Scoping Report

Exploration of the capacity to reduce GHG emissions by 2020 and 2050 through application of policy to encourage integrated urban energy systems

January 23rd, 2009

Prepared for:
Quality Urban Energy Systems of Tomorrow (QUEST)
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Summary

In an environment where carbon were priced at \$100 per tonne CO_2e in 2020, deliberate infrastructure and land use planning could reduce emissions by 65 Mt and virtually eliminate international permit purchases, saving \$6.5 billion in capital outflows annually.

The Government of Canada has set a national goal of reducing greenhouse gas (GHG) emissions, relative to 2006 levels, by 20 per cent by 2020, and by 60 to 70 per cent by 2050. Work by the National Roundtable of the Economy and the Environment has indicated that if Canada were to attempt to meet these targets completely domestically, this would require carbon prices on the order of \$100-\$150 per tonne CO_2e in 2020, and \$300 per tonne CO_2e in 2050. Current consensus amongst experts, however, is that international permit prices are unlikely to rise above \$200 per tonne CO_2e, indicating that significant permit purchases may be a lower cost route to Canada's emissions targets. Political considerations will also likely constrain Canada from sustaining domestic carbon pricing higher than international levels. Work by NRTEE, completed by members of MKJA, has indicated that if a price of \$200 per tonne CO_2e were imposed on all feasible emissions in conjunction with stringent complementary policies (including policies to decarbonise the personal transportation fleet by 2040, build all new commercial and institutional buildings to the basic LEED standard, and build all new residential stock at a standard 50% higher than today's new build standard), international permit purchases could be limited to about 50 Mt per year, at an annual cost of \$5-11 billion CAD in 2005 dollars depending on permit price assumptions.

The NRTEE studies did not, however, consider the potential impact of serious policy efforts to encourage denser urban form and integration of urban energy systems. MKJA Inc., members of who were key researchers for the NRTEE studies, has been charged by the Quality Urban Energy System of Tomorrow (QUEST) consortium with exploring the capacity for policy to encourage integrated urban energy systems to reduce GHG emissions. The project (a.k.a. "Phase I") is broken into two parts – a scoping component and workplan design component. This initial report focuses on our learning to date from the scoping component, whose focus is an assessment of the physical (engineering), economic, and policy feasibility of densifying land use and integrating urban energy systems to reduce Canada's greenhouse gas emissions at a cost per tonne comparable to other possible GHG reduction actions, such as vehicle and building energy efficiency or use of carbon capture and storage in the energy supply industry.[1] Our approach to this

[1] A GHG reduction target can be met most inexpensively if all possible reduction actions are pursued up to a given cost per tonne level until the reduction target is met (i.e. the costs are "equimarginal"). This is perhaps clearer if one considers a target and three different reduction actions. The target is a reduction of 15 megatonnes of CO_2. Action A) costs \$10/t and reduces 5 Mt. Action B) costs \$20/t and reduces 10 Mt. Action C) costs \$30/t and reduces 10 Mt. If A and B are combined the cost of reaching the target would be \$250. If A and C were combined the cost would be \$350. The cheapest course would be to implement A and B. While theoretically simple, implementing policy to isolate and carry out A and B in the real world is not easy. Because individual firm and consumer costs of emissions reduction are typically vary and are unknown, regulations, which apply equally to all firms and consumers, will typically impose a costly mixture of A, B and C. Carbon pricing, by either tax or a cap and trade system, is the preferred tool of

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assessment is two fold: 1) to review the key quantitative research literature on the capacity for land use, transportation, buildings, and waste policy to reduce overall primary energy requirements and GHG emissions, and 2) to apply what was learned to the modelling studies carried out for NRTEE.

A key learning from the literature was that stringent land use policy to encourage densification, including constraints on the geographic footprint of cities, specification of densification corridors with fast and reliable transit, and reform of the property tax system to reflect marginal infrastructure building and maintenance costs, has the capacity to reduce direct and indirect urban emissions by approximately 40 to 50% in the long run, while reducing overall national emissions by about 17-20%. Three Canadian studies have estimated the potential community-level GHG reductions from aspects of integrated urban energy systems to be approximately 43% (Jaccard *et al* 1997), 47% (CSCD 2004), and 50% (CUI 2008). Due to time and resource limitations, at this stage, an estimated percentage reduction in emissions from policies promoting integrated urban energy systems was applied to remaining emissions in CIMS after a maximum realistic level of carbon pricing has been imposed (capped at \$200/tonne CO_2e), with the results showing that deliberate infrastructure and land use planning policy could reduce emissions by 65 Mt in 2020, replace the NRTEE transport and buildings regulations, virtually eliminate permit purchases in 2020, and cut them in half to in 2050. The GHG emissions reductions from the land use policy and transport and buildings regulations *cannot be directly added*, however, as the regulations would reduce the emissions impact of densification (i.e. the GHG intensities of vehicles and buildings would have fallen, reducing the impact of densification policy). These interactions will be modelled in Phase II. The modelling indicates, however, that if aggressive land use policy were imposed along with some level of transport and buildings regulation, the 2020 carbon price could be reduced and the need for international permit purchases in 2050 eliminated. These policy interactions can be investigated further if desired by the QUEST oversight committee.

The literature also indicates that these reductions come with significant capital and energy cost savings, but these claims must be investigated further as they likely come with significant changes in the total financial and welfare costs and benefits associated with densification.[2]

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economists because it leaves it up to market forces to select A and B, i.e. firms and consumers with the lowest cost of abatement will carry out the emissions reductions (and sell permits in the case of a cap and trade system), while those with higher costs of abatement will pay the carbon price or purchase emissions permits.

[2] Economists typically refer to two types of policy costs, "financial" and "welfare". In the context of energy and climate change policy, financial costs are the direct up front and ongoing changes in capital, labour, energy, materials and emissions costs associated with a policy. Welfare costs include financial as well as all non-financial costs that drive firm and consumer behaviour. These non-financial costs include percieved risk, changes in opportunities (i.e. "option value"), changes in consumer surplus in the case of market goods (i.e. the excess in value of a good to a consumer over the market price), and cosnumer surplus changes in those things that are priced imperfectly or not at all, including lifestyle, safety, noise levels, clean air, the social atmosphere and aesthetic appreciation of the surrounding environment.

The given emissions reduction estimates include some but not all of the potential energy cascading benefits made possible by densification, including district heating, combined heat and power, waste recovery systems and other local alternative energy sources. A more complete and explicit estimate of these benefits, along with detailed estimation of the emissions reductions associated with land use policy to encourage densification, would be calculated in the next phase of the project if it goes ahead, for which a workplan is to be provided in the next deliverable. In Phase II the measures discussed in the literature would also be examined more closely, to inform the modelling effort and to identify the most important policies for achieving significant reductions. To reiterate, however, *land use policy to encourage densification is an essential prerequisite to almost all GHG emissions reduction potential associated with integrated urban energy systems*, i.e. buildings and households have to brought closer together before energy integration can take place.

The literature and analysis also makes clear that implementing policy to encourage denser cities and energy integration is a multi-jurisdictional issue. Municipalities have a key role in urban planning, rezoning and revision of the property taxation system, but provinces and the federal government have the most access to infrastructure funding and human resources. Provinces also set the legal context within which municipalities operate. Land use is largely the responsibility of provincial governments, which can set statutes regulating land use planning, with the actual land-use planning carried out by municipalities. Perception of the gains from densification and energy integration needs to be made clear at the federal level; successful achievement of these goals will greatly alleviate the difficulty of the federal government's climate change commitments, especially at the costly margin requiring international permit purchases. All levels of government will have to cooperate closely to manage the costs and achieve the benefits of densification and energy integration.

The proposed workplan for Phase II is proceeding, with the focus on canvassing and selecting potential bottom up modellers for land-use, transportation, buildings, exergy, waste and water. We are proposing a two level participation system: participants, who will directly do modelling (e.g. the transport modelling), and reviewers, who will review the modelling done by the other groups from their perspective (e.g. from an exergy perspective). We have met with and prepared plans with transport modellers and the exergy reviewer. The transport modellers can stand in as land-use modellers if need be, but we are canvassing other candidates. Potential waste modellers have been contacted, as have potential water reviewers. We are going to ask NRCAN to provide reviewers for our buildings component GHG intensity modelling.

This initial scoping report is meant to generate questions from the oversight committee as well as answer questions, and we encourage significant and detailed feedback, including alternative methodology suggestions.

Introduction

The Government of Canada has set a national goal of reducing greenhouse gas emissions, relative to 2006 levels, by 20 per cent by 2020, and by 60 to 70 per cent by 2050. Work by the National Roundtable of the Economy and the Environment has indicated that if Canada were to attempt to meet these targets completely domestically, this would require carbon prices on the order of $100-$150 per tonne CO_2e in 2020, and $300/t CO_2e per tonne in 2050. Current consensus amongst experts is that international permit prices are unlikely to rise above $200/t CO_2e, indicating that significant permit purchases may be a lower cost route to Canada's emissions targets. Political considerations will also likely constrain Canada from sustaining domestic carbon pricing higher than international levels. Work by NRTEE, completed by members of MKJA, has indicated that if a price of $200/tonne CO_2e were imposed on all feasible emissions in conjunction with stringent complementary policies (including policies to decarbonise the personal transportation fleet by 2040, build all new commercial and institutional buildings to the basic LEED standard, and build all new residential stock at a standard 50% higher than today's new build standard), international permit purchases could be limited to about 50 Mt per year, at an annual cost of $5-11 billion CAD in 2005 dollars depending on permit price assumptions.

The NRTEE studies did not, however, consider the potential impact of serious policy efforts to encourage denser urban form and integration of urban energy systems. MKJA Inc., members of whom were key researchers for the NRTEE studies, has been asked by the Quality Urban Energy System of Tomorrow (QUEST) consortium to lead an exploration of how policies to encourage integrated urban energy systems, encompassing land use, transportation, buildings, waste and water systems, may help meet our emissions reduction targets. The project (a.k.a. "Phase I") is broken into two parts – a scoping component and workplan design component. This initial report focuses on our to-date learning from the scoping component, whose focus is an assessment of the physical (engineering), economic, and policy feasibility of integrated urban energy systems to reduce Canada's greenhouse gas emissions at a reasonable cost. Our approach to this assessment is been two fold: 1) to review the key quantitative research literature on the capacity for land use, transportation, buildings, and waste policy to reduce overall primary energy requirements and GHG emissions, and 2) to apply what was learned to the modelling studies carried out for NRTEE.

Managing our cities for 2020 and beyond

Climate change is an issue that impacts all aspects of our economy and urban form, and it is not the only issue facing our cities. The overall approach we propose, in keeping with the QUEST mandate, is to consider how management for climate change will coincide with policy to address the suite of issues facing our cities, including:

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- *Air quality.* All of Canada's major urban regions face air quality issues, especially in the summer. Energy consumption in transport and buildings is a primary cause of these issues.
- *Infrastructure renewal.* Much of Canada's building stock, and especially sewage and water infrastructure, was built more than 50 years ago during the boom following World War II, and now needs to be renewed.
- *Water scarcity.* Many of Canada's cities, especially those that receive their water from glacier fed rivers, are facing reduced supplies of clean water and increasing demand. Historic precipitation patterns, upon which our water supply systems were established, are predicted to change spatially, in time and in volume, which may cause further stress on water supply systems.
- *Liveability.* Like all cities everywhere, Canada's cities face ongoing issues associated with safety, quality of life, equality of opportunity (access to equal health and educational services) and, in the long run, maximization of leisure and work time (e.g. minimization of travel time).
- *Waste reduction and management.* While great strides have been made with recycling, this is only a first stage response to management of the waste stream coming from our urban residences and businesses. Can we also reduce the embodied energy and emissions?

But how do we consciously manage to address these issues and achieve our social goals? Who makes and implements the decisions? Jaccard et al (1997) outlines a general cascade of decision making associated with energy use, laid out below; energy use is at the core of our climate change and air quality issues, and the decisions associated with its management are related and very similar to those associated with water and waste.

1. INFRASTRUCTURE AND LAND USE PATTERNS
(Public decision making)

- Density & mix of land uses
- Energy supply infrastructure
- Transportation network

2. MAJOR PRODUCTION PROCESSES, TRANSPORTATION MODES & BUILDINGS
(Public and private decision making)

- Choice of industrial processes & transportation modes
- Building and site design

3. ENERGY USING EQUIPMENT
(Private decision making)

- e.g., vehicles, motors, appliances & HVAC systems

The core message is that while households and firms choose energy using equipment and structures, it is public policy that sets the spatial environment in which this occurs. The urban form is a public policy choice (or non-choice as occurs in jurisdictions with little governance), and densification and energy use integration can only occur if long term municipal, provincial and federal public policy are aligned with these goals.

But given that urban form is a public policy choice, how can we get from the one in which we now exist, to one that that is denser, cleaner, and more liveable? We require a vision or plan, with emphasis on the transition from where we are now to where want to be. The literature, which is summarized in the next section, indicates a fairly clear and homogenous path to a denser urban form that will enable quality public transit, integration of industry and building energy systems, and, if managed properly, encourage liveability. Put briefly, if they wish to encourage a denser urban form that makes energy integration possible, our governing bodies need to:

- Halt geographic expansion of the city
- Identify densification nodes and corridors
- Change land use zoning, property taxation, and construction permitting to reflect new priorities
- Based on predicted population and economic growth, plan basic transportation, water, waste and energy services for the new urban structure, while:
    - Providing reliable, safe, fast and timely transit services to the chosen densification nodes and corridors.
    - Matching water supply to demand through demand and supply side planning and policy
    - Discouraging use of GHG and CAC intense energy forms in buildings, transport and energy supply
    - Reducing waste and planning for management of what remains

These policy activities must be effective and held in place through decades to achieve their objective. In this project we also choose a strong emphasis on politically feasible policy to generate physically and economically reasonable actions to achieve the desired outcomes. A common set of questions for any policy goal includes:

- Is it physically possible from an engineering perspective?
- Is it least cost from an economic welfare perspective?
- Is it politically actionable from a legal and logistical perspective?
- Is it politically survivable for the politicians who try to implement it?

