is seen between higher density and lower vehicle ownership. However, measuring density as the number of households per total number of acres in the community, including commercial, industrial, parks, and other amenities,[vi] indicates a stronger correlation between higher densities and lower VKT[21]: people drive shorter distances when their travel destinations are closer, thereby reducing their annual VKT even if their number of trips remain the same.[22]

Studies examining transportation and urban form in the US have also found density to be most strongly correlated with VKT. An Atlanta study demonstrated that increases in density result in lower VKT, while low-density neighbourhoods have the highest VKT ratings.[23] A study of Californian cities in the early 1990s found that with a doubling of neighbourhood density, per household driving decreased 20 to 30%. For example, the neighbourhood of Nob Hill in San Francisco had 2 to 3 times the household density of San Ramon in San Francisco, and 25% of its household vehicle ownership and VKT. While multiple variables, including high residential density, nearby shopping, good transit, and a good walking environment, were all found to contribute to lower vehicle ownership and vehicle use in those neighbourhoods, residential density was found to be more significant than the other variables.[24]

The above study also indicates how future growth might affect vehicle use: if an urban population doubles by infill in already developed areas, VKT would not double, but rather would only increase by 40 to 60%. If, however, the population doubles by expanding onto undeveloped land, thereby lowering the overall density of the city by 50%, VKT would likely increase by 150 to 186%.[25]

A subsequent study by the same author, published in 1994, analyzed the density of 27 neighbourhoods in San Francisco, Los Angeles, San Diego, and Sacramento. The study found that doubling residential density reduced vehicle ownership by 16% and VKT by 20%. Doubling the service of public transit further reduced VKT by 5%. If density was accompanied by other characteristics, including good transit service, proximity to retail, and a pedestrian-friendly environment, household vehicular use was found to decline by 25 to 30%.[26] Another U.S. study found that at densities greater than 12 households per residential hectare, daily driving decreased by 38% with a doubling in density.[27]

An international macro-scale study analyzing data from 32 North American, European, and Asian cities showed that as density increases from 20 to 105 units per hectare, VKT drops by 54%. When density is roughly doubled, VKT drops by 30%. Cities with predominantly low-density development (under 50 persons per hectare) have driving-related energy consumption rates that are in some cases triple that of more densely developed cities. By contrast, high-density cities (100 persons per hectare and above) have low energy use attributable to driving. It emerges that there is a “critical point” - around 20 to 30 persons per hectare - “below which vehicle dependent land use patterns appear to be an inherent characteristic of the city,” and vehicular energy expenditures are high.[28]

A review of international research on compact communities, conducted by the Conservation

v Density measure = households per residential acre

vi Density measure=households per acre

Law Foundation in the United States, shows that compact communities produce significantly fewer VKT and vehicle trips. These studies indicate that high-density development served by multiple transportation options can reduce emissions by "at least 15%" compared to low-density development.[29] Travel surveys in the United Kingdom from the 1980s showed a 25% reduction in VKT per capita when density is doubled.[30]

Several studies have examined the effect of density on shifting people from private vehicles to other forms of transportation. Examples from the San Francisco Bay area show that high density causes transit trips to increase unless the trips become so short that they are made by walking or cycling. In lower density neighbourhoods, the number of daily transit trips per household[vii] stays relatively low until density reaches 15 to 17 households per hectare, at which point daily transit trips per household rise from 0.2 - 0.3 trips to 1.3 trips. A similar pattern can be found in walking trips: at 15 to 17 households per hectare, households make 0.6 walking trips; at 74 households per hectare, they make 1.4 walking trips; and at 295 households per hectare, they make 1.5 walking trips per day.[31] Increasing density, however, must be accompanied by pedestrian friendly environments, sufficient transit service, and close commercial and employment centres in order to reduce vehicle travel, as discussed below.[32]

Residential Density and Building Operation Energy Expenditures

In addition to reducing transportation-related emissions, higher density developments also contribute to lower emissions, as less energy is required to heat and cool each residential unit. Shared walls and floors/ceilings, smaller unit sizes, and shared building mechanical systems contribute to lower heating and cooling loads. In addition, district heating and cooling systems become increasingly efficient at higher densities, as central boiler systems can serve multiple buildings more efficiently than individual systems for each building.

A Toronto study examined the combined lifecycle GHG impacts (construction, travel behaviour, building maintenance and operation) of density on different development scenarios. The study revealed that low-density developments result in roughly twice the annual energy use and 2.5 times the annual GHG emissions on a per capita basis compared to high-density developments. The study also found that higher residential densities affect emissions from the manufacture, transportation and construction of urban infrastructure. Bricks, windows, drywall and structural concrete, account for 60 to 70% of the total embodied energy[viii] used in buildings; the greater the sharing of building materials by each unit, the greater the lifecycle GHG savings.[33]

A 2009 life-cycle emissions study of the Greater Dublin area also found emissions to be lower in high-density urban developments: households more than 15 km from the city centre were found to consume 92–98% more energy and emit 50-55% more CO2 than city households. Life-cycle emissions by building type were shown to be three times higher for detached residences versus apartment dwellings. Building operational requirements accounted for the majority of emissions, with individual energy consumption rates in low-density exurban and commuter town areas averaging 85% more than in the city.[34]

While the above life-cycle emissions studies include

vii Daily trips per household refers to the number of transportations trips that members of the household take on average per day. They are often divided in the different transportation modes: vehicle, transit, walking, and cycling.

viii This is a measure of all the energy that goes into construction including the mining, manufacture, transport and assembly of materials both on and off construction sites.

other factors such as transportation to and from developments, low-density residential developments have been shown to consume high levels of energy regardless of location.[35] A 2008 US study comparing urban, suburban, and rural developments across the country found that post-war suburban developments have the highest net emissions rates, largely due to the prevalence of low-density, large single-family homes.[36] Conversely, another study showd that compact development typically reduces residential energy use by 20 to 40 percent relative to single-family home, low-density residential development.[37]

2.2 Employment Density

Employment density[ix] plays an important role in making transit, walking and cycling viable options for commuting to work. By creating mixed-use, transit-oriented employment nodes, the provision of frequent transit service becomes more feasible. Although employment nodes should be distributed throughout a metropolitan area so as to reduce commuting trip lengths, studies have found that commuters are more likely to take transit, and thereby reduce their GHG emissions, if they work in a location of high employment density.

A Seattle study of employment density comparing the central business district with the surrounding municipalities found that the higher the density of employment districts, the fewer the number of trips made and the lower the VKT by each household. The study concluded that people made use of the services and amenities close to their place of employment, used transit more often, and tended to avoid driving in an effort to escape parking costs and congestion.[38]

On the whole, higher density in the home location and higher density in the work location were found to reduce emissions in the Seattle region, but employment density of the work location was found to have a particularly strong effect on emissions compared to all other factors.[39] These findings do not negate the significance of residential density but rather highlight the importance of employment density for work related trips and the need to increase density at both home and work locations.

An earlier Puget Sound study by the same authors found that a dramatic increase in transit trips occurs at densities of more than 185 employees per hectare, and that the use of single occupancy vehicles drops significantly at densities between 50 and 120 employees per hectare. Employment density was also found to be more significant than population density in reducing vehicle travel.[40]

A nationwide US study of the relationship between employment density and VKT, which surveyed just under 35,000 workers, found that employment density at the workplace is associated with both a lower likelihood of commuting by car and reduced personal VKT. The results suggest that each increase of 1.5 employees per gross acre (1,000 employees per square mile) at the workplace decreases the probability of commuting by car by about 3%. Employment density was found to be associated with reduced personal commercial VKT regardless of travel mode. The authors concluded that while the effects appear modest, the net effect in a city could be substantial.[41]

2.3 Mixed Land Use

Through land use policies, local governments can shape the types of activities that occur on single parcels, in neighbourhoods, and throughout districts in order to reduce energy consumption and GHG emissions. By mixing commercial and residential uses, residential homes are closer to daily services such as grocery stores, coffee shops, and child care.

ix Employment density is a measure of the number of jobs per hectare/acre

Mixing office and commercial uses can allow people to run errands, have lunch, and link with business services without having to drive from their places of employment. Higher density commercial hubs are also easier to link to a transit network. Combining office, commercial and residential functions in the same neighbourhood further reduces demand for vehicular travel, as people can walk or cycle to work.

Mixed land use works in tandem with density and transportation patterns to determine travel behaviour. According to a 1996 study of San Francisco households, VKT is lower when a community's major land use differs from a neighbouring community's major land use, and when there is a greater variety of land uses within a kilometre in each community.[42]

Mixing land uses can also reduce GHG emissions in more rural settings. A study comparing alternative modeled scenarios for Salt Spring Island, BC found that GHG emissions were 22% lower in a scenario in which new development was concentrated in a village compared to the baseline scenario of dispersed development. In the village scenario new development would be closer to service nodes. The major difference between the scenarios was the number of VKT per household, which was primarily influenced by a difference in average trip length. Clustered dwellings in the village scenario resulted in reduced average trip lengths, mode shift from driving to walking and cycling, higher use of transit, reduced energy consumption from road construction, and improved energy efficiency of dwellings. This scenario included densities higher than 25 units per hectare with attached dwellings for a per unit energy savings of 29%.[43]

While the scope and methodologies vary across different studies, overall, there is a clear linkage between land use and travel choice.[44] Residents shift from driving to transit use and walking when density and land-use mix increase. A greater mix of land uses at both the origin and destination of a trip also reduces driving and increases transit use and walking.[45] People who live in more compact, mixed-use and pedestrian-friendly neighbourhoods drive less, and walk and take transit more often, even if they do not place a high personal value on such activities.[46] Increased employment density, population density, mixed land uses and a high jobs-to-housing balance all contribute to less vehicle use - and these correlations remain even when household demographics, car ownership and transit are accounted for.[47] The evidence also indicates land use has a greater effect on the VKT and the time spent traveling than it does on the number of trips taken: residents of mixed high-density development still made as many trips by car, but the trips where shorter and they spent less time driving.[48]

2.4 Street Connectivity

Street connectivity refers to the directness of links and the density of connections in path or road networks. A well-connected network has many short links, numerous intersections, and minimal dead-ends or cul-de-sacs. As connectivity increases, travel distances decrease and route options increase, allowing more direct travel between destinations, and thus creating a more accessible and resilient system.[49] This can have a significant influence on travel behaviour and GHG emissions.

Many residential streets that end in cul-de-sacs thwart direct connections for both motorists and pedestrians. Commerce is strung along overcrowded roadways and the lack of connectivity often forces motorists to use those same overburdened corridors for through trips. As a result, people drive greater distances and make fewer trips by other travel modes than they would otherwise.[50]

There is also a relationship between the road connectivity of adjacent neighbourhoods and household trip demand. Increased connectivity between neighbourhoods and efficiency of the street network do not increase the amount of vehicle emissions generated per household[51]; in fact, street connectivity can shorten driving trips and make non-motorized trips easier and more accessible.

As discussed in the previous section, a mixture of land uses across adjacent neighbourhoods also serves to reduce vehicle use. A New Zealand study found a predictable negative correlation between commute distances and walking and cycling: the longer the commute distance the less people walked or cycled. What was less predictable, however, was that residents who had the highest street connectivity along their commute network were approximately seven times more likely to walk or cycle to work than residents who traveled along the least connected routes. Those who had limited connectivity were approximately 90% less likely to walk or cycle to work.[52] Connectivity here indicates the relative prevalence of connecting streets as opposed to cul-de-sacs, and reflects both the distance and flexibility of travel routes.

2.5 Distance to Central Districts

Distance relates to GHG emissions in a number of ways. For example, shorter distances between destinations lead to less driving and a greater likelihood of walking, cycling or taking public transit. In addition, shorter distances enable efficient infrastructure and service provision, whereas long distances, such as those found between houses in single-family, low-density neighbourhoods, require greater material and energy expenditures for road construction and connecting households to public utilities. Combined heat and power systems also become viable when the distances between housing units are virtually eliminated, resulting in increased building energy efficiencies.[53] The largest building-level energy savings come from switching from single-family detached housing to attached single- or multi-family housing.[54]

The discussion on density and mixed-use development above indicates that the higher the density and intensity of land use, the shorter the distances between residences, jobs, services, and amenities. One of the strongest drivers of vehicle dependence is the distance between residential developments and city centres. A study by Statistics Canada using the 2005 General Social Survey found that “the proportion of people aged 18 and over who went everywhere by car – as either a driver or a passenger – rose from 68% in 1992, to 70% in 1998 and then 74% in 2005”.[55] One of the primary reasons cited in the study for increased driving is the increase in populations living further from city centres. The study found that the farther a household lives from a city centre, the more it relies on driving as the primary mode of transportation for day-to-day travel.[56]

The same study also found that people living within 5km of a Canadian census metropolitan area (CMA) spend an average of 55 minutes per day traveling by car, either as a driver or passenger, compared with people living 25km away, who spend an average of 83 minutes traveling by car. The proportion of residents who use a private vehicle was also seen to rise the farther away they moved from the city centre.

This observation extends beyond large cities. In smaller urban areas, rural areas and small towns, driving is as prevalent as it is in communities on the periphery of large cities.[57] Alternately, clustering development around villages reduces car travel. Homes located in rural villages can produce 64% less GHG emissions than homes dispersed across a rural region,[58] the primary difference being total VKT.

A recent Toronto study comparing a central city development to a suburban development showed a strong relationship between distance from the city centre and overall GHG emissions from buildings and transportation combined, with per capita GHG emissions increasing as the distance from the city increased. The study notes that within Toronto's central core, 30% of GHG emissions come from private transportation, while within the surrounding census tracts private transportation accounts for 50% of GHG emissions.[59]

As distances between residences and commercial centres decrease, people are also more inclined to use walking as a form of transportation; as distances between residences and commercial centres increase, residents use driving as the primary form of transportation and the overall share of driving as the transportation choice increases.[60] Distances also matter within a walkable neighbourhood itself. Within small neighbourhoods that are deliberately designed to be walkable, shorter distances to commercial destinations and community amenities within the neighbourhood are more likely to encourage walking.[61] Therefore, reducing travel distances by concentrating development around central districts and village centres is a key factor in any GHG reduction strategy.

2.6 Pedestrian Amenities

Shorter distances to commercial destinations and community amenities are more likely to encourage walking if the neighbourhoods are deliberately designed to be walkable. Sidewalks and connections to other walkable neighbourhoods can be enough to make a transit system viable and to facilitate alternative modes of travel, even in low-density neighbourhoods.

There is a high unmet demand for compact, walkable and transit-friendly neighbourhoods.

Urban and street design characteristics that make walking safer, more comfortable, more pleasant and more efficient are an effective way to help reduce VKT. As trip destinations become more convenient for non-automotive modes, such as walking and cycling, average households' vehicle ownership and use decrease.[62] Amenities that promote walking include: sidewalks that are wide enough to accommodate activities generated by land uses along them; crosswalks that are safe and frequent, providing flexible and efficient pedestrian routes; street furniture that is comfortable, convenient and safe; and an engaging street edge. Trees are also an important street amenity, providing shade and creating a natural canopy. Continuous storefront awnings, outdoor cafes, restaurants, and areas for people to congregate and sit outside in pleasant weather all contribute to an attractive pedestrian environment.

Research shows that pedestrian friendly environments have a significant impact on people's likelihood to walk or take transit rather than drive. The SMARTRAQ project, which is focused on the Atlanta Metropolitan Region, shows that even in communities with densities as low as 10 units per hectare, the presence of sidewalks and connections to other neighbourhoods that are walkable can be enough to make a transit system viable and to facilitate alternative modes of travel. The study defines walkability through a combined measurement of relatively higher residential density, existence of office and retail uses, and the frequency of intersections and streets connecting to adjacent neighbourhoods. The study found that residents of low-walkability neighbourhoods drive 30 % more than residents of the most walkable neighbourhoods, and this difference is even greater for weekend trips.[63]

The SMARTRAQ study also found an inverse relationship between walkability and per capita

GHG emissions: as walkability goes up, emissions go down. The least walkable neighbourhoods generated 20% more travel-related CO2 emisssions than the most walkable neighbourhoods. Other pollutants, such as nitrous oxides and volatile organic compounds, are also lower in highly walkable neighbourhoods.[64]

A 1989 survey of Ontario cities revealed that most residents (77% in Metropolitan Toronto, 70% in Ottawa-Carleton, and 55% in Thunder Bay) would like to be able to walk to work but are restricted by distances between home and work, and the time it would take to walk between the two.[65] Research also shows that people who prefer to walk would be willing to accept changes to their home neighbourhoods, or would consider relocating, in order to gain access to walking amenities – suggesting a high, unmet demand for compact, walkable and transit friendly neighbourhoods.[66] Creating high quality pedestrian environments to meet this demand is an infrastructure investment with direct impacts on GHG emissions: the more attractive walking becomes, the more often community residents will choose to walk to a destination, or to a transit stop, rather than drive.

Good pedestrian design and amenities can increase not only walking mode share, but can also have an impact on transit ridership. For example, sidewalk continuity and greater than average numbers of crosswalks can contribute to larger numbers of transit trips.[67] If the overall experience of the transit trip, including the walking portions, are positive people are more likely to take transit. However, if a walkable neighbourhood that includes a grid pattern with pedestrian-friendly streets and a main street is far away from employment centres and other destinations, overall walking trips will be low due to the longer trips to destinations.[68]

2.7 Transit Infrastructure

Coupled with higher urban densities, an efficient and well-networked transit service is a reliable strategy for reducing GHG emissions. The primary goals of transit planning, as it relates to GHG emissions, are to provide adequate and efficient service and to increase transit's share in the total number of trips generated within the transit region, thereby reducing

Urban design elements for creating a pedestrian-friendly environment[69]:

1. High-density: to bring retail and amenities within walking distance to more people and to attain a critical mass for viability of commercial activity and transit infrastructure
2. Mixture of uses: to bring services, amenities and retail stores to within walking distances of residences.
3. Frequent intersections and short block lengths (less than 92m): to give pedestrians more control and variety on their walking trips and a shorter sense of elapsed time on each trip.
4. Maximum of four lane streets: to minimize the distance of crossing streets and to create a balance between pedestrian flows and traffic flows.
5. Dense network of narrow streets: to distribute traffic across the neighbourhood for mixed-use commercial viability and to avoid a sparse network of wide streets
6. Wide sidewalks, but not so wide as to feel empty most of the time: to enable uninhibited pedestrian movement and congregation while avoiding the abandoned street feeling during off-peak hours.
7. Street walls: to bound the street and crease a sense of enclosure, shelter, and visual continuity
8. Street furniture and pedestrian scaled signs: to provide convenience, comfort, visual variety and safety
9. Paving patterns: to add a sense of human scale, visual interest, linkages between areas, and to denote pedestrian-oriented spaces
10. Public art: adds interest, meaning and delight to the pedestrian experience

private vehicle use. Typical improvements to transit service include creating more frequent stops and a finer-grain network, which reduces walking distances at both trip origins and destinations. Dedicated bus lanes and signal priority are also used in urban centres, especially to avoid congestion during rush hour.

A number of agencies and organizations have conducted research on the positive impact of transportation infrastructure, including the frequency and reliability of service, in lowering vehicle travel and ultimately reducing GHG emissions. For example, when households relocate to neighbourhoods with greater access to multiple modes of transportation, both within and between neighbourhoods, their use of transit increases and their annual VKT decrease.[70] A 2009 study examining the relationship between walking distance to rapid transit and travel mode choice in North York, a relatively low-density suburb of Toronto, found a strong association between convenient walk access, lifestyle, and transit use. The results showed that focusing development within a convenient walking distance of rapid transit service had, over 15 years, been accompanied by a substantial shift in the residents' travel behavior toward increased transit use.[71]

Other research has shown that each 1% increase in service (measured by transit vehicle mileage[x] or operating hours[xi]) correlates to a 0.5% increase in average ridership.[72] The Victoria Transport Policy Institute has published numerous documents that compile and summarize these benefits,[73] and the Transportation Research Board in the US is undertaking a comprehensive study of the effect of different transit infrastructure (i.e. bus rapid transit, light rail, and commuter rail) on travel behaviour.[xii] However, the research also suggests that VKT is not significantly reduced through expanding bus service only.[74,75] Using multiple strategies, such as decreasing transit fares for service in congested areas and improving transit service to major employment concentrations, help to encourage people to utilize public transportation.[76]

High capacity articulated buses that can carry up to 160 passengers are an increasingly attractive option for cities and towns in which the high cost of rapid rail is prohibitive. Also, Bus Rapid Transit (BRT) buses utilize technologies that adjust traffic signals to allow for fast uninterrupted travel between major nodes in urban areas and function almost like subways on the surface of the street.[77] The main advantage of BRT is that it achieves a high transit ridership at a fraction of the cost, and thereby providing a viable option for lowering GHG emissions. However, further comparative research in emissions outputs per passenger between BRTs and rapid transit is needed.

2.8 Cycling Infrastructure

Improved cycling infrastructure, including designating safe and well-networked routes and end-of-trip facilities, increases the use of cycling as a transportation option. Commuting by bicycle rather than by single-occupancy vehicles almost completely eliminates trip-related GHG emissions.[xiii] However, for cycling to become a more viable travel mode, cyclists must feel safe and comfortable on their daily commute. Studies show that a mode shift is possible and that well planned bicycle infrastructure leads to increased cycling rates and

x Transit Vehicle Mileage – the total mileage of transit vehicles on a particular routes or routes in a transit system

xi Operating Hours- total number of hours transit vehicles are operating on a particular route or routes

xii Update to Traveler Response to Transportation System Changes Handbook, to be released in 2011: http://www.trb.org/TRBNet/ProjectDisplay.asp?ProjectID=1034

xiii Nominal amounts of GHGs are emitted through cycling related services such as end of trip showers in the work place.

reduced vehicle use. Bicycle infrastructure includes road features, such as dedicated lanes, routes and signals, and end-of-trip facilities such as showers, lockers and secure bicycle parking and storage.

A study of Minnesota cycling facilities found that even when facilities are added in areas where cycling's mode share is already higher than the city average, a small but statistically relevant increase is observed. The improved facilities analyzed in the study included on-street bicycle lanes and off-street bicycle paths. Areas within the zone of improved facilities showed the mode share increasing from 1.7% to 2.0%. While this increase seems small, it is significant when compared to the 0.2% bicycle mode share in the rest of the region. The study also found that the greatest increase occurred on bridges and high-speed, high-traffic roads where route improvements made cycling safer.[78]

A study of bicycle ridership changes between 1990 and 2000 in cities across the US found that the effectiveness of improving facilities is influenced by three factors[79]:

1. *Location of facilities along usable commuting routes.* Routes connecting densely populated neighbourhoods and/or outlying regions with large employment centres are much more likely to increase ridership. Facilities improvements in accessible urban areas, where a large number of trips can take place across short distances, are most effective.
2. *Overall network connectivity*. A fine network of bicycle routes is much more likely to attract cyclists, as it enables more route choices.
3. *Publicity and Promotion*. Advertising the presence of bicycle facilities and promoting cycling as a commuting option improves the use of facilities. Mode shifts to cycling can only occur when commuters are aware of the existence of facilities and are excited by the prospect of making the shift.

A research project on cycling and the built environment at the University of British Columbia has compared cyclists' preferences for different types of cycling infrastructure, such as bike route densities and street connectivity, and their impact on cycling rates. Findings indicate that a majority of occasional cyclists prefer off-street, separated bike routes.[80]

A similar study from Portland, Oregon examined cycling infrastructure's influence on regular ridership. Cyclists tended to use roads dedicated as cycling routes and roads with cycling lanes for utilitarian trips[xiv], while using a broader variety of roads for recreation and leisure.[81]

2.9 Building Design

Building design has significant impacts on the amount of energy and GHG emissions expended in the heating and cooling of buildings. Building orientation and window placement affect exposure to the sun, which can influence both heating demand in the winter and cooling demand in the summer. A higher number and larger size of window openings on the southern sides of buildings, with shading devices to block the summer sun, is optimal. Designing natural ventilation across multiples sides of a building, or across multiple floors, can further reduce GHG emissions, while higher levels of insulation help maintain indoor temperatures and reduce the load on heating and cooling mechanical systems.

A Toronto study measuring the relative significance of building operations versus transportation

xiv Trips for a purpose other than exercise or just the enjoyment of riding bicycles (i.e. riding to work, shopping, or other transportation purpose.)

found that building operations contribute 50% of GHG emissions and transport operations contribute 36%.[82] These values vary considerably in communities across Canada depending on the method of electricity production. For example, BC's hydroelectric power generation means that transportation-related GHG emissions constitute a higher percentage of the province's emissions than in other parts of Canada.

Similarly, a recent study of GHG emissions at the municipal level found that across all densities, residential and commercial buildings are a larger contributor of emissions than transportation. As density increases, both residential energy use and transportation energy use decreased; however, only in exceptionally high-density developments with transit access and high levels of walkability was a dramatic reduction in emissions observed.[83]

The size and type of housing has a significant impact on energy expenditures and GHG emissions. Households in single family homes consume 54% more energy for heating and 26% more for cooling than households with similar characteristics living in multi-family dwellings.[84]

Construction materials, envelope technology and building form, all have an impact on both the embodied energy and operating energy of buildings. For example, larger homes will consume more energy and produce more GHG emissions: a household living in a 2,000 square foot home will use 16% more energy for heating and 13% more for cooling than a comparable household living in a 1000 square foot home.[85] According to a study of building life cycle costs comparing three different designs for a Toronto single family home, concrete construction for a 2400 square foot home produced 1.5 times the GHGs as a wood home and 1.25 as much as an identical size steel constructed home. In Canada the embodied energy of construction can range from 7 to 20 years worth of operating energy depending on the type of construction and climate.[86]

2.10 Local Energy Production

Viable local energy sources include renewable micro-hydro electric power, active and passive solar energy, renewable wind power, energy from waste sources, and combined heat capture systems. Local energy sources can reduce GHG emissions by reducing the need for building more large-scale hydro projects to accommodate growth and can help educate the public about energy consumption.

District energy systems can be more cost-effective and efficient than individual building heating systems, can be converted to use renewable fuels and can benefit local economic development. The local production of energy (sometimes called distributed generation) can have many benefits for communities, including reducing their GHG emissions. Local energy production reduces the need for the large-scale infrastructure currently necessary to meet projected electricity load growth. It can also benefit local economies through job creation and infrastructure projects. Local production may also help build awareness of the significance of the energy resource, thereby reducing demand.