This theme of policy realism will be returned to regularly.

We now provide a review of the quantitative and selected qualitative literature associated with land use policy for densification and energy integration. The learning from the review will then be extrapolated to the NRTEE studies of an Economically Optimal and Politically Realistic Carbon Price Path to assess the raw potential for land use policy to reduce our GHG emissions. This scoping exercise does not address the potential for energy integration and advanced waste management (CIMS includes landfill capping and flaring); this will be included in Phase II if it proceeds.

Literature Review

A thorough review of the academic literature and credible research reports by government and non-governmental organizations revealed a large amount of research into individual components of urban energy systems management, but very few studies modeling the energy and greenhouse gas savings resulting from aggressive integrated urban energy system scenarios. The Canadian Urban Institute defines an integrated urban energy system as an "integrated system approach to land use, energy, transport, water and water management [that] places [the emphasis] on achieving the efficiency for systems as a whole, and encouraging the development of resources that are efficient, adaptable, resilient and sustainable" (Canadian Urban Institute 2008). Thus, integrated urban energy systems address a much broader spectrum of urban issues than 'community energy systems', which can be defined as integrated approaches to supplying local communities with their energy requirements from renewable energy or high-efficiency co-generation energy sources. Many studies are available that document the planning processes undergone by cities across North America, but the scenarios modeled are generally incremental improvements, rather than fundamental re-imaginings of urban form and its integration with buildings, vehicles, waste and energy flows, and water use. This suggests that a detailed Canadian modeling exercise, as proposed for Phase II, would be a very valuable addition to the field, and help to fill a hole in existing GHG reduction research.

Examples of studies that provide estimates of the energy, GHG, and cost savings associated with two or more aspects of integrated urban energy systems include the following four case studies from Canada, the USA, and Japan. However, none of these studies include all of the components of integrated urban energy systems.

1. Canada - "Demonstrating the economic benefits of integrated green infrastructure". Centre for Sustainable Community Development (CSCD). Report prepared for Federation of Canadian Municipalities. March 2004.
2. Canada – "Energy Mapping Study: Calgary". Canadian Urban Institute (CUI). 2008.
3. USA – "How smart growth can unlock trillion dollar consumer cost savings", Mary Jean Bürer and David B. Goldstein, Natural Resources Defense Council and John Holtzclaw, Sierra Club. 2004.
4. Japan – "Transition to a sustainable urban energy system from a long-term perspective: Case study in a Japanese business district", Y. Yamaguchi, Y. Shimoda, M. Mizuno, Energy and Buildings 39, p. 1–12. 2007.

These studies each investigated different components of integrated urban energy systems. The Canadian CSCD study's scenario was closest to an integrated urban energy system, and estimated the savings resulting from urban planning that capitalized on transportation, energy, and water service synergies in a hypothetical Canadian city. This synergistic city vision included urban design that reduced the need for all types of vehicles; improved pedestrian facilities; increased surface greening; maximized stormwater infiltration, water recycling and cascading, and water efficiency measures;

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and included a cascaded energy system, energy efficient buildings, efficient energy use within buildings, and local generation. The Canadian CUI study modeled the changes in new and retrofitted building efficiency and the investments in renewable energy needed for Calgary to achieve a 50% reduction from 2005 GHG emissions at the community level. The Japanese (Yamaguchi 2007) study looked at a small commercial urban area in Osaka, and modeled the impact of evolving to an efficient urban energy system, with district-level energy generation and distribution planning, district heating and cooling systems, energy efficient building design and retrofits, and efficient use of energy within buildings. In the American (Bürer 2004) study, the focus was on estimating the impact of location efficiency (the average amount of car ownership and distance driven for a household located in a particular neighborhood). Indicators of density, public transit service, and pedestrian friendliness from current 'smart growth' developments were applied to future infill and greenfield growth to estimate the cost savings and emission reductions associated with applying 'smart growth' to all new development in the United States. Yamaguchi *et al* modeled the process of aggressive urban energy system change over the period 2000 to 2050, and CUI looked at emission reductions from 2005 to 2050, while CSCD and Bürer approached the time period issue differently, with both looking at a business as usual (BAU) scenario and an integrated scenario, and measuring the cost savings and emission reductions associated with the integrated scenario over a 10 year period.

The modeling approaches also varied between the three sample studies. Yamaguchi *et al* built a bottom-up simulation model, which calculated the heat and electricity demand profiles for each building in the district on an hourly basis, and used this to determine the end-use energy consumption in the district. CSCD developed a sample community profile, identified clusters of strong service relationships that could be developed in an integrated manner, and then calculated 10 year costs based on infrastructure, operating and replacement costs for the conventional versus the 'green' development. The sample community to which the scenarios were applied represented an urban redevelopment project in a large North American metropolis, and included 28 hectares of existing fully serviced residential land, within reasonable proximity to the central business district. CUI modeled a scenario where Calgary's buildings were retrofitted to reduce energy consumption by 25 percent and all new buildings were built to apply the Model National Energy Code of Canada for Buildings (MNECB) plus 50 percent. To achieve the remaining GHG reductions necessary to reach a 50% reduction from 2005 levels, a least-cost portfolio of alternative energy technologies, including solar hot water, energy sharing, solar air, a district energy system with a combined heat and power and wind generation and the substitution of biomass for fossil fuel electricity generation at source was created to displace gas and electricity use. Bürer *et al* used previously derived equations for the relationships between density, transit service, personal income, household occupancy, and pedestrian friendliness in American 'smart growth' developments to estimate the vehicle miles traveled (VMT) under a scenario where all future US growth matches 'smart growth' principles, and is split between infill and greenfield growth, versus a BAU scenario where growth continues in the current sprawl development pattern.

The results ranged from an estimated 10% reduction in total American GHG emissions over 10 years (Bürer), to a 47% reduction in community GHG emissions over a 10 year period (CSCD), to a 50% reduction in community GHG emissions (CUI), to an estimate that 60-90% GHG emission reductions are possible by 2050 through community energy management (Yamaguchi). Other benefits predicted by CSCD include the ability to supply heating and cooling to the site in the case of a power outage, curbed peak energy demand, and a 60% reduction in potable water consumption. Over the 10-year pay period considered in CSCD's cost analysis, the capital costs of the district energy system are offset more than threefold by the savings on energy costs. CUI calculated the cost of undertaking the building efficiency and alternative energy scenario for Calgary at nearly $17.7 billion (Cdn), but the combined simple payback period was just 12 years. Yamaguchi predicts a reduction of more than 60% in CO_2 emissions in the Japanese commercial sector by 2050, and Bürer calculates U.S. energy cost savings of $2.18 trillion over 10 years, in addition to 49.5 billion gallons of gasoline, 1.18 billion barrels of oil, and 595 million metric tons of CO_2 emissions.

Far more numerous in the literature are studies that examine just one of the components of integrated urban energy systems – the benefits associated with densification. The vast majority of these studies examine the relationship between vehicle miles traveled and urban form, but some studies examine the air pollution benefits, the reductions in spending on infrastructure and government services, and the health improvements. Other studies examine the opportunities to reduce waste output and water use through advanced technologies and urban planning, and investigate the gains possible with technologies not currently available – such as urban electric vehicle networks. Some key results of this research include the following:

- Despite a significant amount of debate about, and research into whether neighborhood design influences travel behavior, or travel preferences influence the choice of neighborhood, the preponderance of evidence concludes that more compact urban form is associated with a 17 – 40% reduction in driving (up to 60% when combining an infill location with higher density and good urban design) (Ewing *et al* 2007, Handy 2005, Bartholomew 2008). Every 10% increase in population density is estimated to be associated with a 3.5% reduction in VMT (Stone *et al* 2007). Key studies that support the connection between neighborhood design and travel behavior include Ewing *et al* 2007 and Cao, Mokhtarian, and Handy 2006, while Crane and Crepeau 1998 provide the counter-view.
- Under a business as usual scenario, urban U.S. VMT are predicted to rise by 48% by 2030 and 102% by 2050 (Ewing *et al* 2007). In the U.S., VMT have grown 3 times faster than population and 2 times faster than vehicle registrations. Of this growth, 36% is estimated by be explained by longer trip lengths and 17% by a shift from more efficient modes of transportation to automobiles – both of which are consequences associated with sprawl (Bartholomew and Ewing 2007)
- CO_2 emissions per capita in suburban-density neighborhoods are estimated to be 25% higher than in urban neighborhoods (Brown *et al* 2008). Case studies from

Toronto estimate that low density suburban development is 2 to 2.5 times more energy and GHG intensive per capita than high-density urban core development (Norman *et al* 2006). Of the GHG reductions associated with locational efficiency, 45-50% are due to efficiencies brought about by district heating, 45-50% from reduced passenger travel, and 3-5% from the reduced need for supporting municipal infrastructures (Brown *et al* 2008).

- Several cities provide good examples of integrated urban energy systems. Masdar City is an integrated development being built in the United Arab Emirates, and when complete, it will feature a 75% reduction in installed power capacity, less than half the water use, and a nearly 100% reduction in landfill area, compared to a conventionally designed city of the same size (www.masdaruae.com). The feasibility study for the Riverbend Heights Community Energy System in London, ON showed that a community based integrated energy system would lead to a 58% reduction in grid energy use and an 86% reduction in energy use for hot water, space heating and cooling (QUEST 2008).
- Scenario planning exercises in several American cities have shown significant emission reductions from scenarios that are much less aggressive than integrated urban energy planning scenarios: a planning scenario adopted in Sacramento will use 46% less new land and reduce CO_2 and particulate matter by 15% versus BAU, a proposed smart growth San Francisco scenario would reduce per capita water consumption by 17% (California Energy Commission 2007), and the Atlantic Station redevelopment in Atlanta will have 30-35% lower VMT and emissions than the alternative greenfield sites that were identified for the development (Ewing *et al* 2007).
- Greener developments are associated with lower air pollution emissions, including reductions in NO_X of 30-45% (Jaccard *et al* 1997)
- Within research on the built environment and obesity, 17 of 20 studies have established statistically significant links between the two (Ewing *et al* 2007). Greening of buildings leads to health improvements as well, with estimated annual benefits of improving indoor environment quality in the US of $6-14 billion from reduced respiratory disease, $1-4 billion from reduced allergies and asthma, $10-30 billion from reduced sick building syndrome symptoms, and $20-160 billion from direct improvements in worker performance that are unrelated to health (Kats 2006).
- Canadian studies on water use have shown that integrated efforts to reduce urban water use can result in savings of almost 44% (Brandes and Maas 2007)
- There is a significant opportunity to realize the savings and benefits discussed above, since U.S. estimates are that most of the built capital stock in 2050 will be built after 2007, that houses in mixed use neighborhoods enjoy price premiums of 40-100% over suburban developments, and that projected demand in 2025 for attached and small-lot housing will exceed current supply, while demand for large-lot housing will fall short of current supply (Ewing *et al* 2007).

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The flip side to the studies showing reduced emissions from compact urban development is the large number of studies investigating the costs associated with 'urban sprawl'. These studies are generally restricted to investigating the costs associated with the provision of infrastructure and government services. However, they provide information that supports the case for making integrated urban energy systems a key component of Canada's climate change strategy. Some key results from these studies include:

- Planned, compact growth consumes 45% less land area, and costs 12-60% less for roads, 6-40% less for utilities, and 5-8% less for schools than conventional growth (Brown *et al* 2008, Muro and Puentes 2004). In townhouse developments versus single-family conventional houses, road building costs are 33% lower, road maintenance costs are 51% lower, utilities building costs are 58% lower, and utilities maintenance costs are 30% lower (Slack 2002).
- The Greater Toronto Area Task Force estimates that more compact and efficient development patterns could save $12.2 billion in capital costs over the next 25 years, with annual savings of $500 million in capital and maintenance expenses, and a further $200 million in costs related to air pollution, health care, and the policing related to automobile accidents. If lower congestion, parking, and land acquisition costs are factored in, the cost savings from containing urban sprawl are estimated at $1 billion annually over 25 years (GTA Task Force 1996 quoted in Slack 2002). Grow Smart Rhode Island estimated that compact development could reduce 20-year infrastructure costs by about 40%, and reduce infrastructure operating costs by 37% (Grow Smart Rhode Island 1999 quoted in Muro and Puentes 2004)
- In a comparison of two California communities, sprawling developments were associated with 35 times as much natural habitat and farmland loss, five times as much copper pipe and wiring use, twice the total building materials, 15 times as much asphalt or concrete (for streets and driveways), and 35-70 times as much water use (much of it for watering lawns) as in dense developments. The dense mixed use neighborhoods cut auto ownership by approximately 66%, driving by 75%, and emissions by 75% compared to the suburban developments (Phillips 1980 quoted in Ewing *et al* 2007).