Examples of local renewable energy sources include: micro-hydroelectric power, including projects utilized within municipal water systems; active (solar water heaters) and passive (building orientation) thermal solar; photovoltaic solar electric technology (solar panels); micro-wind turbines; energy from waste sources, such as anaerobic digestion of organic waste; wood waste and bio-mass sources; geothermal energy; and fuel cell technology[xv].[87,88,89,90]

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xv Light House Sustainable Building Centre has several examples of solar and geoexchange systems http://www.sustainable-buildingcentre.com/resources/product_library?filter0[]=1034

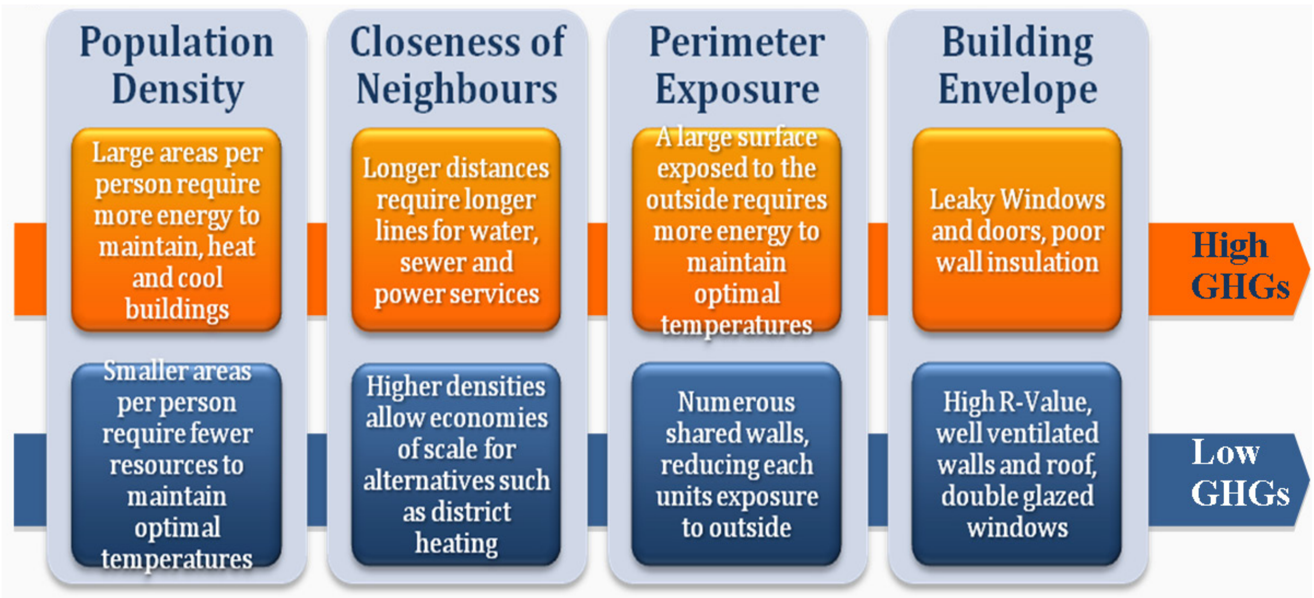

Figure 3 – The effects of density and design on GHG emissions from the heating and cooling of buildings

Using renewable distributed generation like solar, wind, geothermal, and biogas can contribute to long-term emissions reductions and a more sustainable energy future.[91,92] In BC, distributed generation will only lower emissions if it can ease the pressure of increased demand and help reduce the need for new plants.

Most energy experts advocate using waste heat from electricity and heat generation, which would otherwise be vented or flared. District heating systems transfer heat from a centralized source to a number of adjacent buildings. They can recover waste heat from municipal, commercial and industrial operations such as space heating, or from waste generated within the community (e.g., biomass, sewer heat, or landfill gas).[93] While most systems currently burn fossil fuels or organic matter, conversion to renewable energy sources is possible.[94] Over 112 district energy systems are currently in place in Canada. Concentrated urban form increases the efficiency and feasibility of district energy systems, and mixed commercial and residential developments further allow for a distributed energy load over the course of the day.[95] Section 6.3 highlights three district energy systems in Canada, which have saved between 1.7 ktCO2e and 5 ktCO2e per year since their implementation. For example, the Lonsdale Energy Corporation's district heating system in the City of North Vancouver has the capacity to heat approximately 10 buildings and currently serves a building area of 600,000 square feet.[96]

Using recent advances in technology for seasonal heat storage, and capitalizing on a cost reduction for solar collectors in Canada, Drake Landing, a new solar-oriented neighbourhood in Okotoks, AB, expects to use solar thermal technology for 90 % of its space heating requirements and up to 60 % of hot water requirements. The project is expected to save up to 5 tonnes of GHG emissions per house per year.[97]

In the 2008 handbook The New District Energy: Building Blocks for Sustainable Community Development, the Canadian District Energy Association outlines key benefits to communities that utilize district energy systems, including reinvestment of energy dollars into the local community, reduction in long-term energy costs for government and businesses, and local job creation from construction to operation of the district energy system.[98] The Community Energy Association's 2007 document Heating Our Communities: A module of the Renewable Energy Guide for Local Governments in British Columbia, is also an effective resource that provides detailed information on district heating sources. The document outlines multiple issues to consider (i.e. regulations), system costs, the benefits to the community, and strategies for implementing district energy systems.

Energy Security and Community Resilience

Local energy production can increase the resilience and security of urban regions' energy supplies. Generating a diversified energy portfolio within a community, rather than importing energy from centralized locations, can boost local economies and can shield businesses and communities from power upsets and fluctuating power prices.[99,100] Dispersing supply across many decentralized locations and a diversity of sources reduces reliance on externally produced fuel sources.[101,102,103] In addition, on-site power generation (distributed generation) helps to reduce the risk of black-outs by providing backup power during times of peak load.[104,105] In terms of efficiency, producing energy locally can reduce energy loss through the transmission of electricity, as 10 to 15% of electricity is lost through the delivery of power through transmission lines – which translates to costs of approximately 30%.[106,107]

As the preceding sections demonstrate, there is a considerable amount of evidence both linking urban form to GHG emissions and outlining specific strategies for reducing emissions. High-density, compact, walkable, mixed-use developments that are supported by a transit networks and cycling infrastructure result in reduced emissions. The following sections provide specific examples of the emissions profiles of cities and towns of varying sizing and characteristics across Canada, and the strategies local governments are using to improve them.


Columbia St

3

CANADIAN CASES

In BC, Bill 27 (Green Communities Act) required municipalities and regional districts to establish targets, policies and actions to reduce greenhouse gas emissions in their Official Community Plans by May 31, 2010, and in their Regional Growth Strategies by May 31, 2011. This section gives a snapshot of GHG emissions in communities across BC and Canada[i].

i For this report, GHG data from each jurisdiction was generated using a variety of accounting methods, data sources, and inventory boundaries, and are therefore not directly comparable.

3.1 Snap-shot profiles

Recent Data

A number of communities have created inventories of their GHG emissions, either independently with their own planning staff and planning consultants, or in collaboration with the provincial government. Creating emissions inventories is the first step in setting GHG emissions reduction targets. They establish a reference point and profile the emissions produced by different sectors and activities.

Table 3 shows examples of GHG emissions inventories from a range of communities in Canada, measured in kilotons of carbon dioxide equivalent (ktCO2e). Also included in the table are per capita emissions (tCO2e)[i], based on total population counts from Statistics Canada's 2006 census. As shown, total emissions vary by size; however, the size of the community does not necessarily correlate to per capita GHG emissions. The percentage of GHG emissions attributable to personal transportation and buildings is consistently between one-quarter to one-third of total community GHG emissions.. Examples of land use planning strategies aimed at reducing emissions are reviewed in Section 6.

Future Projected GHG Emissions

Many communities are developing future GHG emissions projections through modeling and analysis of the impact of land use decisions on emissions. The following table summarizes expected emissions increases from different communities under a "business-as-usual" scenario. These projections

Community	**Current Data**			**Percent of Total by Sector**[a]	
	Total ktCO2e	**2006 Census Population**	**Per Capita tCO2e**	**Personal Transportation**	**Homes & Buildings**
Canada	747,000[108][64]	31,612,897[109]	23.6	Not available	Not available
British Columbia	67,309[110][66]	4,113,487[111]	16.4	14%[b]	14%[c]
Toronto Metropolitan Area	37,100[112][27]	5,113,149[113]	7.3	35%	50%
Metro (Greater) Vancouver	15,607[114][76]	2,116,581[115]	7.4	35%	31%
Saskatoon	3,583[116][68]	202,340[117]	17.7	Not available	Not available
Fraser Valley Regional District	2,299[118][74]	257,03[119]	8.9	Not available	Not available
Dawson Creek	110[120][72]	10,994[121]	10.0	44%	47%
Salt Spring Island	109[122][70]	9,780[123]	11.1	Not available	Not available

Table 3 – Summary of Current ktCO2e Emissions

[a] Percentages have been rounded.

[b] The share of emissions from Personal Transportation was calculated using British Columbia's 2007 Greenhouse Gas Inventory Report and includes all sources from the category "Road Transportation" excluding all "Heavy-Duty Vehicles".

[c] The share of emissions from Homes and Buildings was calculated using British Columbia's 2007 Greenhouse Gas Inventory Report and includes sources from the categories "Electricity and Heat Generation", "Commercial and Institutional", and "Residential".

i Per capita emissions were converted from ktCO2e to tCO2e in order to enable comparability to other studies range from an increase of only 3% in Saskatoon to 25% in Dawson Creek, with the Metro Vancouver region and British Columbia hovering around 15%, as indicated in Table 4. Descriptions of the research projects follow the table.

	Total Current ktCO2e	Forecast Year	Total BAU ktCO2e	Percent ktCO2e Increase	Population Forecast	Per Capita BAU tCO2e[a]
British Columbia	67,309[124][66]	2020	84,000[125][66]	25%	5,148,500[126][79]	16.3
Saskatoon	3,583[127][68]	2013	3,700	3%	236,842[128][80][b]	15.6
Dawson Creek	110[129][72][c]	2050	138[130][72][d]	25%	13,105[131][72]	10.5
Fraser Valley Regional District	2,299[132][74]	2030	2,660[133][74]	16%	386,050[134][81]	6.9
Metro (Greater) Vancouver	15,607[135][74]	2030	17,967[136][74]	15%	3,129,337[137][82]	5.7

Table 4 – Summary of Projected ktCO2e Emissions under "Business as Usual" (BAU) Scenarios

[a] Per capita tCO2e emissions were calculated by dividing each community's business-as-usual (BAU) ktCO2e projections by the estimated population forecast for that community's BAU forecast year. Per capita emissions were converted from ktCO2e to tCO2e in order to retain consistency with other per capita emissions studies.

[b] Saskatoon's population forecast was to 2011, the latest forecast date available.

[c] Dawson Creek's business-as-usual scenario assumed a 0.4% annual population growth rate. Beginning with the total population count from Statistics Canada's 2006 census, this growth rate was applied each year from 2006 to 2013 to determine a population forecast that would coincide with Dawson Creek's ktCO2e forecast.

[d] Dawson Creek's business-as-usual scenario assumed a 0.4% annual population growth rate. Beginning with the total population count from Statistics Canada's 2006 census, this growth rate was applied each year from 2006 to 2013 to determine a population forecast that would coincide with Dawson Creek's ktCO2e forecast.

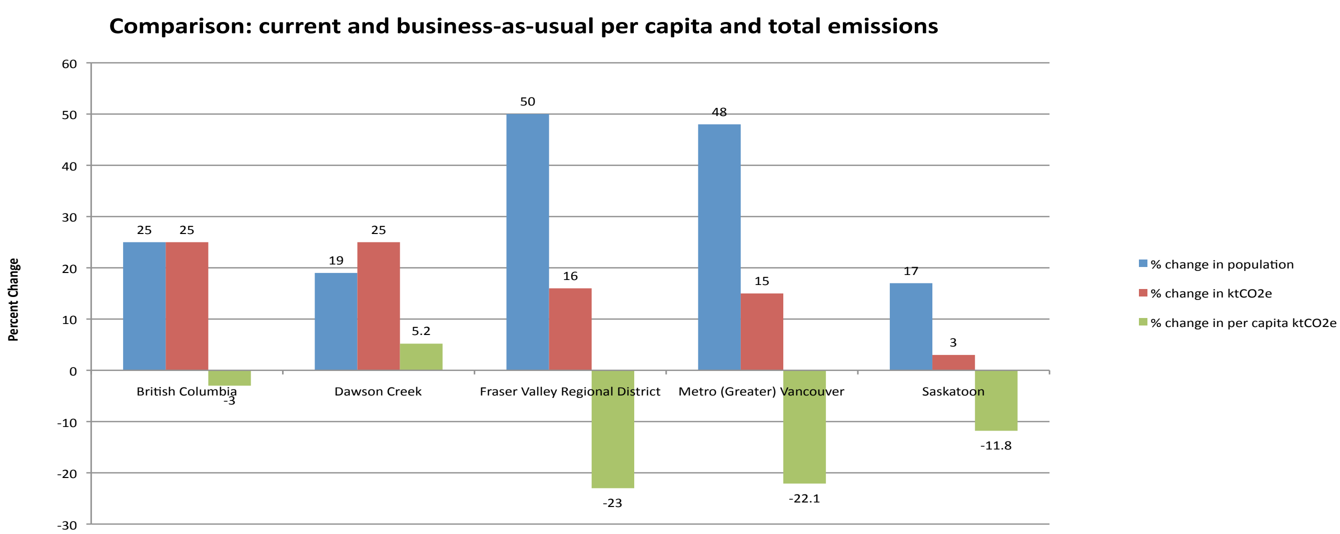

Figure 4 – Scenario comparison by jurisdiction

British Columbia Current Emissions[138]

Geographic Area: British Columbia

Summary: This document reports a comprehensive inventory of GHG sources and sinks in British Columbia for 2007. Sources of GHG emissions include those released from human activity. Sinks refer to the removal of GHG emissions (i.e., trees). The inventory is structured by sector and sub-sector: energy, industrial processes, solvent and other product use, agriculture, waste, and land use, land-use change and forestry.

Method: The B.C. Ministry of the Environment used data from Environment Canada's National Inventory Report on Greenhouse Gases and Sinks in Canada, as well as additional unpublished data from Environment Canada's GHG Division. GHG estimation methods used in Environment Canada's national inventory are consistent with the Intergovernmental Panel on Climate Change guidelines.

Key Findings: Figure 5 illustrates the province's emissions by sector.