Achieving the benefits of integrated urban energy systems requires the implementation of a large number of coordinated policies covering all aspects of urban energy use. A number of studies provide complete sets of policy recommendations, including Tomalty 2008, Ewing *et al* 2007, Jaccard *et al* 1997, Slack 2002, MKJA 1999, and Brown *et al* 2008. The key components of these recommendations are presented in Table 1 below:

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Table 1: Policies to Promote Integrated Urban Energy Systems

Sector	Goal	Sample Policies
Land Use Planning	Increase density of development Reduce transport demand Protect green space Support waste heat utilization	Establish strict urban boundaries and greenbelts Identify areas for compact and nodal development in community plans, and channel growth into these areas Update local development rules and zoning objectives Reduce lot size and street setbacks Impose full cost up front and maintenance infrastructure pricing (e.g. through maintenance trusts) on new developments Shift from property taxes to site-value taxes Establish a market-based regional transfer of development rights program Provide information and fiscal incentives to developers Locate heat sources near heat sinks and locate waste producers near businesses that can use that waste as an input
Transportation Management	Shift the mode of travel Shift to alternative fuels Increase energy efficiency	Create high occupancy and toll lanes; implement parking, fuel, commuter and vehicle registration charges Promote employer trip reduction programs, and discounted transit passes Require pedestrian and bicycle facilities to be provided on all new and reconstructed streets and highways Equalize funding and procedures between highway and transit projects Support intra and inter city rail transport development Promote fleet fuel switching and hybridization Strengthen vehicle fuel efficiency standards
Site and Building Design	Increase efficiency Capture natural heating and cooling potential Reduce water use	Promote the use of vegetation and building orientation for lighting, heating, and cooling, as well as waterless landscaping and tree planting Strengthen building and appliance efficiency standards Provide financing and technical assistance for efficiency improvements Promote cascaded water systems within buildings and communities
Energy Supply	Reduce GHG intensity of energy Increase end use energy efficiency	Proactively involve utilities in planning Promote distributed generation, district heating and cooling, and the use of heat pumps and renewable energy Provide financing and technical assistance for micro-generation
All Sectors	Reduce GHG emissions Reduce energy supply needs	Price carbon through a carbon tax or cap and trade system Make energy planning an explicit function of municipal and regional governments, and a component of development processes. Develop and disseminate standardized tools for evaluating the GHG impacts of land use, transportation, building, and energy supply decisions Develop social marketing programs to promote more energy and GHG efficient housing, transportation, and lifestyles

* A development rights transfer program is a market-based mechanism that encourages the voluntary transfer of growth from places where a community would like less development, referred to as "sending areas", to preferred development "receiving areas".

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While this list of policies may seem overwhelming, certain policies will be prerequisites for significant emission reductions, while others will have a smaller impact. The Phase II study will identify the most important policies or policy packages that need to be implemented in order to achieve the reductions associated with integrated urban energy systems.

It is clear that there is a large body of research that is applicable to the estimation of benefits associated with individual components of integrated urban energy systems. Several studies look at multiple integrated components, but these are often qualitative or based on scenario comparisons, rather than detailed modeling exercises. The literature is lacking a comprehensive and complete integrated modeling study of the GHG, energy, water, waste, and cost savings achievable from urban energy systems management, particularly in the Canadian context. As such, the literature review provides valuable inputs to the modeling project that is proposed for Phase II, and substantial support for the urban energy systems approach to GHG reduction, but is not a substitute for a thorough modeling effort.

Method

Quantitative scoping of the emissions reduction potential of land use policy

The CIMS model was the primary quantitative tool used for NRTEE's *Getting to 2050* analysis, which involved carbon prices rising to $300 and above in order to reduce emissions 65% from 2005 levels, and was also used for follow up work to assess the effects of complementary regulations on top of a politically realistic carbon price path (which was capped at $200/tonne CO_2e), given potential international permit prices. CIMS includes mode shifting in urban and freight transportation as well as cogeneration and combined heat and power in the commercial and residential buildings sectors, but does not include endogenous dynamics to capture the effect of policy to densify the urban form and to link energy use between industry and buildings. In other words, strong carbon pricing will induce fuel shifting, energy and GHG efficiency in CIMS, but will not induce spatially related GHG reduction actions, such as a shift from suburban single home living based on personal vehicles to urban multi-occupancy townhouse living based on transit. This uncaptured component is included in the remaining emissions after carbon policy has been applied.

Unfortunately, identification of the potential for land use and energy integration policy is not as simple as identifying what remains of emissions after carbon pricing has been applied. Carbon prices can be made sufficiently strong to completely eliminate point of use emissions in transportation, through use of electricity, hydrogen or biofuels, and regulations can also be imposed to completely decarbonise point of use transport GHG emissions. The same can be done with buildings; they can be converted completely to electricity through carbon pricing or regulations, which emits no GHGs at point of use and can potentially be made with no GHG emissions[3], and can even become net energy production sites using solar photovoltaics. These measures, if taken far enough, could completely negate the GHG reduction reason for densifying and integrating the urban form.

On the other hand, land use policy and energy integration could to be taken to the extremes of reducing energy requirements by 90% (Yamaguchi 2007) or more; one can imagine an urban form where energy is reused several times, each successive time at a progressively lower level of quality (i.e. starting as electricity to melt recycled scrap steel, transformed to high temperature steam to run turbines, transformed to lower temperature steam to boil water, and finally to low temperature steam to heat homes). Why neither path has been taken, or is likely to be taken, is cost. There is a balance to be struck between cost per tonne reduced, component energy and GHG intensity, fuel switching and land use and energy integration. Carbon pricing automatically balances per tonne costs (i.e. it creates an "equimarginal" costs and benefits environment) for those components of the economy to which it can be applied, mainly private investment and consumption. What it has little effect on are the public policy elements, which include municipal zoning, property taxation, and marginal pricing of the use of public infrastructure, such as the use of toll roads. These are choices that must be made in the public policy realm. Put another way, to achieve the equimarginal level of land use and energy integration policy with a given level of carbon pricing, it must be applied using public policy instruments such as municipal zoning and marginal cost infrastructure taxation.

For this stage of the project, we have chosen to identify the potential for land use and energy integration policy to reduce GHGs by first applying the carbon price paths used by NRTEE for their economically optimal and politically practical carbon pricing scenarios, and then isolating what portion of the remaining emissions may be reducible using land use and energy integration using values from the literature. The forgoing literature review has found that approximately 42.5% of urban GHG emissions, on top of the piece by piece GHG intensity improvements driven by carbon pricing, may be reduced in the long term by aggressive land use policy. This figure was brought together with remaining emissions after carbon pricing to identify the GHG reduction potential of land use and energy integration policy. Please see the results section for step by step description of the methodology.

We have not included energy or waste integration in this stage of the project; this will be included in Phase II (landfill capping and flaring has, however, been included). If Phase II proceeds, the urban emissions reductions associated with land use policy will be identified explicitly through the bottom up modelling segments of the project, not through simple extrapolation of the literature. The next section describes the CIMS model.

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[3] Electricity can be made using many GHG free energy sources: falling water (hydropower), nuclear energy, wind energy, geothermal energy, burning biomass, solar heat, solar photovoltaics, wave energy and tidal energy. It can also be made from fossil fuels such as natural gas and coal, and the CO_2 emissions buried underground.

Modeling Framework: CIMS

The CIMS model was originally designed as a predecessor to the NEMS model of the US Energy Information Administration, and has been subsequently developed for Canada by MKJA and the Energy and Materials Research Group at Simon Fraser University. It simulates the technological evolution of the energy-using capital stock in the Canadian economy (such as buildings, vehicles, and equipment) and the resulting effect on output, investment, labour and fuel costs, energy use, GHG and CAC emissions, and some material flows. The stock of energy-using capital is tracked in terms of energy service provided (m^2 of lighting or space heating) or units of physical product (metric tons of market pulp or steel). New capital stocks are acquired as a result of time-dependent retirement of existing stocks and growth in stock demand. Market shares of technologies competing to meet new stock demands are determined by standard financial factors as well as behavioral parameters from empirical research on consumer and business consumption and investment preferences. CIMS has three modules — energy supply, energy demand, and macro-economy — that can be simulated as an integrated model or individually. A model simulation comprises the following basic steps:

1. A base-case macroeconomic forecast initiates model runs. The macroeconomic forecast is at a sectoral or sub-sectoral level (e.g., it estimates the growth in total passenger travel demand or in airline passenger travel demand). The forecast adopted for this study is described in the reference case appendix.

2. In each time period, some portion of the existing capital stock is retired according to stock lifespan data. Retirement is time-dependent, but sectoral decline can also trigger retirement of some stocks before the end of their natural lifespan. The output of the remaining capital stocks is subtracted from the forecast energy service or product demand to determine the demand for new stocks in each time period.

3. Prospective technologies compete for new capital stock requirements based on financial considerations (capital cost, operating cost), technological considerations (fuel consumption, lifespan), and consumer preferences (perception of risk, status, comfort), as revealed by behavioral-preference research. The model allows both firms and individuals to project future energy and carbon prices with imperfect foresight when choosing between new technologies (somewhere between total myopia and perfect foresight about the future). Market shares are a probabilistic consequence of these various attributes.

4. A competition also occurs to determine whether technologies will be retrofitted or prematurely retired. This is based on the same type of considerations as the competition for new technologies.

5. The model iterates between the macro-economy, energy supply and energy demand modules in each time period until equilibrium is attained, meaning that energy prices, energy demand and product demand are no longer adjusting to changes in each other. Once the final stocks are determined, the model sums energy use, changes in costs, emissions, capital stocks and other relevant outputs.

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The key market-share competition in CIMS can be modified by various features depending on evidence about factors that influence technology choices. Technologies can be included or excluded at different time periods. Minimum and maximum market shares can be set. The financial costs of new technologies can decline as a function of market penetration, reflecting economies of learning and economies of scale. Intangible factors in consumer preferences for new technologies can change to reflect growing familiarity and lower risks as a function of market penetration. Output levels of technologies can be linked to reflect complementarities.

Personal mobility provides an example of CIMS' operation. The future demand for personal mobility is forecast for a simulation of 30 or more years and provided to the energy demand module. After the first five years, some of the existing stocks of personal vehicles are retired because of age. The difference between forecast demand for personal mobility and the remaining vehicle stocks to provide it determines the need for new stocks. Competition among alternative vehicle types (high and low efficiency gasoline, natural gas, biofuel, electric, gasoline-electric hybrid, and eventually hydrogen fuel-cell) and even among alternative mobility modes (single occupancy vehicle, high occupancy vehicle, public transit, cycling and walking) determines technology market shares. The results from personal mobility and all other energy services determine the demand for fuels. Simulation of the energy supply module, in a similar manner, determines new energy prices, which are sent back to the energy demand module. The new prices may cause significant changes in the technology competitions. The models iterate until quantity and price changes are minimal, and then pass this information to the macro-economic module. A change from energy supply and demand in the cost of providing personal mobility may change the demand for personal mobility. This information will be passed back to the energy demand module, replacing the initial forecast for personal mobility demand. Only when the model has achieved minimal changes in quantities and prices does it stop iterating, and move on to the next five-year time period.

The model was recently recalibrated to reflect EC's *National Inventory Report - Greenhouse Gas Sources and Sinks in Canada 1990-2006* as well as EC's online *Criteria Air Contaminant Emissions Summaries: 1990-2015.* We also updated the values from Natural Resources Canada's (NRCan) *Canada's Energy Outlook 2006 (CEO 2006)*, which provides the foundation of CIMS' physical output forecast to 2020, to reflect recently released output, energy and emissions data for 2005 from Natural Resources Canada's *Comprehensive Energy Use Database* and Statistics Canada's *Report on Energy Supply and Demand.* Details of the reference case are provided in an appendix. More on CIMS is also provided in an appendix.

CIMS Limitations and Uncertainties

Like all models, CIMS is a representation of the real world, not a perfect copy. Even though CIMS is very detailed compared to other models used for similar purposes, its broad scope (it represents almost all GHG emissions and energy consumption throughout the economy) requires many simplifying assumptions. The main uncertainties and limitations in the model are:

- **Technological detail and dynamics:** CIMS contains a considerable level of technological detail in each of its sectoral sub-models. This detail enables CIMS to show accelerated market penetration of alternative technologies in response to an energy, climate change or criteria air contaminant policy and to ensure that reference and policy scenarios are grounded in technological and economic reality, including realistic capital stock life and turnover. While care has been taken in representing the engineering and economic parameters of the many technologies in CIMS, including costs, uncertainty exists as to the appropriate cost and operating parameters of specific current and future technologies.

  While CIMS contains a representation of dynamic technological change that depicts how the costs of new technologies can be reduced through economies of scale and production experience based on historical experience, there is no guarantee that these relationships will hold in the future. In addition, CIMS only contains technological options that are known today (including those that are not yet commercialized). By definition, CIMS does not contain a depiction of new technologies that have not yet been invented and as a result, CIMS could miss technological substitution options in later years of the forecast. There are, however, only 12 years to 2020 — 12 years for brand new technologies not currently in CIMS to be invented, prototyped, commercialized and to enter the capital stock. Capital is mostly fairly longed-lived in buildings and industry, and there is simply not enough time for radical change to occur, other than by shutting industrial sectors down. This uncertainty becomes larger over time, but is of more concern after 2025-2030.

- **Behavioural realism:** The technology choice algorithm of CIMS takes into account implicit discount rates revealed by real-world technology acquisition behavior, intangible costs that reflect consumer and business preferences, and heterogeneity in the marketplace. Incorporating behavioral realism is critical in order to predict realistic consumer and firm response to policies; incorporating these preferences at a detailed level into a model that is technologically explicit is challenging. In addition to the sheer volume of the data requirements, the non-financial preferences of consumers and firms are difficult to estimate, and can change over time. The complexities associated with estimating behavioral parameters, combined with the fact that information cannot be collected for all the technology competitions in CIMS, result in a high degree of uncertainty associated with these parameters overall. The potential for preference change is also a key uncertainty.

- **External inputs:** CIMS requires external forecasts of macroeconomic activity in each sub-sector: population growth forecasts and starting fuel price forecasts on which to base the analysis. These forecasts are uncertain and could affect the results of the simulations. In addition, since no individual forecast is available to provide all key inputs over the period of interest in this analysis, we have adopted inputs from several different sources. We have used respected sources that are cited in the reference case appendix, and attempt to ensure consistency between various sources, but it is likely that the various inputs we use are not perfectly consistent with one another.

- **Equilibrium feedbacks:** Unlike most computable general equilibrium models (which do not generally contain technological detail), the current version of CIMS, while it does include direct responses of firms and consumers to increased input and final goods prices, does not equilibrate government budgets nor the markets for employment and investment. Also, its representation of the economy's inputs and outputs is skewed toward energy supply, energy intensive industries, and key energy end-uses in the residential, commercial/institutional, and transportation sectors. As a result, it is likely to underestimate the full structural response of the economy to energy and climate change policies. For this reason, using the pricing results from CIMS, we generally use the DGEEM model of the Canadian economy to estimate the effect of the specified emissions reduction target. This option will be provided in the workplan to be provided in the next deliverable.
- **CIMS is non-spatial below the provincial/regional level:** While CIMS explicitly models the energy demand and supply technology stock at a high level of detail and integration, it does not represent the spatial element of energy demand, i.e. the scale of the road network in the urban form. Changes in kilometres travelled driven by policy or scenario must be entered as scenarios. This is why we refer to the literature in this project to capture this potential source of GHG emissions reduction, and propose to integrate the work of other bottom up modellers in the next phase.

Scenario Assumptions

In order to determine the GHG abatement opportunities in the Canadian economy over time, we use the concept of a reference scenario and a policy scenario. The reference scenario shows how the Canadian economy might evolve in the absence of specific new policies to reduce GHG emissions, while the policy scenario shows how the economy might evolve under the policy package. The difference between the two scenarios is due to the effect of the policy. When doing this type of analysis, many assumptions need to be made. Some key overall conditions include:

- *We have assumed that Canada's OECD trading partners impose GHG policy at least as stringent as Canada's.*
- *NRCan's "Canada's Energy Outlook 2006" was considered to be the starting point for output and energy data* because of its comprehensiveness and status as Canada's national energy use forecast. *EC's GHG Inventory was considered the starting points for all emissions intensity data* because of its comprehensiveness and status as Canada's national emissions forecast, as are EC's emissions coefficients for fuel combustion. When NRCan's energy use is calculated by EC's emissions coefficients, the results do not always match, but we have attempted to reconcile them as best as possible. The differences are most

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significant in the upstream oil and gas sector, specifically the combustion coefficients associated with upstream and transmission oil and gas fugitives. All forecast values have been updated for the most recent official historical data.

- *We have allowed domestic and export demand for crude oil to fluctuate in response to the cost of producing it.* While there are substantial economic rents associated with crude oil when prices are high (>$50/barrel), in the long run its output is sensitive to the cost of producing oil and long run expectations of demand and prices. In our analysis we have assumed minimal rents; as domestic demand rises and falls, and as export demand rises and falls, we assume changes in the cost of production translate into changes in price, with appropriate responses in demand. *We have not allowed natural gas production to fluctuate. We have assumed that any amount of gas produced not used in Canada will be sold to the US.* There is substantial uncertainty about what will happen to Canadian gas production in a carbon limited North America. Domestic consumption of natural gas drops due to the imposition of policy to encourage land use densification, but if the United States imposes any sort of carbon restrictions, as we have assumed, it will need to make significant efforts to decarbonise its electricity system. This will likely involve a substantial switch from coal to natural gas generation, which will likely require some combination of more LNG imports, shale gas production, and Mexican and Canadian gas imports.
- Given the focus on urban energy systems, agricultural emissions and emissions reductions are not included in this phase of the project, but there may be reason to include them in future phases.

Results

Tables 1 and 2 summarize the scoping analysis with CIMS. Table 2 describes the Business as Usual (BAU) and policy emissions, including the effect of land use policy, for the NRTEE economically optimal carbon price path, which rises to $300/tonne CO_2e. Table 3 describes the same, but for the NRTEE politically feasible carbon path, which rises to $200/tonne CO_2e but also includes complementary transport and buildings regulations, as well as international permit purchases.

Both sets of analyses include both direct combustion emissions and indirect emissions associated with electricity and natural gas production. These indirect emissions have been calculated directly from CIMS electricity and natural gas models, which evolve in response to the carbon prices. For example, carbon capture and storage may be used to capture formation CO_2 from raw natural gas, and its cost is passed on to consumers of the gas. In electricity production the capital, energy and emissions cost of the generation technology (e.g. wind or natural gas with carbon capture and storage) is passed on the consumer. Tables 3 through 8 provide CIMS' calculated GHG intensities, which are based on its internal capital stock turnover, competition and energy supply and demand balancing mechanisms. We have not included indirect emissions associated with refined petroleum products such as gasoline as these are highly correlated to the petroleum crude

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source (or biofuel production system), which is subject to some variability (e.g. heavy crude oil has significantly more venting GHG emissions than light and medium crude) and subject to emissions reduction policy at the source. These can be included at a later date if necessary.

Table 2 BAU and Policy Emissions in the NRTEE Economically Optimal World, with land use policy to encourage densification (Carbon price path: $18 2011-15, $115 2016-2020, $215 2021-25, $300 2026-50). Does not include agriculture or forestry, halocarbon, nitric and adipic acid and solvents.

		2005	2020	2030	2040	2050
	Carbon Price $/tonne CO_2e	$0	$115	$300	$300	$300
	BAU Emissions Mt					
A	Direct residential	41	40	41	40	39
B	Indirect residential	44	42	48	57	74
C	Direct commercial & institutional	34	41	47	56	66
D	Indirect commercial & institutional	37	36	40	47	56
E	Personal Transport*	93	118	124	130	136
F	Indirect personal transport*	0	0	2	3	4
G	Direct Total	168	198	212	226	240
H	Direct and Indirect Total	250	277	301	333	374
I	National emissions	655	801	853	939	1,045
J	% of national	38%	35%	35%	35%	36%
	Policy Emissions Mt					
K	Direct residential	41	26	15	8	4
L	Indirect residential	44	36	25	16	12
M	Direct commercial & institutional	34	31	25	20	19
N	Indirect commercial & institutional	37	29	20	14	10
O	Personal Transport*	93	104	56	42	43
P	Indirect personal transport*	0	1	4	3	2
Q	*Direct Total*	*168*	*161*	*96*	*70*	*67*
R	*Total*	*249*	*226*	*145*	*104*	*90*
S	*National emissions*	*646*	*552*	*361*	*262*	*229*
T	*% of national*	*39%*	*41%*	*40%*	*40%*	*39%*
U	Policy emissions as % of 2005		84%	55%	40%	35%
V	Regs or permit purchases necessary (Mt)		27.6			-0.3
W	Cost (billions, $100/t in 2020, and $200/t in 2050)		2.8			0.0
X	Reductions from aggressive land use policy		63.5	61.7	44.2	38.4
Y	National emissions if land use policy applied		488	299	217	191
Z	Reduction in 2005 emissions		75%	46%	33%	29%
AA	Target reduction		80%			65%
BB	Gap (Mt) to be met with regs or permit purchases		-35.6			-38.6
CC	Permit Cost (billions, $100/t in 2020, and $200/t in 2050)		-3.6			-7.7

*Includes domestic point to point aviation and intercity, which will be removed for future analysis.

Lines A through F describe the direct and indirect GHG emissions from the residential, commercial and personal transportation sectors. In future versions of the analysis (Phase II) we shall include components of the light manufacturing sector, which are interwoven

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with the urban form. Indirect emissions are those associated with creating retail electricity and natural gas, and do not include the combustion emissions from natural gas, which are counted as direct emissions. Transport includes aviation and intercity emissions, which will be extracted in future versions of this analysis if desired by the QUEST project committee (time did not permit their extraction for this analysis). Lines G and H provide total direct and indirect plus direct emissions. Line I provides national emissions, and J the percentage of national emissions associated with commercial and residential buildings and personal transportation. These average about 36% of national emissions. We have not included urban freight in this analysis, which may be affected by land use policy. Urban freight will be included in a Phase II analysis. Lines K through T provide the same for the policy case.

Line U shows the reduction in national emissions from 2005 levels due to carbon pricing. The 2050 target, a 65% reduction, is met, but the 2020 target is not. This difference is due to changes that have occurred in the CIMS model since the initial NRTEE analysis was done, including revised energy prices and output forecasts, but also the fact that a couple of years have passed without announcement of significant carbon pricing for the buildings and transport sector. CIMS includes anticipation of announced policy, and two more years of delay have now occurred in a high growth environment. A carbon price for the transport and buildings sectors of approximately \$150/tonne CO_2e in 2020 would now be necessary to hit the 2020 target if it were announced today. This may be less if recent economic setbacks reduce economic output over the next couple of years.

Line V indicates the international permit purchases that will necessary to hit Canada's announced targets. The modelling indicates 27.6 Mt will be required in 2020, while 0.3 Mt can be sold in 2050. The 2020 purchases, if permit prices are \$100/tonne CO CAD, will cost \$2.8 billion CAD (Line W).

Line X indicates the emissions reductions that may be possible from aggressive land use densification policy (Jaccard *et al* 1997 is the primary reference). They are calculated as 42.5 % of remaining direct and indirect emission from the sector after carbon pricing, based on the literature. The 2020 emission reductions are reduced by one third to reflect political and physical inertia, while all other years reflect the full 42.5%.

Line Y shows national emissions as a percentage of 2005 levels if the reductions from Line X are applied. 2020 emissions are 75% of 2005 levels, and 2050 emissions 29%. The 2020 target of 80% of 2005 emissions has been overshot by 35.6 Mt, and the 2050 target by 38.6 Mt. If the carbon price were maintained these excesses could potentially be sold as international emissions permits, with annual revenues of \$3.6 and \$7.7 billion, but a more likely and logical response would be to reduce the carbon price until the targets are met. This can be explored in further analysis if desired by the QUEST project committee.

Table 3 provides the same analysis, but for the NRTEE politically feasible carbon price, which is capped at \$200/tonne CO_2e. A key difference from the initial NRTEE analysis is that we removed the transport (e.g. zero GHG by 2040) and buildings regulations (e.g. LEED standard for all new commercial and institutional buildings). The reduction of the

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carbon price and removal of the regulations means that the target is missed by 73.4 Mt in 2020, and 123.3 Mt in 2050, at an annual permit purchase cost of $7.3 and $24.7 billion respectively. If aggressive land use policy is imposed, the new target deficits are 8.0 and 65.3 Mt respectively, which reduces the annual permit costs to $0.8 and $13.1 billion in 2005 dollars. The modelling indicates that if aggressive land use policy were imposed along with transport and buildings regulation, the need for international permit purchases would be eliminated. This is with the caveat that the transport and buildings regulations would reduce the effectiveness of the land use policy.

Table 3 BAU and Policy Emissions in the NRTEE Politically Feasible Carbon Price World, with land use policy to encourage densification (Carbon price path: $18 2011-15, $100 2016-2020, $200 2021-50). Does not include agriculture or forestry, halocarbons, nitric and adipic acid and solvents.

		2005	2020	2030	2040	2050
	Carbon Price \$/tonne CO_2e	\$0	\$100	\$200	\$200	\$200
	BAU Emissions Mt					
A	Direct residential	41	40	41	40	39
B	Indirect residential	44	42	48	57	74
C	Direct commercial & institutional	34	41	47	56	66
D	Indirect commercial & institutional	37	36	40	47	56
E	Personal Transport*	93	118	124	130	136
F	Indirect personal transport*	0	0	2	3	4
G	Direct Total	168	198	212	226	240
H	Direct & Indirect Total	250	277	301	333	374
I	National emissions	655	801	853	939	1,045
J	% of national	38%	35%	35%	35%	36%
	Policy Emissions Mt					
K	Direct residential	41	28	20	15	10
L	Indirect residential	44	37	27	18	13
M	Direct commercial & institutional	34	33	30	29	30
N	Indirect commercial & institutional	37	29	21	15	11
O	Personal Transport*	93	107	74	67	71
P	Indirect personal transport*	0	1	3	3	2
Q	Direct Total	168	168	124	110	110
R	Total	250	234	176	146	137
S	National emissions	652	598	455	376	353
T	% of national	38%	39%	39%	39%	39%
U	Emissions as % of 2005		91%	69%	57%	54%
V	Regs or permit purchases necessary (Mt)		73.4			123.3
W	Permit Cost (billions, \$100/t in 2020, and \$200/t in 2050)		7.3			24.7
X	Reductions from aggressive land use policy		65.7	74.7	61.9	58.1
Y	National emissions if land use policy applied		532	381	315	295
Z	Reduction in 2005 emissions		81%	58%	48%	45%
AA	Target reduction		80%			65%
BB	Gap (Mt) to be met with regs or permit purchases		8.0			65.3
CC	Permit Cost (billions, \$100/t in 2020, and \$200/t in 2050)		0.8			13.1

*Includes domestic point to point aviation and intercity, which will be removed for future analysis.