British Columbia GHG Emissions 2007: 67,309 ktCO2e

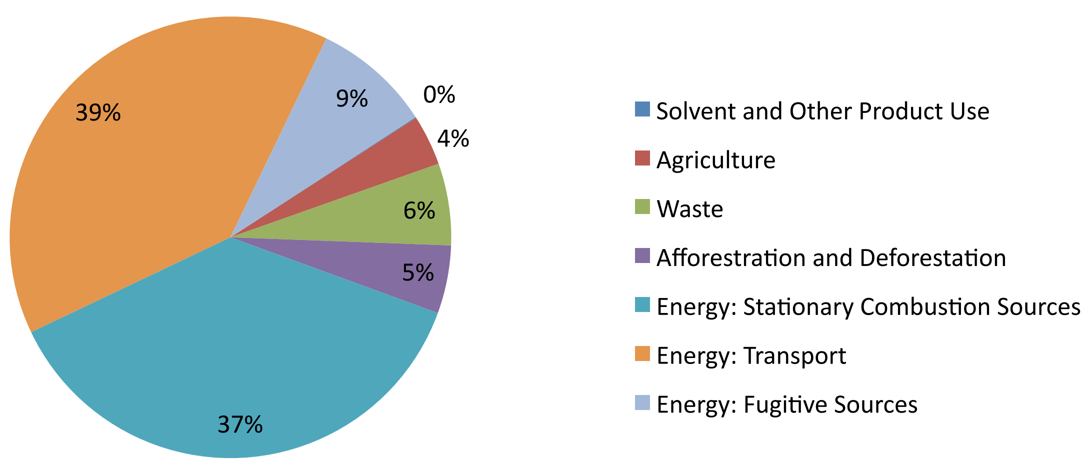

Figure 5 – GHG emissions in B.C. by source

British Columbia Business-As-Usual Projections[139]

Geographic Area: British Columbia

Summary: The document is an analysis of current and projected future GHG emissions in British Columbia, and indicates that provincial targets for GHG emissions reductions cannot be met through current provincial policy.

Method: Statistical projections were calculated using Environment Canada GHG emission data from 2000, with the incorporation of GHG emissions that are imported into B.C. (e.g., emissions associated with hydrofluorocarbons and electricity). To calculate emissions trends, the Pembina Institute began with Natural Resources Canada's report Canada's Energy Outlook: Reference Case 2006, but used B.C. government assumptions of population growth rather than Natural Resource Canada's growth projections.

Key Findings: Total business-as-usual emissions in British Columbia are likely to grow from approximately 73 MtCO2e in 2007[a], to 84 MtCO2e in 2020, an increase of approximately 15%.

[a] At the time of the cited report by The Pembina Institute, British Columbia's 2007 Greenhouse Gas Inventory Report had not been completed. The actual figure as accounted for in British Columbia's 2007 Greenhouse Gas Inventory Report was 67.3 MtCO2e.

Lower Fraser Valley[140]

Geographic Area: Metro Vancouver and Fraser Valley Regional District, British Columbia

Summary: This document, published in 2007, is a 2005 air emissions inventory and an emissions forecast for the Greater Vancouver Regional District. The forecast includes air emissions projections, including CO2 and GHG emissions, to 2030.

Method: Statistical projections were based on variables that include changes in population, economic activity, vehicle kilometres traveled, and fuel consumption. The projections also incorporated all current policy actions committed to by federal, provincial and regional agencies (e.g. B.C.'s proposed tailpipe emissions standards and Metro Vancouver's proposed Boiler and Heater Regulation).

Key Findings:

- Because of population growth and increased economic activity, GHG emissions are expected to increase in the Lower Fraser Valley between 2010 and 2030.
- Per capita GHG emissions are expected to decline between 2005 and 2030, while total emissions will increase.
- Metro Vancouver's CO2 emissions are projected to increase almost 17%, from 14,685 ktCO2 in 2005 to 17,116 ktCO2 in 2030.
- The Fraser Valley Regional District's CO2 emissions are projected to increase approximately 17%, from 1,765 ktCO2 in 2005 to 2,062 ktCO2 in 2030.
- The two main sources of GHG emissions for the total Lower Fraser Valley are heating buildings (24%), and personal transportation, including vehicular and transit use (24%).

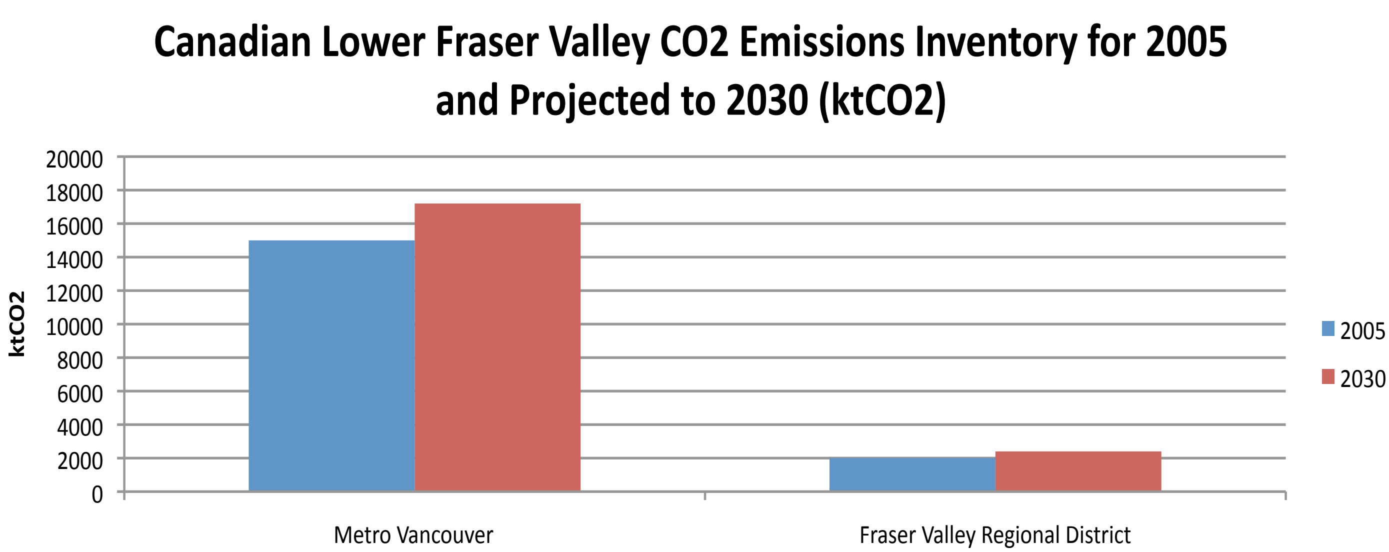

Figure 6 – Lower Fraser Valley GHG Emissions

City of Dawson Creek[141]

Geographic Area: City of Dawson Creek, British Columbia

Summary: The City of Dawson Creek has initiated a number of actions to plan for climate change. This report provides a look at current GHG emissions and projected business-as-usual trends to 2050, and then follows with recommended GHG emissions reductions targets. The City of Dawson Creek Climate Action Plan outlines the development of their stated targets, while the first phase of their Community Energy Plan provides a baseline of energy use in the community. The following findings focus on current and projected GHG emissions.

Method: Dawson Creek's GHG emissions inventory was compiled by the Pembina Institute based on provincial data. Using 2005 as a baseline year, the inventory included GHG emissions from buildings (homes, businesses, and industry), vehicles and waste. Data from vehicle emissions was compiled through vehicle registrations. Industrial emissions from buildings were not included if the industry was located outside the city limits. Non-combustion industrial sources were also excluded. Only emissions from electricity, natural gas, diesel, and gasoline were included in the GHG emissions inventory.

Projected GHG emissions were based upon three population growth scenarios between 2000 and 2050. The projections do not include fluctuations in per capita emissions over time or potential policy initiatives, and do not assume changes in behaviour or technology that could affect emissions. Scenario A had a "likely" population growth of 0.4% per year, Scenario B had a "possible" population growth rate of 1% per year, and Scenario C had a "maximum" population growth rate of 2% per year.

Key Findings:

- Total GHG emissions for the City of Dawson Creek were 110 ktCO2e in 2005 and are "likely" to increase 25% to approximately 138 ktCO2e by 2050 under a business-as-usual scenario with population growth of 0.4%.
- In 2005, GHG emissions from transportation made up 44% of total community emissions, with emissions from buildings comprising 47% of the total.
- Municipal emissions generated by municipal government operations (e.g. buildings and fleet vehicles) contributed approximately 2% of total GHG emissions in the baseline year of 2003/2004, or 2.34 ktCO2e. 70% of municipal GHG emissions were from buildings, fleet vehicles made up 23.5%, and other infrastructure produced 6.5%.
- The City of Dawson Creek established the following GHG emissions reductions targets:
  - 14% below 2006 levels by 2012
  - 33% below 2006 levels by 2020
  - 85% below 2006 levels by 2050

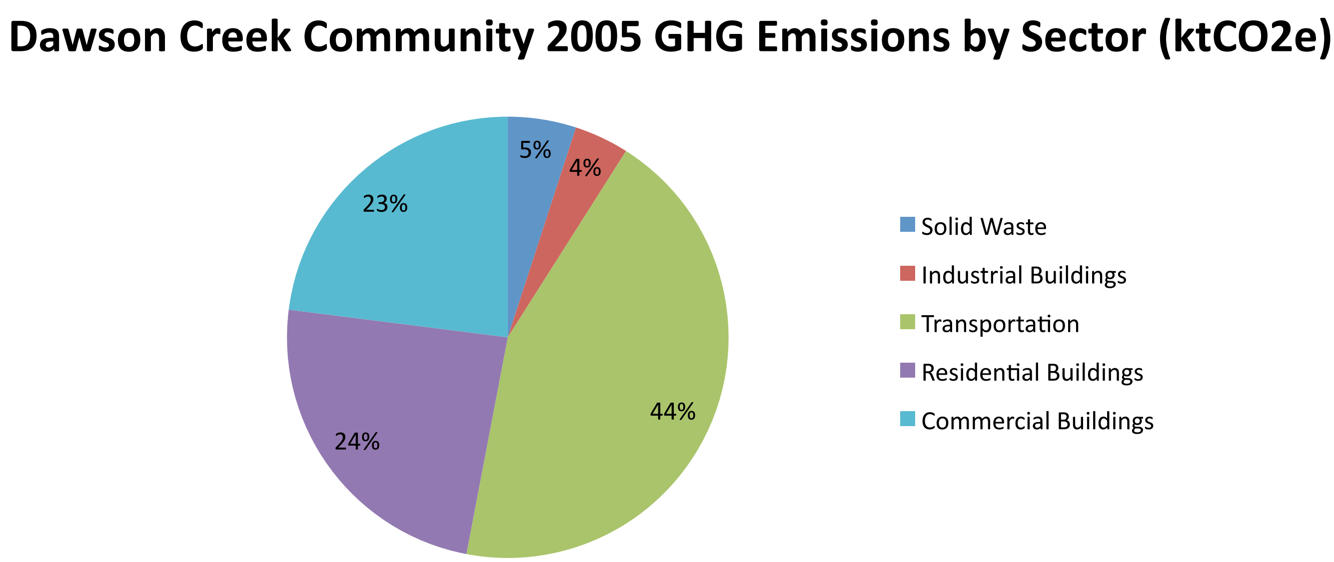

Figure 7 – Dawson Creek Emissions by Sector

City of Saskatoon[142]

Geographic Area: City of Saskatoon, Saskatchewan

Summary: The City of Saskatoon's Draft Energy and Greenhouse Gas Management Plan is a fulfillment of Milestone 3 of the Federation of Canadian Municipalities' Partners for Climate Protection Program (PCP). The document provides a baseline of GHG emissions as a benchmark for future reductions. Business-as-usual GHG emissions projections were used to determine appropriate actions for GHG reductions targets.

Method: The business-as-usual GHG emissions scenarios were based on 2013 electricity demand projections from Saskatoon Light and Power and SaskPower.

Key Findings:

- The land base for Saskatoon increased between 2001 and 2006 from 148 square kilometres to 170 square kilometres. Population density has in turn decreased from 1,326 people to 1,184 people per square kilometre.
- The number of dwelling units in Saskatoon increased from 84,281 in 2001 to 89,696 in 2006.
- Municipal GHG emissions increased 23%, from 74 to 91 ktCO2e, between 1990 and 2003, while community GHG emissions increased 45%, from 2,466 to 3,583 ktCO2e, due primarily to increases within the industrial sector.
- By 2013, corporate municipal GHG emissions are projected to increase by almost 13% to 103 ktCO2e, assuming the current trend of energy use remains constant, along with additional buildings and services needed for increased growth.
- Community GHG emissions are projected to increase approximately 4% to 3,700 ktCO2e by 2013.

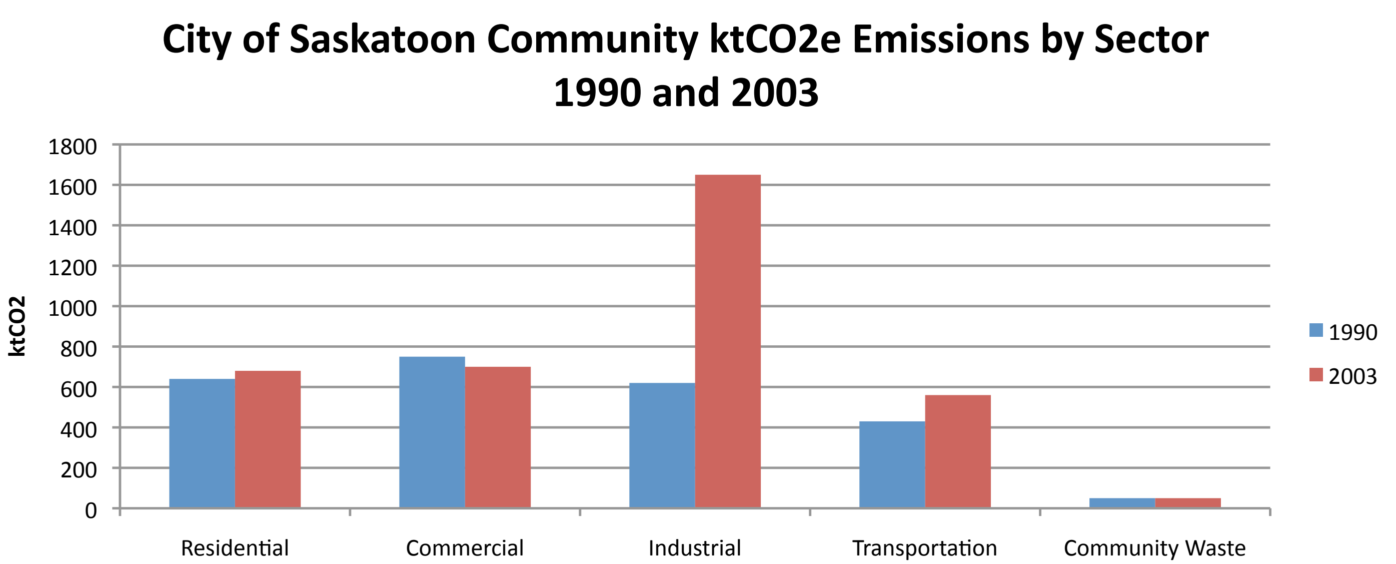

Figure 8 – City of Saskatoon GHG Emissions by Sector

Toronto Current Emissions[143]

Geographic Area: Toronto region, Ontario

Summary: The Pembina Institute's September 2006 report on Building Sustainable Urban Communities in Ontario is the fifth update of a report first published in February 2003 report which outlined a smart growth policy framework for Ontario. The study states a case for a smart growth strategy for Ontario beginning with statistics as to how a business-as-usual scenario will affect land use, transportation, and infrastructure.

Method: This study utilizes a literature review with case study assessment to compare what the Pembina Institute recommended in February 2003 with what the province has actually achieved during the period of June 2005 to 2006, within the following categories: infrastructure, land use, fiscal/taxation, and governance.

Key Findings:

- Between 2000 and 2031 there will be a population increase of 43% from 7.4 million;
- Urbanization of land will increase by 45% (1,070 square kilometres);
- Transit use will decrease by 11%;
- Development may occur in the greenbelt, despite the province of Ontario's intentions that development should intensify in existing urbanized areas through strategies of mixed use, redevelopment, and alternative mobility options, as it appears that some regions are pursuing land use amendments that would facilitate rural estate development on new lands.

Toronto Business-as-Usual Projections[144]

Geographic Area: Toronto region, Ontario

Summary: The study examines a possible future business-as-usual scenario for the Toronto region if current development processes and and plans are used to accommodate the region's assumed continued growth to 2031.

Method: This statistical projection for a business-as-usual growth scenario for the Toronto region to 2031 was based upon assumptions and historic trends such as population growth of 100,000 people per year, economic growth that includes strong growth in employment, consistent infrastructure growth and maintenance, new urban development directed toward existing areas first, and a slight rise in average residential densities.

Key Findings:

- Vehicle ownership will increase by 50% to 5.6 million vehicles;
- Vehicle kilometres traveled will increase 64% (from 157 million to 258 million daily kilometres traveled);
- GHG emissions related to transportation will increase by 42%[a] from 10,871 ktCO2e to 15,456 ktCO2e.

[a] Pembina notes that GHG emissions will increase by 526 percent in suburban areas relative to current levels (Winfield 2003, 4).

Toronto GHG Emissions and Housing Density[145]

Geographic Area: Toronto, Ontario

Summary: This study analyzes two case studies from the City of Toronto (high-density and low-density residential) in order to assess the life-cycle (i.e. construction materials, building operations, and transportation) implications of density on energy use and GHG emissions.

Method: A life-cycle assessment (LCA) was used to determine energy use and GHG emissions for two case studies that represent one high-density and one low-density development. The LCA included an analysis of all materials for buildings and infrastructure, operational requirements for housing, and operational requirements for public and private transportation. The study applied an economic input-output LCA for construction materials, used nationally averaged data for building operations, and utilized Greater Toronto Area data to determine transportation energy use and GHG emissions.

High-Density Case Study

The high-density example analyzed in this study was a new 15-story residential condominium building with a density of 150 dwelling units/hectare, located near downtown Toronto.

Low-Density Case Study

The low-density example analyzed was a 161 single-detached dwelling unit subdivision located near the Toronto boundary and adjacent to the Town of Markham, with a density of 19 dwelling units/hectare of land.

Key Findings:

- GHG emissions related to transportation (measured in either per capita or per square metre) are higher for the low-density scenario due to the high vehicle dependence of its land use patterns.

Per Capita Results

- Per capita life cycle emissions for construction material, building operations, and transportation in the low-density case study are 2.5 times the annual emissions for the high-density example.
- Embodied energy and GHG emissions for the life cycle of construction materials only are 1.5 times higher for the low-density case study as compared to the high-density example.
- GHG emissions from transportation are 3.7 times higher in the low-density development than the high-density development.

Per Square Metre Results

- Overall life cycle emissions of construction materials, building operations, and transportation per square metre of living space are 1.5 times for the low-density case study than the annual emissions of the high-density example.
- However, when comparing by per square metre of living space for construction materials and building operations only, the high-density example has higher GHG emissions than the low-density example. Per square metre, embodied energy and GHG emissions for the life-cycle of construction material are 1.25 times higher for the high-density case study as compared to the low-density example.
- Per square metre of living space, high and low-density scenarios are equal in their annual energy use for building operations.
- GHG emissions from transportation are 2 times higher in low-density developments than high-density developments.

Toronto GHG Emissions and Urban Form

Geographic Area: Toronto Census Metropolitan Area, Ontario

Summary: This study spatially analyzes residential GHG emission in the Toronto Census Metropolitan Area in order to determine a relationship between urban form and GHG emissions.

Method: The study focuses on the spatial distribution of GHG emissions within the Toronto Central Metropolitan Area. Building emissions were calculated through average annual payments for electricity and fuel service reported for each census tract in the 2001 Statistics Canada Census. Emissions from transportation were analyzed using data from the 2001 Transportation Tomorrow Survey to generate total trip distance estimates for trips by private vehicle, public transportation, cycling, and walking.

Key Findings:

- The study estimates that in 2001 total GHG emissions in the Toronto Census Metropolitan area were 37,100 ktCO2e.
- GHG emissions from building operations encompassed 50% of the GHG emissions (18,800 ktCO2e), while private transportation accounted for 35% (12,500 ktCO2e).
- The study indicates that the central core census tracts of Toronto produce more GHG emissions from residential buildings (4.41 tCO2 per capita) than suburban census tracts (3.88 tCO2 per capita); higher-density developments in the central core have additional energy loads, due to the demands of elevators and common areas and facilities, and in this case also attain higher occupancies.
- When considering GHG emissions from buildings and transportation combined, per capita GHG emissions increase as distance from the Toronto's central core increases. Per capita GHG emissions within the central core averaged 6.42 tCO2, with the surrounding area averaging at 7.74 tCO2 per capita.
- Within Toronto's central core, 30% of GHG emissions come from private transportation, while within the surrounding census tracts, 50% of GHG emissions come from private transportation.

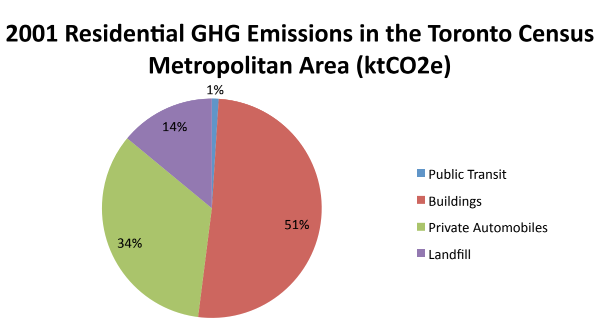

Figure 9 – Toronto CMA GHG emissions by sector

3.2 Future Development Scenarios

What have some communities predicted will be the effect of urban development on GHG emissions?

In contrast to the studies in the previous section, which examined the GHG emissions of particular communities at a particular point in time based largely on current development practices, this section summarizes several studies that have looked at future development scenarios, and their impact on GHG emissions, for their communities. The subsequent studies of Langford, Toronto, and Salt Spring Island then go further, analyzing the relationship between land use patterns and GHG emissions through alternative land-use scenario modeling.

City of North Vancouver – 100 Year Sustainability Vision[146]

Geographic Area: City of North Vancouver, British Columbia

Summary: The City of North Vancouver's 100 Year Sustainability Vision is a planning document designed to guide the City towards its goal of becoming carbon neutral by 2107. It is based on six principles: access to linked public places, parks and natural areas; green, durable, timeless infrastructure; mixed-use corridors accessible to all; five minute walking distance to commercial services and transit; appropriate housing for all; and, good and plentiful jobs close to home[147]. It is meant to work in conjunction with the OCP.

Method: This project used GHG emissions models for energy use for a variety of residential, commercial, industrial, and institutional buildings and GHG emissions from transportation connected to different dwelling unit types. Residential proximity to major transit nodes was modeled separately and then linked with the development pattern analysis. Energy and emission inventories for the City were applied to the models to determine GHG emissions associated with different land use patterns. Four scenarios were modeled for this project; the 2007 baseline, a scenario each for 2050[a] and 2107, and a scenario based on results from a public charrette process.

[a] The 2050 scenario is the midpoint in development between the baseline scenario of 2007 and the target scenario of 2107. The 2050 and 2107 scenarios were used to predict the feasibility of the charrette scenario targets of an 80% reduction of GHG by 2050 and a 100% reduction by 2107 (Miller and Cavens 2008).

Key Findings:

2050 and 2107 Scenarios

- GHG emissions for 2050 were estimated to decline by 82%.
- GHG emissions for 2107 were estimated to be zero.
- These emissions decreases assume building retrofits and energy efficient new building construction as well as zero-carbon renewable energy sources for all energy needs.

Charrette Scenario

- Population and job growth would be located within dense building forms. Assuming typical building efficiency, this shift would decrease per unit average energy use by approximately 20%.
- Per capita transportation demand would decrease by 38% as compared with the 2007 baseline scenario. Assuming increased investment in transit infrastructure that includes light-rail, 95% of the city's population will live within 400 metres of major transit. This scenario also assumes that GHG-neutral fuel powers all non-vehicular modes of transportation.
- Per capita building energy demand would decrease by 21% with no increased building efficiency as compared with the 2007 baseline scenario. Assuming "aggressive building technology changes", this scenario could achieve a 76% reduction in per capita building energy demand as compared with the 2007 baseline scenario.
- Total per capita energy demand (buildings and transportation) would decrease by 31% with no increased building efficiency. "Aggressive building technology changes" would allow for a 53% reduction in per capita building energy demand as compared with the 2007 baseline scenario.

Salt Spring Island[148]

Geographic Area: Salt Spring Island, British Columbia

Summary: The document models alternative land use patterns for maximum build-out scenarios and then compares GHG emissions between business-as-usual, hamlet, and village scenarios. The following factors were used to determine GHG reductions: proximity to transit, average trip distance, community energy systems, energy efficiency of buildings, and road construction. In addition, it was assumed that a rural transit system was put into place for each scenario.

Method: The study determined potential GHG reductions through land use planning thresholds (the points at which GHG emissions reductions related to a change in land use pattern become feasible). Threshold factors included: changes to different modes of transportation due to changes in density and proximity of housing and services to the village centre, the introduction of public transportation, increased building efficiency and community energy systems, and an increase in the number of roads. Scenario characteristics were as follows:

Scenario 1: Existing conditions.

Scenario 2: Maximum build-out under current zoning.

Scenario 3: New development clustered in eight hamlets and two villages.

Scenario 4: New development cluster in two villages.

The study used 2002 data to determine current GHG emissions, from a report by the Earth Festival Society [89]. At this time, the population of Salt Spring Island was 9,000 and generated 67,723 tCO2e, with an additional 41,313 tCO2e from indirect emissions from food consumption, for a total of 109 ktCO2e.

Key Findings:

Baseline Build-out Scenario Emissions

Under the baseline build-out scenario, the maximum potential new dwelling units based on existing land use bylaws would increase 291% from 4,464 to 13,034. GHG emissions related to land use would increase 293%, from 41.5 ktCO2e to 121.4 ktCO2e.

Hamlet Scenario Emissions

The hamlet scenario would transfer 3,486 dwelling units (those that currently could only be created through subdivision of property) to eight new hamlets and two villages that already exist (Ganges and Fulford Harbour). The scenario distributes the dwelling units in a way that preserves the rural character of the island. The hamlet scenario would decrease GHG emission by 7% compared to the baseline build-out scenario. GHG emissions related to land use would increase 272%, from 41.5 ktCO2e to 113 ktCO2e. Potential GHG emissions reductions are low due to the overall dispersed housing pattern, which provides less opportunity for pedestrian access to services.

Village Scenario Emissions

The village scenario would transfer 3,486 dwelling units to two existing villages (Ganges and Fulford Harbour). This scenario creates land use patterns that reduce GHG emissions by increasing walking access to services, by gaining energy efficiency from increased housing density, and by utilizing a new community energy system. The study concluded that GHG emission would decrease by 22% in the village scenario compared to the baseline build-out scenario. GHG emissions related to land use would increase 227%, from 41.5 ktCO2e to 94 ktCO2e.

Thresholds

Certain land use planning thresholds identified in the study could be utilized in other communities:

- A combined heat and power (CHP) community energy system is feasible when housing density is at least 55 units per hectare. Such an energy system is almost 30% more efficient than traditional electricity and heat sources[149].
- Attached single housing reduces annual heating requirements by 29% as compared with detached single houses. Such attached housing is best achieved at a minimum of 25 units per hectare.
- The Salt Spring Island study contends that the most substantial part of GHG emissions related to the community's land use come from transportation emissions[a]; equaling approximately 90% for each land use scenario.

Given the combined impacts of land use assumptions (e.g. proximity to transit, housing density, etc.), a home located in a village will produce 64% less GHG emissions than a home located in a rural location.