Table 4 BAU electricity GHG intensity (Mt/GJ)

	2005	2020	2030	2040	2050
Emissions Mt	129.0	112.7	119.6	138.4	170.6
Output Twh	545.3	646.5	740.1	873.8	1046.8
Mt/GJ	6.6E-08	4.8E-08	4.5E-08	4.4E-08	4.5E-08

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Table 5 NRTEE economically optimal electricity GHG intensity (Mt/GJ)

	2005	2020	2030	2040	2050
Emissions Mt	129.0	97.8	70.8	48.7	33.8
Output Twh	545.3	724.5	936.7	1,185.0	1,441.7
Mt/GJ	6.6E-08	3.7E-08	2.1E-08	1.1E-08	6.5E-09

Table 6 NRTEE politically feasible carbon price path electricity GHG intensity (Mt/GJ)

	2005	2020	2030	2040	2050
Emissions Mt	129.0	99.8	72.6	48.4	34.9
Output Twh	545.3	714.7	898.3	1115.4	1354.0
Mt/GJ	6.6E-08	3.9E-08	2.2E-08	1.2E-08	7.2E-09

Table 7 BAU natural gas GHG production intensity

	2005	2020	2030	2040	2050
Emissions Mt	64.9	55.5	46.9	41.8	36.8
Output BCF per day	16.8	17.3	14.4	13.1	11.7
Mt/GJ	9.9E-09	8.2E-09	8.3E-09	8.2E-09	8.0E-09

Table 8 Policy NRTEE economically optimal natural gas GHG production intensity (Mt/GJ)

	2005	2020	2030	2040	2050
Emissions Mt	64.9	41.6	31.4	25.2	19.7
Output BCF per day	16.8	16.6	12.9	11.4	9.9
Mt/GJ	9.9E-09	6.4E-09	6.2E-09	5.6E-09	5.1E-09

Table 9 Policy NRTEE politically feasible carbon price path natural gas GHG production intensity

	2005	2020	2030	2040	2050
Emissions Mt	64.9	42.2	32.5	26.8	21.8
Output BCF per day	16.8	16.7	13.1	11.7	10.2
Mt/GJ	9.9E-09	6.5E-09	6.3E-09	5.9E-09	5.4E-09

Appendix – CIMS

CIMS has a detailed representation of technologies that produce goods and services throughout the economy and attempts to simulate capital stock turnover and choice between these technologies realistically. It also includes a representation of equilibrium feedbacks, such that supply and demand for energy intensive goods and services adjusts to reflect policy.

CIMS simulations reflect the energy, economic and physical output, GHG emissions, and CAC emissions from its sub-models as shown in Table 10. CIMS does not include adipic and nitric acid, solvents or hydrofluorocarbon (HFC) emissions. CIMS covers nearly all CAC emissions in Canada except those from open sources (e.g., forest fires, soils, and dust from roads).

Table 10: Sector Sub-models in CIMS

Sector	BC	Alberta	Sask.	Manitoba	Ontario	Quebec	Atlantic
Residential	■	■	■	■	■	■	■
Commercial/Institutional	■	■	■	■	■	■	■
Personal Transportation	■	■	■	■	■	■	■
Freight Transportation	■	■	■	■	■	■	■
Industry							
Chemical Products	■	■			■	■	
Industrial Minerals	■	■			■	■	■
Iron and Steel					■	■	
Non-Ferrous Metal Smelting*	■			■	■	■	■
Metals and Mineral Mining	■		■	■	■	■	■
Other Manufacturing	■	■	■	■	■	■	■
Pulp and Paper	■	■			■	■	■
Energy Supply							
Coal Mining	■	■	■				■
Electricity Generation	■	■	■	■	■	■	■
Natural Gas Extraction	■	■	■	■	■	■	■
Petroleum Crude Extraction	■	■	■		■		■
Petroleum Refining	■	■	■		■	■	■
Agriculture & Waste	■	■	■	■	■	■	■

* Metal smelting includes Aluminium.

Model structure and simulation of capital stock turnover

As a technology vintage model, CIMS tracks the evolution of capital stocks over time through retirements, retrofits, and new purchases, in which consumers and businesses make sequential acquisitions with limited foresight about the future. This is particularly important for understanding the implications of alternative time paths for emissions reductions. The model calculates energy costs (and emissions) for each energy service in the economy, such as heated commercial floor space or person kilometres travelled. In each time period, capital stocks are retired according to an age-dependent function (although retrofit of un-retired stocks is possible if warranted by changing economic conditions), and demand for new stocks grows or declines depending on the initial exogenous forecast of economic output, and then the subsequent interplay of energy supply-demand with the macroeconomic module. A model simulation iterates between energy supply-demand and the macroeconomic module until energy price changes fall below a threshold value, and repeats this convergence procedure in each subsequent five-year period of a complete run.

CIMS simulates the competition of technologies at each energy service node in the economy based on a comparison of their life cycle cost (LCC) and some technology-specific controls, such as a maximum market share limit in the cases where a technology is constrained by physical, technical or regulatory means from capturing all of a market. Instead of basing its simulation of technology choices only on financial costs and social discount rates, CIMS applies a definition of LCC that differs from that of bottom-up analysis by including intangible costs that reflect consumer and business preferences and the implicit discount rates revealed by real-world technology acquisition behaviour.

Equilibrium feedbacks in CIMS

CIMS is an integrated, energy-economy equilibrium model that simulates the interaction of energy supply-demand and the macroeconomic performance of key sectors of the economy, including trade effects. Unlike most computable general equilibrium models the current version of CIMS does not equilibrate government budgets and the markets for employment and investment. Also, its representation of the economy's inputs and outputs is skewed toward energy supply, energy intensive industries, and key energy end-uses in the residential, commercial/institutional and transportation sectors.

CIMS estimates the effect of a policy by comparing a business-as-usual forecast to one where the policy is added to the simulation. The model solves for the policy effect in two phases in each run period. In the first phase, an energy policy (e.g., ranging from a national emissions price to a technology specific constraint or subsidy, or some combination thereof) is first applied to the final goods and services production side of the economy, where goods and services producers and consumers choose capital stocks based on CIMS' technological choice functions. Based on this initial run, the model then calculates the demand for electricity, refined petroleum products and primary energy commodities, and calculates their cost of production. If the price of any of these commodities has changed by a threshold amount from the business-as-usual case, then supply and demand are considered to be out of equilibrium, and the model is re-run based on prices calculated from the new costs of production. The model will re-run until a new equilibrium set of energy prices and demands is reached. Figure 1 provides a schematic of this process. For this project, while the quantities produced of all energy commodities were set endogenously using demand and supply balancing, endogenous pricing was used only for electricity and refined petroleum products; natural gas, crude oil and coal prices remained at exogenously forecast levels (described later in this section), since Canada is assumed to be a price-taker for these fuels.

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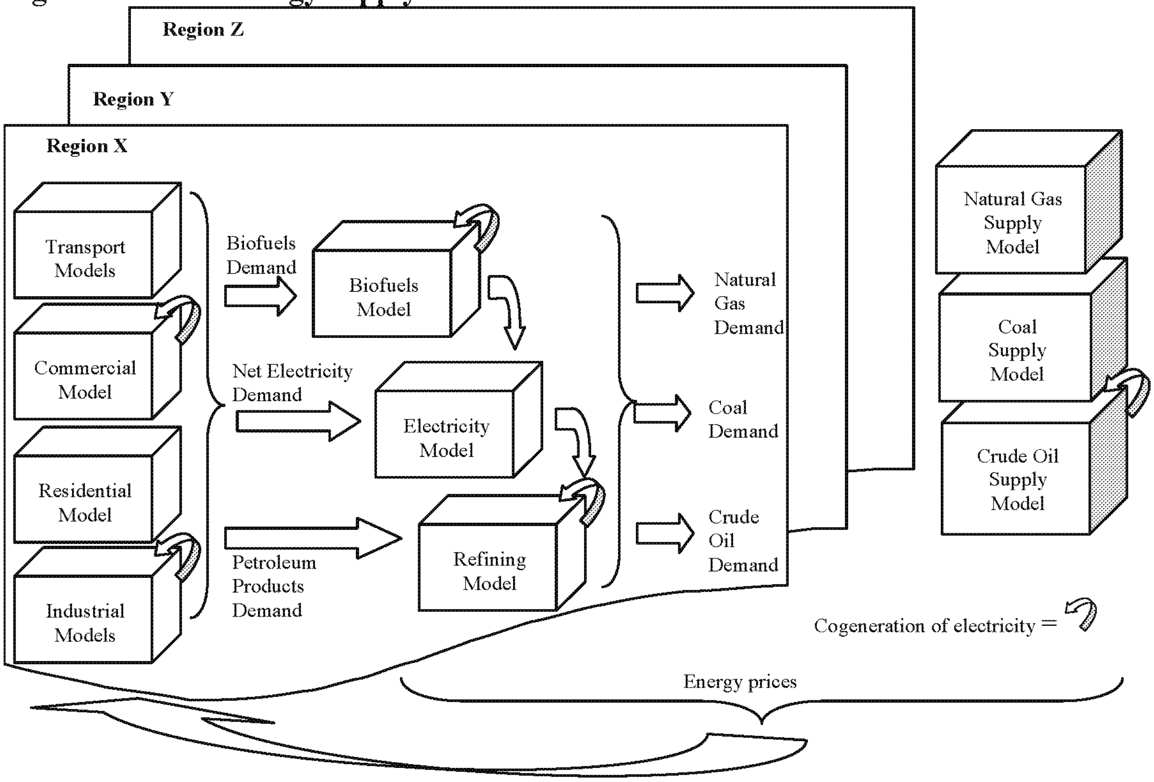
Figure 1: CIMS energy supply and demand flow model



In the second phase, once a new set of energy prices and demands under policy has been found, the model measures how the cost of producing traded goods and services has changed given the new energy prices and other effects of the policy. For internationally traded goods, such as lumber and passenger vehicles, CIMS adjusts demand using price elasticities that provide a long-run demand response that blends domestic and international demand for these goods (the "Armington" specification).[4] Freight transportation is driven by changes in the combined value added of the industrial sectors, while personal transportation is adjusted using a personal kilometres-travelled elasticity (-0.02). Residential and commercial floor space is adjusted by a sequential substitution of home energy consumption vs. other goods (0.5), consumption vs. savings (1.29) and goods vs. leisure (0.82). If demand for any good or service has shifted more than a threshold amount, supply and demand are considered to be out of balance and the model re-runs using these new demands. The model continues re-running until both energy and goods and services supply and demand come into balance, and repeats this balancing procedure in each subsequent five-year period of a complete run.

Empirical basis of parameter values

Technical and market literature provide the conventional bottom-up data on the costs and energy efficiency of new technologies. Because there are few detailed surveys of the annual energy consumption of the individual capital stocks tracked by the model

[4] CIMS' Armington elasticities are econometrically estimated from 1960-1990 data. If price changes fall outside of these historic ranges, the elasticities offer less certainty.

(especially smaller units), these must be estimated from surveys at different levels of technological detail and by calibrating the model's simulated energy consumption to real-world aggregate data for a base year.

Fuel-based GHGs emissions are calculated directly from CIMS' estimates of fuel consumption and the GHG coefficient of the fuel type. Process-based GHGs emissions are estimated based on technological performance or chemical stoichiometric proportions. CIMS tracks the emissions of all types of GHGs, and reports these emissions in terms of carbon dioxide equivalents.[5]

Both process-based and fuel-based CAC emissions are estimated in CIMS. Emissions factors come from the US Environmental Protection Agency's FIRE 6.23 and AP-42 databases, the MOBIL 6 database, calculations based on Canada's National Pollutant Release Inventory, emissions data from Transport Canada, and the California Air Resources Board.

Behavioral parameters are estimated through a combination of literature review, judgment, supplemented with the use of discrete choice surveys for estimating models whose parameters can be transposed into behavioral parameters in CIMS.

Simulating endogenous technological change with CIMS

CIMS includes two functions for simulating endogenous change in individual technologies' characteristics in response to policy: a declining capital cost function and a declining intangible cost function. The declining capital cost function links a technology's financial cost in future periods to its cumulative production, reflecting economies-of-learning and scale (e.g., the observed decline in the cost of wind turbines as their global cumulative production has risen). The declining capital cost function is composed of two additive components: one that captures Canadian cumulative production and one that captures global cumulative production. The declining intangible cost function links the intangible costs of a technology in a given period with its market share in the previous period, reflecting improved availability of information and decreased perceptions of risk as new technologies become increasingly integrated into the wider economy (e.g., the "champion effect" in markets for new technologies); if a popular and well respected community member adopts a new technology, the rest of the community becomes more likely to adopt the technology.

Please see the following list of publications for further information on CIMS:

Bataille, C., M. Jaccard, J. Nyboer and N. Rivers. (2006). "Towards General Equilibrium in a Technology-Rich Model with Empirically Estimated Behavioral Parameters." *Hybrid Modeling: New Answers to Old Challenges, Special Issue of the Energy Journal.*

Jaccard, M., J. Nyboer, C. Bataille, and B. Sadownik (2003). "Modeling the Cost of Climate Policy: Distinguishing Between Alternative Cost Definitions and Long run Cost Dynamics." *The Energy Journal* 24(1): 49-73.

Rivers, N. and M. Jaccard. (2005) "Combining Top-Down and Bottom-Up Approaches to Energy-Economy Modeling Using Discrete Choice Methods." *The Energy Journal* 26(1): 83-106.

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[5] CIMS uses the 2001 100-year global warming potential estimates from Intergovernmental Panel on Climate Change, 2001, "Climate Change 2001: The Scientific Basis", Cambridge University Press, UK.

Appendix - The Reference Scenario

The reference scenario described in this report is based on several external inputs showing how the economy will evolve over the coming years to 2050. Many key inputs underlying the reference scenario are highly uncertain, and if the economy evolves differently than as shown in this reference scenario, energy consumption and emissions will also differ from what we show here. Credible sources have been used to guide key inputs wherever possible, but no amount of research allows perfect foresight into the future of the economy. As a result, the scenario described here should be considered just one possible reference scenario. We consider it a reasonable "business as usual" forecast, based on historic trends and research into likely future technological and economic evolution, but the uncertainty remains large. We begin by highlighting our key assumptions, and follow by showing the results of our forecast.

Key economic drivers and assumptions

CIMS uses an external forecast for the economic or physical output of each economic sector to develop the business as usual forecast. For example, CIMS requires an external forecast for the number of residential households, another for the amount of cement produced in the province, and another for amount of natural gas produced as applicable. These forecasts can be internally adjusted when a policy is applied.