[a] Transportation emissions make up a large proportion of overall emission in part because energy for heating on Salt Spring Island comes from electricity with low GHG emissions.

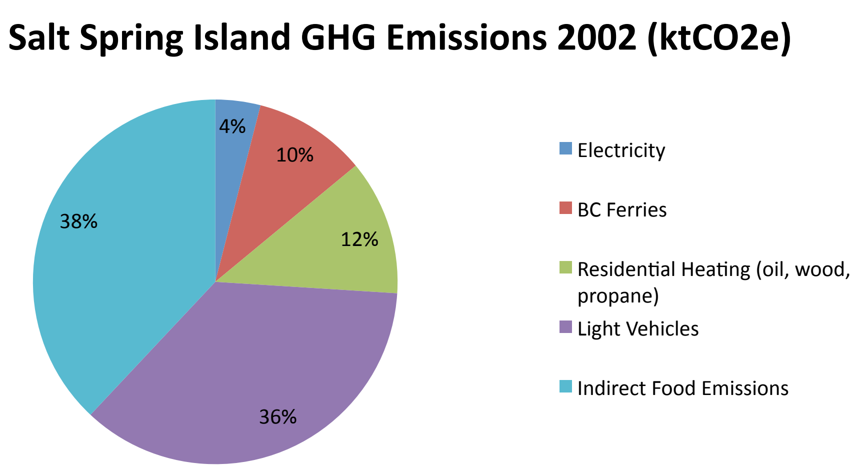

Figure 12 – Salt Spring Island GHG emissions by sector

Toronto[150]

Geographic Area: Toronto region, Ontario

Method: The document models alternative land use patterns and related transportation and water/wastewater infrastructure systems, and compares these alternatives with a business-as-usual (BAU) scenario in terms of infrastructure performance and costs. The study does not specify reductions in GHG emissions. Three different land use patterns were analyzed in relation to infrastructure performance and costs.

Consolidated Development Pattern

This development pattern would incorporate new development into existing urban areas that already have access to infrastructure.

Multi-Centred Development Pattern

This development pattern would incorporate new development into both existing urban areas and small regional centres.

Dispersed

This development pattern is a business-as-usual scenario, but with additional investment in roads that would relieve traffic congestion and increase access to undeveloped land.

Key Findings:

- The consolidated development pattern has the lowest vehicle-kilometres traveled of each development pattern in the study (6.4% lower than BAU).
- The consolidated development pattern has the largest proportion of municipal transit in the transit region (20% more than BAU).
- The consolidated development pattern uses the least fuel for transportation (a reduction of 6% compared to BAU).
- The consolidated development pattern reduces the most transportation emissions (a reduction of 15% compared to BAU).

4

COMMUNITY ASSESSMENT

One of the greatest challenges of GHG emissions planning is calculating emissions to establish baseline values and to monitor progress towards target reductions. The BC Ministry of the Environment has established the Communities Energy and Emissions Inventory which provides baseline data for building operation and transportation related emissions. Detail within these categories requires additional data and research work. This chapter covers one of many general approaches that may be used to calculate emissions.

Calculating Emissions

Calculating emissions at the neighbourhood scale involves disaggregating community energy and emissions into:

1. the embodied energy of buildings in the community, in terms of initial construction and ongoing maintenance,
2. the operating energy of the structures, in terms of heating and cooling energy demands, and
3. the transportation activity of the community's inhabitants.

Emissions for commercial and mixed-use neighbourhoods would additionally include the transportation of goods, as well as all the energy that goes into manufacturing a product or running a business. Calculating emissions begins with generating data sets for each category. The source and quality of the data for each category varies considerably depending on the scale of the study and whether the community is already established or is being proposed. The smaller the study area, the easier it is to accurately assess the embodied energy and operating energy by using actual utility data. As the analysis scales up to larger areas, it becomes increasingly difficult to gather data for every user within all the different land uses, and it becomes necessary to use aggregations, based on assumptions of average consumption by land use type or business type. Computer modeling rather than direct accounting also becomes necessary. However, the larger the scale, the easier it is to use aggregated transportation information from existing data sources, such as the census and regional transportation studies. Transportation data can also be accurate at a small scale but obtaining the data requires conducting transportation surveys of a small group of residents, which can be costly on a per resident basis.

The following steps help to simplify the complexity of actual relationships when undertaking a city wide or regional analysis:

1. Create appropriate categories representing the variety of buildings, land uses and transportation patterns;
2. Create representative examples for each category in which a small sample of land-use, building, and infrastructure types are used to represent conditions across the entire region;
3. Make assumptions about the scaling of the representative examples to the larger study area; and
4. Identify and include any sources of emissions that may have been left out of the categorization and representative sample production.

Table 5 summarizes some of the strengths and weaknesses of different methodological approaches that are used in generating data and calculating GHG emissions. Most GHG inventories do not include the embodied energy of buildings, in terms of initial construction and ongoing repair and maintenance, because when amortized over the life of a building embodied energy represents only a fraction of annual heating and cooling costs.

Category	Scale	Data Source	Accuracy	Strengths	Weaknesses
Embodied Energy	Neighbourhood	Construction document values entered into auditing software such as ATHENA	High, although using representative buildings to substitute for quantification of every building reduces accuracy	Detailed inputs of buildings generate greater awareness of the relative significance of each component and allow for scenario modeling	Time-consuming
	City	Census counts of building types and assume a typical construction for each type	Low	Creates broad figures that can be used as a baseline estimate for more detailed analysis	Only represents a general approximation of the actual urban form
Operating Energy	Neighbourhood	Public utility data	Very high	Provides precise inputs ifor any kind of modeling framework, and can be monitored over time	Data is difficult to obtain because of privacy concerns.
	City	Aggregated regional rates of power and fuel use	Moderate	Accessible data	Inaccurate for detailed built form analysis; cannot be scaled down to neighbourhood level
Transportation	Neighbourhood	Trip diaries and/or survey responses for study neighbourhood	Variable; Remembered or noted behaviour might under report actual travel	Data can be fairly detailed and specific to the study community	Expensive to administer and response rates could be too low for statistical relevance in smaller studies
		Use urban form variables (i.e. population density) and regional fleet characteristics to mathematically model vehicle ownership and VKT	Variable; equations modeled after specific city data and may be inconsistent with local conditions	Allows for modeling of proposed or speculative development or for generating estimates when neighbourhood-specific data is unavailable	Models simplify factors affecting vehicle ownership and driving behaviour ,and do not account for all variables
	City	ICB.C. registration for car ownership figures	High accuracy for vehicle ownership but data does not translate directly to use rates	Aggregation and disaggregation possible	Data can be misleading for VKT rates
		Odometre readings from AirCare	High for annual driving	Accurate data that can be organized by household	Data difficult to obtain due to privacy concerns and do not account for vehicles that never enter AirCare system due to their newness
		Traffic counts and engineering traffic models	High	Accurate and can be used to assess different scenarios	Requires highly trained and specialized modelers and difficult to scale to neighbourhood level behaviour
		Census travel statistics	High	Readily available datasets	Only useful at regional and city wide scales
		Regional travel surveys	Moderate	Detailed information	Expensive to administer

Table 5 – The pros and cons of different data sources for calculating GHG emissions

Assessing Transportation Impact

Vehicle Kilometres Traveled – measuring VKT through travel surveys, traffic counts, road network analysis, census data, etc. Values need to be scaled to the planning area (VKT per unit, per person).

VKT can be used to calculate GHG emissions by assuming average fuel efficiencies and multiplying by the weight of GHGs that each kilometre of travel produces. For example, average vehicle fuel efficiency in Canada was 12.6 litres per 100km in 1977 and dropped to 9.2 l/100km in 2002.[151] The 2006 figure for fuel efficiency of cars and light tucks (including SUVs) is 10.6 l/ 100km[i].[152] Since every litre of gasoline produces 2.4 kg of CO2,[153] we can directly estimate annual GHG emissions from VKT data using 254 grams per km traveled. The actual age and type of vehicles in a community varies considerably, so the more specific the calculation is to the actual vehicles in the community, the more accurate this assessment will be.

Calculating vehicle efficiencies at a community level requires precise vehicle inventories for the vehicles used in a community with the respective VKT for each vehicle. The age and state of repair of a vehicle can also significantly alter fuel efficiency performance. The higher amount of GHGs that are emitted while an engine is still cold further complicates calculations. The number of vehicle trips that make up VKT is therefore an equally important consideration to VKT, as many small trips would emit more GHGs than a single trip covering the same distance.

Assessing GHG Emissions From Buildings

When assessing GHG emissions from buildings, most studies focus on the operation of buildings in terms of heating and cooling. The following factors are typically taken into consideration:

- Building type, age and construction
- Source and efficiency of heat
- Electric usage rates and fuel source used to generate electricity
- Gas or fuel usage rates for heating

Data can be combined and entered into comprehensive analytical software managed by environmental consultants.

Using Neighbourhood Design Types To Determine GHG Emissions At Municipal And Regional Levels

Representative neighbourhood types (archetypes) can be used as a proxy for the communities being studied to generate estimates about the study area. Natural Resources Canada's CANMET Energy Technology Centre has conducted a study of urban archetypes, through which they produced GHG emissions calculations for 3 neighbourhoods in each of eight cities: Halifax, Ottawa, Clarington, Regina Whitehorse, Calgary, Lethbridge and Coquitlam. The intent of the project is to create a variety of neighbourhood profiles that can be patched together to determine city-wide GHG emissions. Other communities will also be able to use these neighbourhood profiles to determine GHG emissions in their own communities with comparable characteristics. The community profiles for Whitehorse and Coquitlam are outlined in section 5.0.

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i The 10.6 litres/100km figure is calculated using average fuel efficiency values and adjusting for the market share of each of the small car, luxury car and light truck sectors.

Community Energy and Emissions Inventory

Developing a Community Energy and Emissions Inventory[ii] is also an important starting point for communities planning their future GHG emissions reduction targets. These inventories can be based on current community wide energy and emissions, government operations energy and emissions, or both. These reports meet Climate Action Charter commitments for local governments to measure and report GHG emissions and can aid in establishing targets and goals for GHG reductions as required in B.C.'s Green Communities legislation (Bill 27).[154]

ii The Community Energy Emissions and Inventory is a B.C. Ministry of Environment initiative.

5

TYPICAL GHG EMISSIONS

A number of international authorities have developed protocols for counting and reporting GHG emissions,[155,156,157] and several studies have shown the relationship between urban development and GHG emissions in Canada.[158,159,160,161,162] Natural Resources Canada's Urban Archetypes project, is a study of the GHG emissions of specific neighbourhoods in different municipalities across Canada that can be categorized as representative of typical neighbourhoods.[163,164]

5.1 Low-Density At Varied Distances To The City Centre

The NRCan Urban Archetypes project constructed inventories using home power and gas data for household energy use as well as estimated annual VKT per household. The following sections summarize some of the characteristics of the case study neighbourhoods in Whitehorse[165] and Coquitlam[166].

Porter Creek, Whitehorse

This development has a density of 4 units per hectare, with 93% single-family detached with almost no mixed use and is situated 6.4km from the central business district. The average household operates 2.4 vehicles per household and has an average of 4 people per household and 193m2 of heated floor area. Homes are equipped with conventional appliances and were constructed between 1961 and 1983. Insulation R values vary between 12 and 32 and the primary fuel source for heat is oil.

Wolf Creek and Mary Lake, Whitehorse

This development has a density of 0.46 units per hectare, is exclusively single-family detached homes with no mixed use and is 15km from the central business district. The average household operates 2.5 vehicles per household and has an average of 3.6 persons per household and 245m2 of heated floor area. Homes are equipped with conventional appliances and were constructed between 1978 and 1995. Insulation R values are between 13 and 40 and the primary fuel source for heat is oil.

Granger, Whitehorse

This development has a density of 6.6 units per hectare, is exclusively single-family detached units with almost no mixed use and is 3.2 km from central business district. The average household operates 1.9 vehicles per household and has an average of 4 persons per household and 263m2 of heated floor area. Homes are equipped with conventional appliances and were constructed between 1984 and 1995. Insulation R values are between 16 and 36 and the primary fuel source for heat is propane.

Burquitlam, Coquitlam

This development has a density of 8.65 units per hectare, is exclusively single-family detached houses with little mixed use and is 7.58 km from the central business district. The average household is 3 people, and operates 2.1 vehicles and occupies an average of 212m2 of heated floor area. Homes are equipped with conventional appliances and were constructed between 1945 and 1983. Insulation R values are between 4 and 20 and the primary fuel source for heat is natural gas.

Eagle Ridge, Coquitlam

This development has a density of 12.27 units per hectare, with 97% single-family detached houses, some mixed use and is 1.38 km from the central business district. The average household operates 2.5 vehicles at an average of 4 people per household and 246.5m2 of heated floor area. Homes are equipped with conventional appliances and were constructed between 1978 and 1995. Insulation R values are between 7 and 23 and the primary fuel source for heat is natural gas.

Ranch Park, Coquitlam

This development has a density of 12.15 units per hectare, is exclusively single-family detached houses with no mixed use and is 2.12 km from the central business district. The average household consists of 3 people, operating 2.2 vehicles and using an average of 204.5m2 of heated floor area. Homes are equipped with conventional appliances and were constructed between 1961 and 1983. Insulation R values are between 9 and 22 and the primary fuel source for heat is natural gas.

Westwood Plateau, Coquitlam

This development has a density of 10.69 units per hectare, is exclusively single-family detached houses with no mixed use and is 1.57 km from the central business district. The average household operates 2.5 vehicles and has an average of 4 people per household and an average of 373m2 of heated floor area. Homes are equipped with conventional appliances and were constructed between 1984 and 1995. Insulation R values are between 10 and 23 and the primary fuel source for heat is natural gas.

Table 6 displays calculations for GHG emissions and density for the above communities.

Whitehorse							
Community	**VKT GHGs (tonnes)**	**Operating Energy GHGs (tonnes)**	**Total (tonnes)**	**Density (units per hectare)**	**Distance from Central Business District (km)**	**Average Area per Person (m2)**	**Per Capita GHG emissions (tonnes)**
Porter Creek	10.7	8.6	19.3	4	6.4	48.25	4.8
Wolf Creek and Mary Lake	14.1	10.5	24.6	0.46	16	68	6.7
Granger	8.5	6.5	15	6.6	3.2	65.75	3.75
Coquitlam							
Community	**VKT GHGs (tonnes)**	**Operating Energy GHGs (tonnes)**	**Total (tonnes)**	**Density (units per hectare)**	**Distance from Central Business District (km)**	**Average Area per person (m2)**	**Per Capita GHG emissions (tonnes)**
Burquitlam	8.7	9.87	18.57	8.65	7.58	70.7	6.2
Eagle Ridge	8.8	9.9	18.7	12.27	1.38	61	4.68
Ranch Park	10.8	8.75	19.55	12.15	2.12	68	6.5
Westwood Plateau	10.3	11.3	21.6	10.69	1.57	93	5.4

Table 6 – Broad comparison of GHG emissions per household compiled from NRCan.[167,168]


Howe St
P
Hornby St
Burrard St.

6

POLICY RESPONSES AND ACTIONS

Communities in Canada are developing a variety of policy responses toward reducing GHG emissions. As a foundational policy driver, they are setting specific GHG emissions reductions targets, followed by the development of more specific policies that look specifically at buildings, land use, and transportation. This section begins by looking at some of the current planning approaches being adapted, to very degrees, across the country. The subsequent lists summarize specific policy actions being undertaken by communities in the areas of building codes, energy, land use and transportation. An outline of each community follows in sections 6.1 and 6.2, providing a fuller picture of the holistic approach of most community plans.

Integrated Sustainability Planning Smart Growth

Smart growth policies, which have been implemented in a number of jurisdictions in Canada and the United States, make a deliberate shift away from suburban sprawl towards more compact, mixed-use and walkable communities. Many of these policies are explicitly aimed at reducing vehicle dependence and improving quality of life, and have been discussed throughout this report. They include: limiting outward expansion of new developments; increasing density; mixing land uses; pedestrian-friendly design; and improving public transit.[169]

Conventional development policies, regulations, and standards have not only actively encouraged sprawl by depressing the market price of new low-density development through hidden subsidies, they have also discouraged more sustainable, innovative forms of development. For example, there is considerable evidence that Calgary's regulatory framework presents major barriers to the creation of compact, walkable, transit-oriented mixed use communities, despite policy statements to the contrary.[170] A necessary step in creating low emissions communities then is to create incentives that encourage developers to implement Smart Growth initiatives.[171]

Smart Growth Principles[172]

1. Create Range of Housing Opportunities and Choices
2. Create Walkable Neighborhoods
3. Encourage Community and Stakeholder Collaboration
4. Foster Distinctive, Attractive Communities with a Strong Sense of Place
5. Make Development Decisions Predictable, Fair and Cost Effective
6. Mix Land Uses
7. Preserve Open Space, Farmland, Natural Beauty and Critical Environmental Areas
8. Provide a Variety of Transportation Choices
9. Strengthen and Direct Development Towards Existing Communities
10. Take Advantage of Compact Building Design

Natural Step

The Natural Step[173] is a sustainability framework based on systems-thinking. It approaches planning through 'backcasting' from a vision of the future that is based on its four sustainability principles; it aims to create comprehensive, holistic solutions by asking the question "what do we need to do today to reach that successful outcome?", allowing communities to move forward with their end goals in mind. Whislter's 2020 plan, for example, utilizes the Natural Step framework to develop its definition of sustainability.

Natural Step's Four Principles of Sustainability

1. eliminate our contribution to the progressive buildup of substances extracted from the Earth's crust (for example, heavy metals and fossil fuels)
2. eliminate our contribution to the progressive buildup of chemicals and compounds produced by society (for example, dioxins, PCBs, and DDT)
3. eliminate our contribution to the progressive physical degradation and destruction of nature and natural processes (for example, over harvesting forests and paving over critical wildlife habitat); and
4. eliminate our contribution to conditions that undermine people's capacity to meet their basic human needs (for example, unsafe working conditions and not enough pay to live on).

Community Energy Planning

Community energy and emissions plans incorporate land use, transportation, building and site, infrastructure, and renewable energy supply planning elements into one complete plan. When developing a community energy plan, communities first look at existing energy use and GHG emissions, with the goal of targeting specific reductions in energy consumption and emissions, improving energy efficiency, and increasing the supply of local renewable energy. Some benefits to community energy planning are an increase of local economic development opportunities, an increase in local energy independence and security, the creation of more energy efficient communities, the improvement of local air quality, increased walking and cycling opportunities, and ultimately a reduction of GHG emissions. A community energy plan can also be incorporated into other sustainability and planning processes, such as Regional Growth Strategies and Official Community Plans.[174]

Common Land-Use Planning Actions

- Growth Management: Urban containment boundaries and nodal development plans can direct growth to the city and village centres or designated neighbourhood nodes in the community rather than on undeveloped or ‘greenfield’ sites on the periphery of the community. Growth management plans include strategies to promote infill development, such as the development of vacant lands, redevelopment of greyfield sites (e.g., parking lots or failing retail developments), and brownfield sites (abandoned or under-used industrial land).[i]
- Mixing land-uses: Community plans and zoning by-laws can be used to create compact neighbourhoods that have a mix of housing types within walking distance to goods, services, cultural activities, and jobs.
- Planning for transit-oriented neighbourhoods: Neighbourhood and transportation planning can be used to plan and design neighbourhoods that are clustered around transit nodes for convenient and accessible transportation options.
- Green Building Standards: Development permit areas (DPAs) and comprehensive development zones (CDs) can be used to promote or require energy-efficient buildings and siting strategies and programs[ii].
- Community Energy: Implementation of more efficient and sustainable local energy supply distribution systems can provide energy security. Some examples include district energy (discussed in Section 2.10) or combined heat and power systems, with an emphasis on alternative fuels.

Specific Policy Actions

GHG Emissions Reductions Targets

The communities discussed here have set specific GHG emissions reduction targets; other communities are approaching GHG emissions reductions through actions, such as land-use and transportation planning goals, for which it is difficult to quantify their expected emissions reductions. The targets differ widely, as the chosen baseline years, reduction targets, and target dates range. Sections 6.1 and 6.2 document more comprehensively the steps some example small and large communities are undertaking.

i More information on urban containment strategies can be found in “Urban and Rural Containment Boundaries” www.smartgrowth.B.C..ca/Portals/0/Downloads/SGB.C._UCB_positionstatementFinal.pdf. A description of the Regional Growth Strategies in British Columbia can be found at http://www.cd.gov.B.C..ca/lgd/planning/growth_strategies.htm

ii See also Bill 27 description in Section 1.

City of Dawson Creek[175]

- 14% below 2006 levels by 2012.
- 33% below 2006 levels by 2020.
- 85% below 2006 levels by 2050.
- City operations should be carbon neutral by 2012.

City of Vernon[176]

- City facilities should be carbon neutral by 2012.

City of North Vancouver[177]

- Reduce GHG emissions 80% below 2007 levels by 2050.
- Zero net GHG emissions by 2107.
- Calgary Long Range Sustainability Plan
- 6% below 1990 levels by 2012.
- 50% below 1990 levels by 2036.

Calgary Long Range Sustainability Plan[178]

- 6% below 1990 levels by 2012.
- 50% below 1990 levels by 2036.

City of Saskatoon[179]

- The City of Saskatoon expects to reduce community GHG emissions by 39% by 2013 (a reduction of 1,400 ktCO2e).

Metro Vancouver – Regional Growth Strategy[180]

- Reduce emissions associated with land use and transportation by 33% below 2007 levels by 2020.

Building Code Targets

The following communities have specific policies to promote energy efficient buildings.

City of Vernon[181]

- New civic buildings will meet LEED Gold or its equivalent.
- The B.C. Green Building Code will be required for all new development.

Calgary Long Range Sustainability Plan[182]

- All new and existing elements of the city that entail energy use (communities, residential buildings, non-residential buildings, vehicles, equipment, and processes) will perform at within 5% of the most economical (life cycle cost) and most energy-efficient design available by 2036

Town of Golden – Official Community Plan[183]

- New developments and retrofits will include LEED guidelines and standards.

Energy Targets

The following communities have set overall energy reduction targets.

District of Maple Ridge – Town Centre Concept Plan[184]

- Reduce per capita total energy consumption of transportation and new buildings by 40 to 60 %.

Calgary Long Range Sustainability Plan[185]

- Reduce energy consumption by 30% from 1999 levels by 2036.
- 30% of Calgary's energy will be produced from low-impact renewable sources, within the Calgary area by 2036.

Land Use and Transportation Targets

The following communities specifically link their land-use and transportation planning objectives to emissions reduction targets.

District of Maple Ridge – Town Centre Concept Plan[186]

- Population growth target: 21,750 people (70 – 100 persons per hectare).
- New jobs per new dwelling unit target: 0.25 to 0.75
- Reduce VKT by 40 to 60%
- Alternative modes of transportation to account for 40 to 60% of travel within the Town Centre

Calgary Long Range Sustainability Plan[187]

- Reduce per capita VKT 20% below 2006 levels by 2036.
- Increase travel by alternative modes of transportation for peak travel to downtown by 50% for transit, 40% for walking and cycling, and 20% for carpooling by 2036.
- Increase per capita transit trips by 40% above 2006 levels by 2036.

Town of Golden – Official Community Plan[188]

Expansion of the Town of Golden boundary will only be considered if the following conditions are met: "small footprint, green, enticing, ecological, and controlled".

City of Vernon[189]

- New development directed to the City Centre District and specific neighbourhood centres within the Neighbourhood District.
- By 2031, 20% mode share is targeted for walking, bicycling (5% mode share target), and transit.

Metro Vancouver[190]

Create compact urban areas by directing growth to urban centres and transit development corridors within what Metro Vancouver designates as the "Urban Area" (serves as an urban growth boundary that is meant to protect non-urban areas)

6.1 Comprehensive Actions By Small And Medium Communities

City of Dawson Creek – Climate Action Plan[191]

Geographic Area: City of Dawson Creek, BC

Document: Climate Action Plan for reaching stated GHG emissions reductions targets for the entire community.

Key Findings:

- City operations will be carbon neutral by 2012.
- Establishes the following GHG emissions reductions targets for the community as a whole:
  - 14% below 2006 levels by 2012
  - 33% below 2006 levels by 2020
  - 85% below 2006 levels by 2050
- Improving energy efficiency of new residential construction from an EnerGuide rating of 72 to 81 would reduce GHG emissions by over 30% (4 ktCO2e) in a 20-year period of home building.
- If 60% of existing homes installed solar hot water systems, GHG emission would decrease by 2.19 ktCO2e per year.
- Total potential capacity for photovoltaic installations is between 6.4 to 21.7 MW. If installed, GHG emissions would decrease between 0.24 and 0.71 ktCO2e per year.
- Other potential actions to decrease GHG emissions in the City of Dawson Creek include electricity generation from bio fuel waste and wind.
- A feasibility study will move forward to establish a community wind energy project with a goal of implementation by 2010.
- A demonstration project titled the “Energy House” was slated for completion in 2008 through Northern Lights College. The project will be a student laboratory and a means to educate the Dawson Creek community.
- Future air shows will strive to reduce GHG emissions through offsetting, encouraging alternative modes of transportation to the show, increasing parking fees, and offering discounts to those who used alternative modes of transportation.

Town of Golden – Official Community Plan

Geographic Area: Town of Golden, British Columbia

Document: Official Community Plan

Key Findings: **Compact Urban Form**

- Implement a density bonus program in order to trade increased density for increased open space, amenities, and/or Leadership in Energy and Environmental Design (LEED) standards.
- Encourage development that would reduce Golden's ecological footprint through higher-densities, including a smaller building footprint with increased open space, integrated with a mix of uses.
- Encourage multi-family housing developments.
- Create a high-density downtown with mixed uses.
- Designate land for comprehensive land use planning that encourages compact, diverse, and mixed-use neighbourhoods that support pedestrian activity, promote neighbourhood scale retail nodes, and which cluster development in order to reduce sprawl.

Growth Management

- Expansion of the Town of Golden boundary will only be considered if the following conditions are met: "small footprint, green, enticing, ecological, and controlled".
- Develop new housing within existing infrastructure (infill) to encourage efficient land use
- Work to ensure that the commercial strip development along the Trans-Canada Highway is not expanded.
- Redevelop brownfield sites and dilapidated properties to further achieve infill.
- Sustainable Development
- New developments and retrofits will include LEED guidelines and standards.
- A sustainability guidelines document will be created and distributed to development permit applicants.

Sustainable Energy

- Promote a change to alternative energy within the industrial area.
- Investigate the feasibility of implementing a community energy system.
- Implement landfill gas recapture to produce clean energy.
- Create "energy zones" that require development and urban design standards for density and infrastructure.
- Create "solar energy zones" that require appropriate siting of buildings for solar access, roof pitches, and street orientation.

Key Findings:

Sustainable Planning

- The OCP states that paying special attention to the role of GHG emissions in planning within the following categories will reduce emissions:
  - Land use, energy and transportation planning.
  - Infrastructure design.
  - Green procurement.
  - Building retrofits.
  - Water conservation.
  - Solid waste diversion.
  - Renewable energy.
- Set GHG emissions reductions targets.
- Implement a GHG emissions reductions incentives program such as carbon trading or offsetting.
- Integrate energy and land use planning.
- Implement a strategic planning framework for sustainability planning (e.g., The Natural Step).

Transportation

- Develop a comprehensive integrated trail system.
- Develop commercial areas that encourage pedestrian activity.
- Promote smart growth principles within the downtown area that integrate transportation and land use decisions and promote multi-modal transportation systems and alternatives to vehicular transportation.