For all energy demand sectors, the external forecast through 2050 is based on the same data used by NRCan to develop the national energy outlook in 2006.[6]

Table 11: Canada economic and demographic forecast

	Units	*2020*	*2030*	*2040*	*2050*
Gross Domestic Product	*Billion 1997$ [a]*	1,817.72	2,003.47	2,178.68	2,393.70
Population	*Millions*	36.34	36.34	36.34	36.34

Note: [a] Gross domestic product is presented in basic prices

While the residential, commercial and transportation sectors are not the direct subject of policy in this analysis, their demand for electricity, processed natural gas and refined petroleum products set the stage for many of the industrial sectors subject to the *Regulatory Framework*. The CIMS models for each of these sectors were updated with 2005 data to ensure their demand for energy end use commodities fits history, is reasonable, and adjusts in a credible fashion with population, economic growth and technology.

Physical output in each of the industrial sectors was also updated to reflect recently released 2005 statistics. Energy use for each sector was also checked against Statistics Canada's *Report on Energy Supply and Demand 2005*, as well as NRCan's *Comprehensive Energy Use Database*. 2005 emissions of GHGs and CACs were

[6] Natural Resources Canada, 2006, "Canada's Energy Outlook: The Reference Case 2006", Analysis and Modelling Division, Natural Resources Canada.

calibrated against the aforementioned energy use statistics and EC's draft *GHG Inventory for 2005*.[7]

Table 12 summarizes the reference case economic output forecast that is adopted for this forecast. As has been emphasized throughout, this forecast reflects historic and anticipated future trends, but is highly uncertain, particularly in the later years of the forecast.

Table 12: Reference case forecast of physical output[8]

	Units	2020	2030	2040	2050
Demand Sectors					
Residential	*thousands of households*	15,222	16,566	17,253	17,815
Commercial	*million m^2 of floorspace*	911	1,091	1,316	1,561
Transportation					
Passenger	*billion passenger-km*	944	1,152	1,339	1,493
Freight	*billion tonne-km*	1,198	1,420	1,689	1,987
Manufacturing Industry					
Chemical Products	*thousand tonnes* [a]	21,979	24,376	26,927	29,744
Industrial Minerals	*thousand tonnes* [b]	21,393	24,616	28,639	33,217
Pulp and Paper	*thousand tonnes* [c]	22,114	23,838	25,618	27,460
Iron and Steel	*thousand tonnes*	16,403	18,218	20,234	22,473
Metal Smelting	*thousand tonnes*	4,916	5,076	5,241	5,413
Mining	*thousand tonnes*	274,301	282,115	29,1918	304,358
Other Manufacturing	*million $2005*	260,052	317,821	391,282	471,976
Waste	*million tonnes of waste in place*	747	787	813	832
Supply Sectors					
Crude Oil (CAP report)					
Conventional Light	*thousand barrels/day*	305.86	240.96	195.92	162.62
Conventional Heavy	*thousand barrels/day*	321.91	237.74	185.81	151.40
Synthetic	*thousand barrels/day*	2,076.84	2,250.84	2,376.92	2,419.20
Blended Bitumen	*thousand barrels/day*	1,968.54	2,664.48	3,398.82	4,163.03
Natural Gas (CIMS)	*billion cubic feet/day*	17.26	14.40	13.06	11.72
Coal Mining	*million tonnes*	87.21	91.82	97.16	105.91
Electricity Generation	*TWh*	646.5	740.1	873.8	1,046.8
Petroleum Refining	*million m^3*	115.8	122.4	135.3	149.9
Ethanol	*TJ*	388	7,199	15,479	26,405

[7] Environment Canada, "National Inventory Report: 1990-2005. Greenhouse Gas Sources and Sinks in Canada." November 2007.

[8] Notes: [a] chemical product output is the sum of chlor-alkali, sodium chlorate, hydrogen peroxide, ammonia, methanol, and petrochemical production
[b] industrial mineral output is the sum of cement, lime, glass, and brick production
[c] pulp and paper output is the sum of linerboard, newsprint, coated and uncoated paper, tissue and market pulp production
[d] natural gas production includes coal bed methane

Energy prices

CIMS also requires an external forecast for energy prices. As for sectoral output, fuel prices can change while a policy scenario is running if the policy induces changes in the cost of fuel production. Reference case prices for most fuels through 2050 are derived from the recent energy outlook published by NRCan (the industrial and electricity coal price forecasts were derived from forecasts by the U.S. Environmental Protection Agency), with some modification based on the latest NEB forecasts. Table 13 shows the fuel prices used to develop the reference case forecast in this report. These remain constant after 2020 for each fuel type because fuel price forecasts are highly uncertain, particularly in the longer term. The fuel price forecasts that we have adopted are intended to reflect long-term trends only, and will not reflect short-term trends caused by temporary supply and demand imbalances. The values differ slightly by province depending on supply costs and taxation. Where different provinces are not shown, prices in Ontario are used.

Table 13: Ontario reference case price forecast for key energy commodities

	Units	*Price 2020 - 2050*
Crude Oil (WTI)	*2003$ / barrel*	62.45
Natural Gas		
Industrial	*2005$ / GJ*	8.71
Residential	*2005$ / GJ*	11.30
Commercial	*2005$ / GJ*	9.87
Electricity Generation	*2005$ / GJ*	8.89
Coal		
Market	*2005$ / GJ*	3.56
Electricity Generation	*2005$ / GJ*	3.0
Gasoline	*2005$ / GJ*	19.40
Diesel (Road)	*2005$ / GJ*	16.94
Electricity		
Industrial		
British Columbia	*2005$ / GJ*	9.81
Alberta	*2005$ / GJ*	15.54
Saskatchewan	*2005$ / GJ*	15.25
Manitoba	*2005$ / GJ*	7.37
Ontario	*2005$ / GJ*	19.37
Quebec	*2005$ / GJ*	9.52
Atlantic	*2005$ / GJ*	20.0
Residential		
British Columbia	*2005$ / GJ*	18.04
Alberta	*2005$ / GJ*	26.45
Saskatchewan	*2005$ / GJ*	20.17
Manitoba	*2005$ / GJ*	13.58
Ontario	*2005$ / GJ*	27.39
Quebec	*2005$ / GJ*	23.29
Atlantic	*2005$ / GJ*	30.11
Commercial		

British Columbia	*2005$ / GJ*	11.21
Alberta	*2005$ / GJ*	18.62
Saskatchewan	*2005$ / GJ*	21.91
Manitoba	*2005$ / GJ*	8.03
Ontario	*2005$ / GJ*	25.41
Quebec	*2005$ / GJ*	23.29
Atlantic	*2005$ / GJ*	24.54

Note: All prices in Canadian dollars.

Reference case energy and emissions outlook

Based on the key economic assumptions highlighted above, we used CIMS to develop an integrated reference case forecast for energy consumption and GHG and CAC emissions through 2050. The CIMS model captures virtually all energy consumption and production in the economy.

The reference case forecast for total energy consumption is shown in Table 14, while Tables 14 through 16 show natural gas, refined petroleum product, and electricity consumption, respectively. The residual energy consumption of other fuel types (total minus natural gas, refined petroleum products, and electricity) is not explicitly shown in this report.

Table 14: Reference case total energy consumption

	Units	*2020*	*2030*	*2040*	*2050*
Demand Sectors					
Residential	*PJ*	1,567.41	1,760.28	1,976.58	2,303.09
Commercial	*PJ*	1,411.86	1,638.57	1,956.29	2,298.15
Transportation	*PJ*	3,451.60	3,834.35	4,361.39	4,937.50
Manufacturing Industry	*PJ*	2,526.87	2,769.72	3,104.84	3,496.72
Waste	*PJ*	94.44	99.21	102.13	104.22
Supply Sectors					
Crude Oil	*PJ*	1,996.62	2,202.70	2,341.42	2,504.66
Natural Gas	*PJ*	606.85	512.25	457.24	403.16
Coal Mining	*PJ*	24.04	24.63	25.63	27.24
Utility Electricity Gen.	*PJ*	4,127.59	4,627.73	5,450.94	6,564.59
Petroleum Refining	*PJ*	427.53	482.07	559.81	635.52
Biodiesel	*PJ*	2.56	3.89	5.26	7.15
Ethanol	*PJ*	0.34	6.11	6.72	7.22
Total	***PJ***	***16,238.71***	***17,962.51***	***20,348.25***	***23,289.22***

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Note: Producer consumption of energy (e.g., consumption of hog fuel in the pulp and paper sector or refinery gas in the petroleum refining sector) is included in these totals. Energy consumption in the electricity generation sector includes consumption of water, wind, nuclear, and biomass using coefficients adopted from the International Energy Agency.[9]

Table 15: Reference case natural gas consumption

	Units	2020	2030	2040	2050
Demand Sectors					
Residential	PJ	736.83	765.60	758.21	736.93
Commercial	PJ	744.52	880.25	1,055.21	1,235.26
Transportation	PJ	2.31	0.99	0.55	0.24
Manufacturing Industry	PJ	820.86	907.08	1,059.77	1,244.79
Waste	PJ	0	0	0	0
Supply Sectors					
Crude Oil	PJ	954.64	1,058.04	1,071.94	1,162.34
Natural Gas	PJ	535.49	448.23	397.20	347.05
Coal Mining	PJ	3.13	3.52	3.84	4.24
Electricity Generation	PJ	303.74	346.74	421.68	488.14
Petroleum Refining	PJ	111.56	135.24	162.56	185.88
Biodiesel	PJ	0.49	0.85	1.33	1.92
Ethanol	PJ	0.29	3.02	3.19	3.28
Total	***PJ***	***4,213.86***	***4,549.58***	***4,935.48***	***5,410.06***

Table 16: Reference case refined petroleum product consumption

	Units	2020	2030	2040	2050
Demand Sectors					
Residential	PJ	18.42	11.33	9.03	7.40
Commercial	PJ	40.42	32.54	36.84	42.92
Transportation	PJ	3,434.89	3,772.05	4,243.88	4,778.16
Manufacturing Industry	PJ	161.01	159.99	182.91	202.87
Waste	PJ	0	0	0	0
Supply Sectors					
Crude Oil	PJ	88.87	115.49	187.78	235.74
Natural Gas	PJ	24.38	20.43	18.11	16.21
Coal Mining	PJ	7.67	8.48	8.94	9.63
Electricity Generation	PJ	56.13	5.93	5.47	5.25
Petroleum Refining	PJ	93.08	94.58	107.47	121.31
Biodiesel		0.84	1.28	1.72	2.33
Ethanol	PJ	0.03	0.53	0.78	1.10
Total	***PJ***	***3,925.74***	***4,222.62***	***4,802.94***	***5,422.90***

[9] International Energy Agency, 2007, "Energy Balances of OECD Countries: 2004-2005". Renewable electricity generation is assumed to require 1 GJ of energy (e.g., wind, hydro) for each GJ of electricity generated. Nuclear electricity generation is assumed to require 1 GJ of energy for each GJ of thermal energy generated.

Table 17: Reference case electricity consumption

	Units	2020	2030	2040	2050
Demand Sectors					
Residential	PJ	749.17	918.81	1,148.52	1,501.69
Commercial	PJ	626.92	725.78	864.23	1,019.97
Transportation	PJ	9.85	44.49	82.61	101.68
Manufacturing Industry	PJ	715.76	752.60	830.32	926.17
Waste	PJ	-0.92	-1.14	-1.33	-1.51
Supply Sectors					
Crude Oil	PJ	91.77	91.70	87.89	86.20
Natural Gas	PJ	46.98	43.59	41.92	39.91
Coal Mining	PJ	4.54	4.40	4.63	4.99
Electricity Generation	PJ	0.00	0.00	0.00	0.00
Petroleum Refining	PJ	14.83	14.58	16.05	17.94
Biodiesel		0.32	0.55	0.85	1.16
Ethanol	PJ	0.01	0.93	1.00	1.04
Total	***PJ***	***2,259.25***	***2,596.11***	***3,076.33***	***3,698.70***

Based on total energy consumption as well as on process emissions in the industrial sector and supply sectors, we calculate the GHG emissions associated with the reference case forecast (Table 18). In the absence of new policies to control GHG emissions, emissions are expected to grow in all sectors of the Canadian economy. Especially strong growth is expected in the crude oil sector as a result of rapidly expanding output.

Table 18: Reference case GHG emissions

	Units	2020	2030	2040	2050
Demand Sectors					
Residential	Mt of CO_2e	39.61	40.57	39.95	38.68
Commercial	Mt of CO_2e	40.63	46.92	56.12	65.72
Transportation	Mt of CO_2e	246.34	270.44	304.21	342.50
Manufacturing Industry	Mt of CO_2e	90.39	96.60	109.10	124.89
Waste	Mt of CO_2e	31	31	32	33
Supply Sectors					
Crude Oil	Mt of CO_2e	158.17	169.73	181.30	192.65
Natural Gas	Mt of CO_2e	55.55	46.94	41.83	36.83
Coal Mining	Mt of CO_2e	2.54	2.68	2.76	2.91
Electricity Generation	Mt of CO_2e	112.74	119.57	138.44	170.64
Petroleum Refining	Mt of CO_2e	24.27	27.23	31.63	35.92
Biodiesel	Mt of CO_2e	0.15	0.22	0.28	0.38
Ethanol	Mt of CO_2e	0.02	0.32	0.35	0.38
Total	***Mt of CO_2e***	***800.94***	***853.35***	***939.09***	***1,045.35***

Note: CIMS does not include nitric and adipic acid production, consumption of halocarbons, "other and undifferentiated production", and solvents.