District of Maple Ridge – Town Centre Concept Plan[192]

Geographic Area: District of Maple Ridge, BC

Document: Town Centre Concept Plan (proposal), to be integrated into the Official Community Plan

Key Findings:

Density

- Between 2001 and 2021, the population of Maple Ridge is expected to increase 41% from 66,300 to 93,700. By directing population growth to the Maple Ridge Town Centre, this area is expected to accommodate 50% of the total projected population increase, or 13,700 people. The District's target for population growth for the Town Centre is 21,750 (70 – 100 persons per hectare).
- New housing units should be developed as infill on undeveloped and underutilized land within the Town Centre area, as well as through densification of single-family housing lots in the form of coach houses or secondary suites.

Transportation

- In order to decrease commuting, create 0.25 to 0.75 new jobs per new dwelling unit.
- New retail development should be accommodated in the mixed use areas of the Town Centre Plan.
- VKT should be reduced by 40% to 60% through sustainable development patterns like increased density, a mix of uses, and an increase in alternative modes of transportation.
- 40% to 60% of travel within the Town Centre should be through alternatives to the private vehicle.

Land Use

- Focus on smart growth principles for land use

Energy

- Per capita total energy consumption of transportation and new buildings should be reduced by 40% to 60% through means such as energy efficient building strategies and compact, mixed use development.
- By implementing a district energy system, 12% to 16% t of energy use could be reduced by capturing and using waste heat from adjacent buildings that could be used for hot water in 500 existing downtown apartments. Additional energy savings (20% to 35%) are possible through the replacement of electric space or water heating with a ground source heat pump.

City of Vernon – Official Community Plan[193]

Geographic Area: City of Vernon, BC

Document: Official Community Plan (final draft)

Key Findings:

Growth Management

- New development will be directed to the City Centre District and specific neighbourhood centres within the Neighbourhood District.
- A new zone to designate undeveloped property will be established that implements policies to ensure infill sites are developed almost to their potential, which dictates a specific nodal development pattern, and which requires a neighbourhood plan once the property is allowed to develop.

Sustainable Planning

- A scorecard system will be implemented for development applications that give preference to developments within designated growth zones and which ensures sustainable development principles are followed.

Transportation

Integrate land use and transportation planning to encourage an increase in the use of alternative modes of transportation, a decrease in the use of cars, and the preservations of effective mobility levels as Vernon's population increases.

- By 2031, 20% mode share is targeted for walking, bicycling, and transit.
- Develop transportation projects that focus on the City Centre, neighbourhood centres, and other existing neighbourhoods.
- Collaborate in transit service improvements within the region.
- Improve transit access within the City of Vernon by implementing service within walking distance of developments that generate significant amounts of traffic, and through the development of transit hubs in neighbourhood centres.
- Increase the viability of cycling as a mode of transportation by linking key traffic areas, integrating public transit and bicycle routes, and funding bicycle infrastructure projects.
- Develop a carpool plan while also accommodating cooperative car programs.

Energy

- Develop a carbon neutral strategy to uphold the City of Vernon's commitment to the UBCM Memorandum of Understanding on the British Columbia Climate Action Charter.
- City facilities should be carbon neutral by 2012
- Include energy efficiency, alternative energy infrastructure, and/or district energy systems in the neighbourhood centre planning process.
- Meet LEED Gold or its equivalent for all new civic buildings
- Develop a community energy plan.

6.2 Comprehensive Actions By Large Communities

Calgary – Long Range Sustainability Plan[194]

Geographic Area: Calgary, Alberta

Document: Imagine Calgary Plan for Long Range Urban Sustainability, a vision for the city for 2036, meant to inform Calgary's official community plan

Key Findings: **Energy (Targets for 2036)**

- Energy consumption will be reduced 30% below 1999 levels.
- GHG emissions will be reduced by 6% from 1990 levels by 2012 and by 50% from 1990 levels by 2036.
- 30% of Calgary's energy will be produced from low-impact renewable sources from within the Calgary area. Actions related to urban form include elements such as distributed generation from renewable sources, building heat exchangers, geothermal technology, and micro-production.
- All new and existing elements of the city that entail energy use (communities, residential buildings, non-residential buildings, vehicles, equipment, and processes) will perform at within 5% of the most economical (life cycle cost) and most energy-efficient design available.
- Programs on the ecological efficiency of commercial and residential buildings will be developed, which will include the identification of the impacts of a variety of development types and forms, the development of a benchmarking and labeling system for "eco-efficient" buildings, and potential subsidization of eco-efficient buildings and site design.
- Energy efficient urban form and building standards that reduce energy consumption will be promoted, including the expansion of Calgary's "Built Green" program.
- The proportion of higher-density dwelling units will be increased, along with the promotion of eco-neighbourhoods and co-operative housing that emphasizes walking and cycling.
- Energy planning will be integrated into neighbourhood design.
- A community energy plan will be developed with a requirement that a portion of Calgary's energy will be produced from zero/low emission sources of fuel.
- Alternative energy sources (wind, geothermal, solar-thermal, and photo-voltaic solar) will be established as the primary energy sources for residential, community, and governmental operations.
- Renewable or waste energy sourced district energy systems will be developed.
- Industrial waste heat will be utilized for neighbourhood water and space heating.

Key Findings:

Land Use

- Land use efficiency will increase by 30% by 2036 through thresholds of public transit and increased density.
- Encourage employment intensity near major transit facilities that include suburban locations.
- Calgary's ecological footprint will decrease below 7.25 hectares (the 2001 Canadian average) by 2036.
- Encourage site design planning that orients buildings for improved solar orientation.
- Encourage new development on vacant land in established areas and support brownfield and greyfield restoration and redevelopment.
- Intensify development in existing communities and target development in strategic areas such as transit stations and employment areas.
- A regional growth boundary will be developed.
- Prior to new development, ecological impact assessments will be performed.

Transportation (Targets for 2036)

- Reduce per capita VKT by 20% from 2006 levels.
- Reduce GHG emissions by 50% from 1990 levels through a combination of alternative fuel sources and energy-efficient vehicles, convenient transit service, and car and ride-sharing programs.
- Increase the percent of travel by alternative modes of transportation for peak travel to downtown by 50% for transit, 40% for walking and cycling, and 20% for carpooling. These goals will be met through the use of alternative transportation and work schedules.
- Increase per capita transit trips by 40% above 2006 levels by providing better transit service and through increasing homes and jobs within walking distance of transit stations and zones.
- Increase bikeways by 200% and pedestrian pathways by 100%.
- Reduce vehicle stops and starts by improving traffic flow.
- Encourage alternative modes of transportation to the private vehicle in the design of all new commercial buildings, while also emphasizing access, comfort, and connectivity to transit.
- Increase transit use through transit-oriented development, high-quality pedestrian connections to transit stops, and comfortable, convenient and improved transit service and facilities.
- Incorporate multi-modal transportation options in community design by prioritizing pedestrian needs, incorporating bike lanes in the road network, encouraging transit-oriented high-density mixed use developments, and through the integration of land use and transportation planning.

City of North Vancouver – Official Community Plan[195]

Geographic Area: City of North Vancouver, BC

Document: Official Community Plan

Key Findings:

- Concentrated land use and increased housing densities to promote more efficient land use in terms of transportation and energy.
- Create "complete communities" that balance opportunities for housing and jobs while emphasizing good quality of life for residents.
- Reduce GHG emissions by providing transportation alternatives to the private vehicle, encouraging energy efficient design of buildings and neighbourhoods, and implement community energy systems.

City of Saskatoon – Energy and Greenhouse Gas Management Plan[196]

Geographic Area: City of Saskatoon, Saskatchewan

Document: Energy and Greenhouse Gas Management Plan, which is a fulfillment of Milestone 3 of the Federation of Canadian Municipalities' Partners for Climate Protection Program (PCP). The goals of the PCP aim to decrease corporate municipal GHG emissions by 10% and community GHG emission by 6% below 1990 levels by 2013.

Key Findings:

- Raise public awareness of GHG emissions through outreach and education programs in order to facilitate reductions at community and municipal scales.
- Create a diverse energy system based on local resources with an emphasis on alternative fuels.
- Adhere to Smart Growth principles that emphasize compact urban form, a mix of uses in proximity to one another, smaller building footprints and buildings that are more energy efficient.
- Land use planning will be an integrated process where energy use and GHG emissions are considered within the initial stages in the planning process.
- Implement a transportation emissions reduction program that includes incentives for fuel efficient vehicles and a car sharing program.

Metro Vancouver[197]

Geographic Area: Metro Vancouver, British Columbia

Document: Livable Region Strategic Plan, the regional growth strategy for Metro Vancouver

Key Findings:

- Trends show that the Metro Vancouver region has an increase of 20,000 vehicles each year.
- 2005 GHG emissions in Metro Vancouver totaled 15,600 ktCO2e. Emissions from cars and trucks (35%) and buildings (31%) were the largest contributors.
- Promote higher-density housing in urban centres and along transit corridors to meet project population growth of 55% between 2006 and 2040. Such density also contributes to a reduction in GHG emissions and provides opportunities for implementing district energy systems.
- Reduce GHG emissions associated with land use and transportation by 33% below 2007 levels by 2020 through compact urban development and energy efficient land use patterns.
- Link transportation and land use planning and direct policies toward compact urban development to reduce VKT.

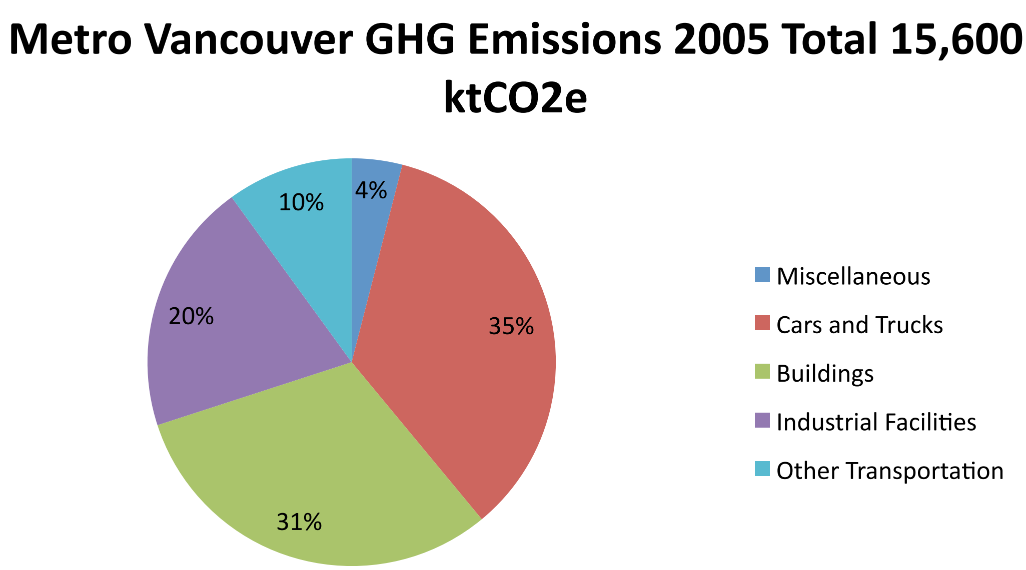

Figure 13 – Metro Vancouver GHG emissions by sector

District of Squamish – Downtown Neighbourhood Plan[198]

Geographic Area: District of Squamish, BC

Document: Downtown Neighbourhood Plan (DNP)

Key Findings:

Land Use

- Work toward establishing a complete community that incorporates a mix of land uses.
- Direct a large share of new residential development to the downtown area.
- Implement a density bonus system where additional density for new developments will be allowed in exchange for elements such as public amenities, open space, and elements of a transit hub.
- Promote compact urban form to lessen the need for private vehicles.
- Use design guidelines to promote elements of sustainable design (e.g., green roofs and building materials).

Energy

- The implementation of sustainable energy systems should be considered in the downtown area within a variety of scales (e.g., neighbourhood, block, parcel, or building). Such new energy systems should also be connected to a local district energy system.
- New and existing developments (public and private) should incorporate energy efficient building design and systems, and in addition should incorporate certified and progressive building performance standards such as LEED.
- Industrial uses included in the downtown area will incorporate closed-loop systems; e.g., recover and reuse waste.

Transportation

- Pedestrian connections will be encouraged in new developments in addition to pedestrian oriented building design
- Alternative modes of transportation will be encouraged by prioritizing walking and cycling in street redesign, by the provision of cycling facilities in parks, on streets, and as part of new buildings, and through compact urban form that lessens the need for the private vehicle.

Whistler – Comprehensive Sustainability Plan[199]

Geographic Area: Whistler, BC

Document: Whistler 2020: Moving Toward a Sustainable Future, a strategic planning document to the year 2020 based on principles of The Natural Step. The goals and targets outlined here are based on a 2020 timeframe.

Key Findings:

- The plan is based on an "upstream" philosophy where planning actions aim to reduce and avoid issues (e.g. avoiding waste) before they occur rather than reducing the impact of the action later (e.g. recycling waste).

Land Use and Transportation

- New resident housing will be developed within existing infrastructure in a compact and mixed use development pattern so as to avoid developing within natural areas and reduce transportation GHG emissions from commuters. Housing will be located in proximity to services and amenities to provide convenience and reductions in vehicle travel.
- New residential neighbourhoods will be connected to existing neighbourhoods by roads, paths, and trails.
- New residential development will be developed in proximity to transit and pedestrian and bicycling paths.
- Planning for transportation will be prioritized with non-motorized transportation options first, followed by transit and freight movement, high occupancy vehicles, and finally by private vehicles.
- Whistler is working to transition toward renewable vehicle fuel.

Energy

- New residential buildings and retrofits to existing buildings will be designed to be high performing and energy efficient.
- Energy will be primarily from local and regional sources by 2020.

7

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