Figure 2 compares the total GHG emissions reported in this reference case to those in the NRCan reference case, a recent forecast by Informetrica Ltd. prepared for the federal government, and the recently released NEB 2007 forecast. All show Canada's energy-related GHG emissions increasing over time from 734 Mt in 2005 to between 900 and

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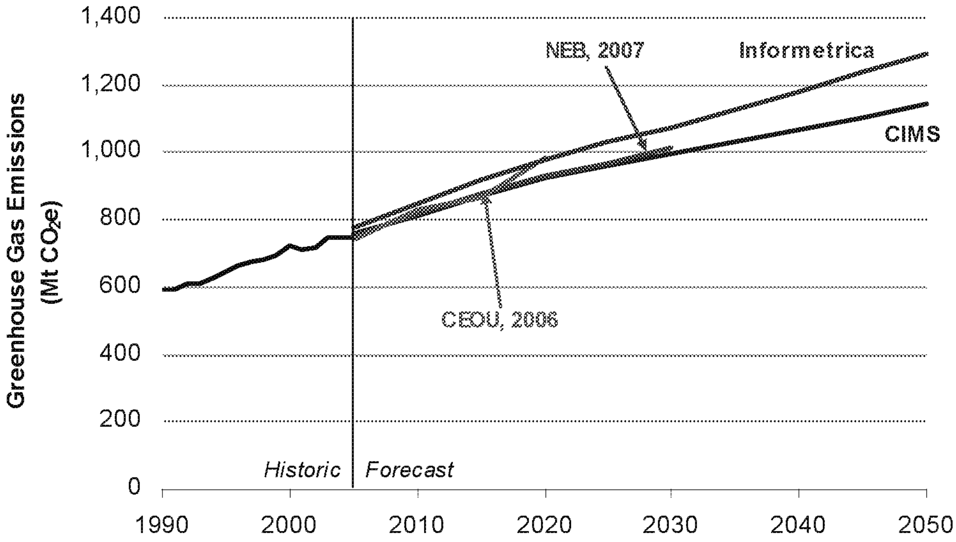
1000 Mt by 2020. Forecasting emissions for Canada is a highly uncertain process, especially given the rapidly changing forecasts for oil sands production.

Figure 2: Reference case GHG emissions (all adjusted to include nitric and adipic acid production, solvents, halocarbons, and "other & undifferentiated emissions").



Note: Historic emissions in this chart are from Environment Canada's 2005 Greenhouse Gas Inventory.

Appendices – Literature Review

Simulation and Case Study Estimates – Multiple Metrics

Canadian Urban Institute (CUI). (2008). *Energy Mapping Study: Calgary*. CUI: Toronto, ON.

This study models the changes in building efficiency and requirements for renewable energy in order to achieve a 50% reduction in GHG emissions at the community level from 2005 levels, by 2050. This study also spatially depicts the energy outputs from various land use scenarios.

Centre for Sustainable Community Development. (2004). *Demonstrating the economic benefits of integrated green infrastructure.* Report prepared for Federation of Canadian Municipalities.

Provides case study of the costs and benefits of several advanced energy systems, and lifecycle costing for a sample Canadian community for base case versus integrated green infrastructure.

Yukon Energy Commission. (1998). Opportunities *for Community Energy Management in the Yukon.* Quoted in Campbell, B. and A. Pape. (1999). Economic Development from Renewable Energy: Yukon Opportunities.

Case study of community energy management.

Herbert, Y. *Towards Green Buildings: Calgary.* Available from http://www.crcresearch.org/node/3216. Accessed December 2008.

Kats, G. (2006). *Greening America's Schools: Costs and Benefits.* Capital E.

Benefits associated with use of green building strategies in U.S. schools.

Ewing, R., K. Bartholomew, S. Winkelman, J. Walters and D. Chen. (2007). Growing *Cooler: Evidence on Urban Development and Climate Change.*

Comprehensive summary of current research relating urban form to vehicle miles travelled (VMT), CO_2 and costs.

Masdar – United Arab Emirates. *Abu Dhabi's Masdar Initiative Breaks Ground on Carbon Neutral City of the Future.* 9 February 2008. Available from http://www.masdaruae.com/mediaCenter/newsDesc.aspx?fst=mc&nws=18. Accessed December 2008.

Masdar City is an integrated development being built in UAE.

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Jaccard, M., L. Failing and T. Berry. (1997). *From equipment to infrastructure: Community energy management and greenhouse gas emission reduction.* Energy Policy, Vol. 25, No. 13, pp. 1065-1074.

Summary of a modelling project applying community energy management to four representative communities in British Columbia.

Bartholomew, K. February 2005. *Integrating Land Issues into Transportation Planning: Scenario Planning Bibliography.* Publication FHWA-HEP-05-033. University of Utah.

Summary of all American city level urban planning scenario modeling processes.

Gilbert, R. (2006). *Hamilton – The Electric City.* Prepared for the City of Hamilton

Proposal to make Hamilton into a highly efficient electricity-based city, incorporating efficiency, land use, behavior and technology change.

1000 Friends of Oregon. February 1997. *Making the Connections: A Summary of the LUTRAQ Project. Vol 7.* Available from http://www.onethousandfriendsoforegon.org/resources/lut_vol7.html. Accessed December 2008.

A summary of Oregon's integrated transit and land use proposal (called LUTRAQ) and comparison to a base case of highway expansion.

Brown, M. A. and F. Southworth. (2008). *Mitigating climate change through green buildings and smart growth.* Environment and Planning A. Vol 40 (pp. 653 – 675).

Investigates the potential role of a climate-friendly built environment including not only considerations of how buildings are constructed and used, but also how they interface with the electric grid and where they are located in terms of urban densities and access to employment and services.

California Energy Commission. (2007). *The Role of Land Use in Meeting California's Energy and Climate Change Goals.* Report Number CEC-600-2007-008-SF.

Summary of California research and action related to the impact of land use on energy use and climate change.

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Simulation and Case Study Estimates – Transportation Demand Reductions and the Debate over the Land Use / Vehicle Miles Travelled Connection

Stone, B. Jr., A. C. Mednick, T. Holloway and S. N. Spak. (2007). *Compact growths good for air quality?* Journal of the American Planning Association, Vol 73 (4).

This article presents the results of a study of alternative development futures and their effects on vehicle travel and pollutant emissions across 11 major metropolitan areas of the Midwestern United States over a 50-year planning horizon.

Holtzclaw, J. with the Sierra Club. (2004). A Vision of Energy Efficiency. ACEEE Summer Study on Energy Efficiency in Buildings, Asilomar, Pacific Grove, CA.

Comparison of high density versus low density developments.

Sacramento Area Council of Governments and Valley Vision. *Special Report: Preferred Blueprint Alternative*. Sacramento Region Blueprint Transportation Land Use Study. June 2007. Available from http://www.sacregionblueprint.org/sacregionblueprint/the_project/BP_Insert_JAN_2005.pdf. Accessed December 2008.

Presentation and comparison of five alternative development scenarios for the Sacramento area.

Handy, S. et al. (2005). *Correlation or causality between the built environment and travel behaviour? Evidence from Northern California*. Transportation Research Part D, 10: 427 – 444.

Discusses whether neighborhood design influences travel behavior or whether travel preferences influence the choice of neighborhood.

Crane, R. and R. Crepeau. (1998). *Does neighborhood design influence travel? A behavioural analysis of travel diary and GIS data*. Transportation Research Part D, 3 (4): 225 - 238.

Discusses whether neighborhood design influences travel behavior or whether travel preferences influence the choice of neighborhood.

Cervero, R. (1996). *Mixed land-uses and commuting: Evidence from the American Housing Survey*. Transportation Research Part A, 30 (5): 361 – 377.

Impact of mixed land-use developments on mode of travel.

Gilbert, R., N. Irwin, B. Hollingworth and P. Blais. (2002). *Sustainable Transportation Performance Indicators (STPI).*

This paper reports on the development of an initial set of 14 Sustainable Transportation Performance Indicators (STPI). These indicators are designed to show movement of transportation in Canada towards or away from sustainability.

Heart, B., and J. Biringer. *The Smart Growth – Climate Change Connection*.

Investigation of how to correlate VMTs and vehicle trips with greenhouse gas emissions.

Cervero, R. and K. Kockelman. (1997). *Travel demand and the 3Ds: Density, Diversity and Design*. Transportation Research Part D, 2 (3): 199 - 219.

Investigation of how density, diversity, and design affect trip rates and mode choice of residents in the San Francisco Bay Area.

Khattak, A. J. and D. Rodriguez. (2005). *Travel behavior in neo-traditional neighborhood developments: A case study in USA.* Transportation Research Part A, 39: 481 - 500.

Investigation of the impact of urban form on transportation mode and patterns.

Newman, P. and J. Kenworthy. (2006). *Urban design to reduce automobile dependence.* An International Journal of Suburban and Metropolitan Studies, 2 (1) Article 3. Available from http://repositories.cdlib.org/cssd/opolis/vol2/iss1/art3

This article seeks to determine a theoretical base for the observed decrease in automobile dependence above a certain threshold of urban density.

Bartholomew, K. (2006). Land use transportation scenario planning: Promise and Reality. Transportation.

Bartholomew, K., and R. Ewing. (2008). Land use-transportation scenarios and future vehicle travel and land consumption: A meta-analysis. Journal of the American Planning Association.

Bartholomew, K., and R. Ewing. (2007). Land use Transportation Scenario Planning in an Era of Global Climate Change.

Bartholomew, K., and R. Ewing. (2007). *Land use Transportation Scenario Planning in an Era of Global Climate Change.*

All of these articles report on various results from a meta-analysis of studies on land use density and VMT.

Yamaguchi, Y., Y. Shimoda and M. Mizuno. (2007). *Transition to a sustainable urban energy system from a long-term perspective: Case study in a Japanese business district.* Energy and Buildings, 39: 1 - 12. **

This paper models a transition to an urban energy system in a commercial district in Osaka, Japan.

Energy Research Group and M.K. Jaccard and Associates. (1999). *Community Measures in the Buildings and Transportation Sectors: GHG Reductions in the Short and Long Term.*

This report identifies and analyzes key measures for reducing GHG emissions relating to land use, transportation and privately owned buildings.

Kats, G. (2004). *What are the Costs and Financial Benefits of Green Buildings?* Capital E.

Summary of energy use and cost savings associated with green buildings in the United States.

QUEST. (2008). *Integrated Energy Systems in Canadian Communities: A Consensus for Urgent Action.*

Presents the case for integrated urban energy systems in Canada.

Bhat, C. R., and J. Y. Guo. (2007). *A comprehensive analysis of built environment characteristics on household residential choice and auto ownership levels.* Transportation Research Part B, 41: 506 - 526.

Investigation of the extent to which car ownership patterns in different density areas are the result of resident selection of neighbourhoods matching their car use preferences, or the result of density.

Reed, J. H., J. Riggert and K. Johnson. 2005. *Are Implementers and Evaluators Missing the Forest for the Trees? Winning the Battle and Losing the War from Embedded Energy use and Location.* Innovologie.

Discussion of the need to move beyond project-level analysis to an integrated society-level analysis of energy conservation and efficiency efforts.

California Energy Commission / Oregon Department of Energy / Washington State Energy Office. (1996). *The Energy Yardstick: Using PLACE^{3}S to Create more Sustainable Communities.* Produced for the Center of

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Excellence for Sustainable Development, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy.

Application of the PLACE^{3}S land use/transportation software to San Diego growth scenarios.

Norman, J., H. L. MacLean and C. A. Kennedy. (2006). *Comparing high and low residential density: Life-cycle analysis of energy use and greenhouse gas emissions*. Journal of Urban Planning and Development.

This study provides and empirical assessment of energy use and GHG emissions associated with high and low residential development.

Burer, M, K. Tanaka, D. Favrat and K. Yamada. (2003). *Multi-criteria optimisation of a district cogeneration plant integrating a solid oxide fuel cell-gas turbine combined cycle, heat pumps and chillers.* Energy, 28: 497 – 518.

Modeling results for a district cogeneration plant integrated with a fuel cell.

Yamaguchi, Y., Y. Shimoda, T. Asai and M. Mizuno. (2004). *Development of District Energy Supply System for CHP Implementation.* Proceedings of 2004 ACEEE Summer Study on Energy Efficiency in Buildings, pp 9-121.

Yamaguchi, Y., Y. Shimoda, and M. Mizuno. (2003). *Development of District Energy System Simulation Model Based on Detailed Energy Demand Model.* Eighth International IBPSA Conference, Eindhoven, Netherlands.

This paper presents a district energy system simulation model in which the energy flow of a district is modeled as the sum of total energy flow in each building.

Shimoda, Y., T. Nagota and M. Mizuno. (2005). *Verification of Energy Efficiency of District Heating and Cooling System Using Realistic Parameters.* Proceedings of the Ninth International IBPSA Conference, Montreal, Canada.

Roth, K. W., T. Rhodes, and R. Ponoum. *The Energy and Greenhouse Gas Emissions Impacts of Telecommuting in the U.S.*

Analysis of the energy and GHG emissions impacts of telecommuting in the U.S. from a lifecycle perspective.

Omer, A.M. 2008. *Energy, environment and sustainable development*. Renewable and Sustainable Energy Reviews 12, p. 2265–2300.

Investigation of urban density on energy demand.

Rong, F. (2006). *Impact of Urban Sprawl on U.S. Residential Energy Use.* Dissertation submitted to the Faculty of the Graduate School of the University of Maryland, College park, in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

This dissertation develops an original conceptual framework linking urban sprawl to residential energy use through electricity transmission and distribution losses and two mediators, housing stock and formation of urban heat islands.

Glaeser, E. L., and M. E. Khan. (2008). *Carbon Dioxide Emissions and Urban development WP-2008-07.* Harvard Kennedy School Taubman center for State and Local Government.

This paper attempts to quantify the carbon dioxide emissions associated with new construction in different locations across the country.

Rickwood, P., G. Glazebrook and G. Searle. (2008). *Urban Structure and Energy – A Review.* Urban Policy and Research, 26 (1): 57 - 81.

Examination of the current state of research into the energy and greenhouse gas emissions attributable directly or indirectly to urban form.

Simulation and Case Study Estimates – Waste Reduction

Bogner, J., R. Pipatti, S. Hashimoto, C. Diaz, K. Mareckova, L. Diaz, P. Kjeldsen, S. Monni, A. Faaij, Q. Gao, T. Zhang, M. Abdelrafie Ahmed, R. T. M. Sutamihardja and R. Gregory. (2008). *Mitigation of global greenhouse gas emissions from waste: Conclusions and strategies from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report.* Working Group III, Waste Management Research: 26 (11).

Discussion of current mitigation technologies include landfill gas recovery, improved landfill practices, and engineered wastewater management, as well as strategies and incentives for promoting improved waste management.

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Simulation and Case Study Estimates – Cost Savings

Burer, M. J., and D. B. Goldstein. *How Smart Growth Can Unlock Trillion Dollar Consumer Cost Savings.* Natural Resources Defense Council and John Holtzclaw, Sierra Club.

This report reviews recent research on location efficiency and uses these results to project scenarios for reductions in energy use, global warming pollutants, and consumer costs.

Slack, E. (2002). *Municipal finance and the pattern of urban growth. C.D. Howe Institute Commentary, 160.*

Discussion of the impact of municipal finance (taxation) on urban growth and land use density.

Clark, C., P. Adriaens, and F. B. Talbot. (2005). *Green Roof Valuation: A Probabilistic Economic Analysis of Environmental Benefits.*

Quantification of public health cost savings associated with green roofs in Chicago.

Yang, J., Q. Yu, and P. Gong. (2008). *Quantifying air pollution by green roofs in Chicago.* Atmospheric Environment, 42: 7266-7273.

Quantification of air pollution removal by green roofs in Chicago.

Muro, M. and R. Puentes. (2004). *Investing in a Better Future: A Review of the Fiscal and Competitive Advantages of Smarter Growth Development Patterns.* A discussion paper prepared by the Brookings Institution Center on Urban and Metropolitan Policy.

Provides a literature review of infrastructure and operating cost savings from concentrated development and dense urban areas.

Cosgriff-Dunn, B., and A. Steinemann. (1998). *Industrial Ecology for Sustainable Communities.* Journal of Environmental Planning and Management, 41 (6): 661 - 672.

This paper examines the scientific basis and planning implications of industrial ecology, which models urban systems on natural systems to increase efficiency and to reduce resource consumption and disposal.

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Simulation and Case Study Estimates – Health Improvements

Wilkinson, P., K. R. Smith, S. Beevers, C. Tonne and T. Oreszczyn. (2007). *Energy, energy efficiency and the built environment.* Lancet, 370: 1175 – 1187.

This article analyses the connections between the built environment, energy, and human health.

Jones, P., J. Patterson and S. Iannon. (2007). *Modelling the built environment at an urban scale – Energy and health impacts in relation to housing.* Landscape and Urban Planning, 83: 39 – 49.

This paper describes the Energy and Environment Prediction (EEP) tool which was developed to model existing urban scale built environments, incorporating building energy use, traffic flow and health.

Frank, L., S. Kavage and T. Litman. *Promoting public health through Smart Growth: building healthier communities through transportation and land use policies and practices.* Prepared for SmartGrowth BC.

This report explains how the built environment shapes transportation choices, and in turn, human health. It reviews the existing research for a range of transportation-related health impacts on seven public health outcomes: Physical Activity and Obesity, Air Quality, Traffic Safety, Noise, Water Quality, Mental Health, and Social Capital.

Jackson, L. E. (2003). *The relationship of urban design to human health and condition.* Landscape and Urban Planning, 64: 191 – 200.

This paper surveys the state of the science on the impacts of urban design on human health and well-being.

Frumkin, H. (2001). *Urban sprawl and public health.* Public Health Reports, 117.

This paper reviews direct and indirect impacts of urban sprawl on health.

Simulation and Case Study Estimates – Water Use Reductions

Brandes, O. M., and T. Maas. *Urban Water Soft Path 'Back of the Envelope' Backcasting Framework.* POLIS Discussion Series Papers 07-02. February

2007. Available from http://www.waterdsm.org/pdf/BEBF_lowres.pdf. Accessed December 2008.

This Canadian study uses backcasting to calculate specific water use estimates and specific measures for water saving under scenarios ranging from Business as Usual to the aggressive Soft Path.

Brandes, O. M., T. Maas, A. Mjolsness and E. Reynolds. *A New Path to Water Sustainability for the Town of Oliver, B.C.: A Soft Path for Water Case Study.* POLIS Discussion Series Papers 07-01. February 2007. Available from http://www.waterdsm.org/pdf/oliver_casestudy.pdf. Accessed December 2008.

Application of backcasting to a water use scenario planning study on the town of Oliver, BC. Includes several scenarios, required measures and assumptions, and calculated water use.

Brandes, O. M., and D. B. Brooks. *The Soft Path for Water In a Nutshell.* Friends of the Earth Canada and the POLIS Project on Ecological Governance. August 2007. Available from http://www.waterdsm.org/pdf/nutshell_revised_aug07_lowres.pdf. Accessed December 2008.

This report describes the theory behind the "soft path for water".

Brandes, O. M., and K. Ferguson. *The Future in Every Drop – The Benefits, Barrier and Practice of Urban Water Demand Management in Canada.* POLIS Project on Ecological Governance. February 2007. Available from http://www.waterdsm.org/pdf/report3_full.pdf. Accessed December 2008.

This report describes the need for a comprehensive, long-term approach to water provision that fully integrates demand management. It discusses barriers to the adoption of DSM measures and outlines practical actions that will facilitate a demand management approach in Canada.

Bennett, D. *Regional Collaboration for Water Efficiency.* Southern Nevada Water Authority. Powerpoint presentation.

Summary of water use statistics for southern Nevada. Includes statistics on water use in conventional versus highly efficiency landscapes and policy suggestions.

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Costs of Sprawl

Deala, B., and D. Schunk. (2004). *Spatial dynamic modelling and urban land use transformation: A simulation approach to assessing the costs of urban sprawl.* Ecological Economics, 51: 79 - 95.

This paper focuses on the theoretical underpinnings and the practical application of an economic impact analysis submodel developed within the Land Use Evolution and Impact Assessment Modeling (LEAM) environment. The conceptual framework of LEAM is described, followed by an application of the model to the assessment of the cost of urban sprawl in Kane County, Illinois.

Sierra Club of Canada. (2003). *Sprawl Hurts Us All! A Guide to the Costs of Sprawl Development and How to Create Liveable Communities in Ontario.*

This report examines the differences in benefits and costs between land-use decisions that stimulate low-density sprawl development at the outer edges of urban centers and alternatives which would result in smarter growth. The report includes much province-wide information, but focuses on the Greater Toronto Area and municipalities from Hamilton to Niagara.

Curran, D. (2002). *Challenging the Sprawl of Big Box Retail: The Smart Growth Approach to 'Zone it and They Will Come' Development.* Co-published by the Polis Project on Ecological Governance and Smart Growth British Columbia.

The purpose of this paper is to outline the impacts of big box retail land uses on communities in North America and to explore legal and integrated land use strategies to address the problems associated with big box retail.

David Suzuki Foundation. *Understanding Sprawl: A Citizen's Guide*. 2003. Available from www.davidsuzuki.org/files/Climate/Ontario/Understanding_Sprawl.pdf. Accessed December 2008.

This study provides a discussion of the impact of sprawl in Canada on household costs, land use, public health, climate change, energy, water, wildlife, aesthetics, and quality of life.

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David Suzuki Foundation. *Driven to Action – A Citizen's Toolkit – Sprawl Facts.* 2003. Available from www.davidsuzuki.org/files/Climate/Ontario/sprawlfacts.pdf. Accessed December 2008.

This report provides statistics about the costs of sprawl in Canada on homeowners, businesses, farms, and governments, as well as on energy use, GHGs, land use, wildlife, and water.

Other Useful Information About Integrated Urban Energy Systems

The Government Office for Science (GOS). (2008). *Foresight Sustainable Energy Management and the Built Environment Project – Final Project Report.* GOS: London.

Scenario-development project in which four scenarios were developed around the future of sustainable energy management and the built environment in the UK. The scenarios were developed along two axes: uncertainties in the global political and economic context in 2050 and the type of innovation that attracts investment, and include Carbon Creativity, Resourceful Regions, Green Growth, and Sunshine State. However, there is no quantitative analysis and no energy use or GHG estimates attached to the scenarios.

Brown, D. G., S. E. Page, R. Riolo and W. Rand. (2004). *Agent-based and analytical modelling to evaluate the effectiveness of greenbelts.* Environmental Modelling & Software, 19: 1097 – 1109.

Modeling approach to evaluate the effectiveness of greenbelts at delaying development beyond the greenbelt.

Gilbert, R. and A. Perl. (2006). *Grid-connected vehicles as the core of future land-based transport systems.* Energy Policy.

A description of futuristic grid-connected vehicles (GCVs)—e.g., electric trains, metros, trams, and trolley buses—that are propelled by electric motors directly connected to remote power sources.

Shimazaki, Y. (2003). *Evaluation of refrigerating and air-conditioning technologies in head cascading systems under the carbon dioxide emissions constraint: The proposal of the energy cascade balance table.* Energy Policy, 31: 1685 – 1697.

The aim of this study was to evaluate the refrigerating and air-conditioning technologies in cases of introducing both heat cascading systems and thermal recycling systems in industries located around urban areas.

The Cities Alliance. (2007). *Liveable Cities: The Benefits of Urban Environmental Planning – A Cities Alliance Study on Good Practices and Useful Tools.*

This report investigates how policy instruments are applied to integrating environmental concerns into urban planning.

Seymour, N-K. (2004). *Planning for Long-term Urban Sustainability: A Guide to Frameworks and Tools.* +30 Network.

This report provides an overview of many different sustainability frameworks and tools, case studies of their use, and an analysis of their application.

Gilbert, R. (2006). *Putting Energy First, 2.* Presentation to the Liveable Peel Conference Living Arts Centre, Mississauga, February 10, 2006.

This presentation contains a variety of energy statistics, including the efficiencies of electrically fuelled public transit and personal transportation equipment compared to fossil fuelled alternatives.

Tomalty, R. and D. Alexander. (2005). *Smart Growth in Canada: Implementation of a Planning Concept – Final Report.* CMHC.

This report seeks to address how municipalities move from a general commitment to Smart Growth to actually implementing it on the ground, and how the obstacles that are preventing them from doing so can be overcome.

Example Cities

Bohdanow, G., and S. Bohdanow. (2008). *New urbanism developments in Canada: A survey.* Journal of Urbanism, 1(2): 109 – 127.

A study of proposed "new urbanism" projects in Canada, and how most of them became more conventional during development.

Policy Recommendations

Tomalty, R. Innovative Infrastructure Financing Mechanisms for Smart Growth. Smart Growth BC.

This report describes 15 financing tools that raise funds for municipal or regional infrastructure while promoting smart growth. A summary of each tool provides an overview of the mechanism, indicates what kind of infrastructure it can be applied to, describes the potential smart growth outcomes, lists the advantages and disadvantages, identifies cities where the tool is being used, and provides an information source.

Gilbert, R. (2004). *Optimal Policies for Transit Infrastructure.* Presentation at conference 'What is Good Public Policy in Canadian Municipalities?', Ottawa, October 28 – 29, 2004.

Southworth, F. (2001). *On the potential impacts of landuse change policies on automobile vehicle miles of travel.* Energy Policy, 29: 1271 – 1283.

Recent US traffic growth is summarized and its causes discussed, emphasizing the complex causal linkages between automobile travel and the underlying land use patterns that shape it. This causal framework is used to frame a discussion of how the demands for vehicle travel might be reduced through suitable land use impacting policy instruments.

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Appendix – MKJA Proposal, November 20 2008

Introduction and context

The government of Canada has announced a goal to reduce greenhouse gas (GHG) emissions from 2005 levels by 20% by 2020, and 60-70% by 2050. The focus has been on the use of carbon pricing instruments such as a carbon tax or cap-and-trade systems to reduce CO_2 emissions from large point sources; no policy has yet been announced to deal with the 50% of emissions in Canada that come from urban energy uses such as heating, lighting and transportation. To achieve a reduction of 60% in emissions, these end-use sectors must be addressed. End-use requirements at this level of the economy will also lead to direct reductions in production emissions in the energy supply sectors (e.g., less gasoline, natural gas and electricity will be required for final end use, requiring less emissions for their processing).

In response to this overall policy context, the Quality Urban Energy Systems of Tomorrow (QUEST) conference was undertaken in 2007. The result of the conference was to emphasize a strategy to reduce CO_2 emissions through an integrated urban energy systems approach. This integrated, smaller scale more-distributed energy systems approach is fundamentally different from current energy systems and will require major changes in thinking, investment and policy. While efforts to raise the profile of integrated urban energy systems within policy discussions has had success, it was recognized that further work is needed to fully understand how energy use could evolve in the future and the challenges to implementing integrated urban energy systems. Even more work would be required to establish policy to encourage the development of integrated urban energy systems.

To this end, the QUEST participants are interested in an expert examination of the realistic potential of applying the QUEST approach to community energy. The examination must offer a credible quantitative view of the energy saving and GHG reduction potential of an integrated community level approach to energy, waste, land use, buildings, transport systems, and the economics and policy means of achieving this. Some of the questions that need to be asked include (and this list is not meant to be exhaustive):

- **Land use.** How can land use planning and zoning be structured to include GHG emissions reduction as a criteria, e.g., through zoning that encourages combined heat and power and district heating that increase primary system efficiency while maintaining local air quality standards?
    - **Possible metrics for success:** A key difficulty with land use is the identification of metrics of success; what is good land use from both a carbon emissions and community perspective? It is likely that non-carbon metrics or standards for good land use (e.g. safety, access, minimum nature set aside) will need to be maintained, while also applying direct

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carbon emission metrics in the energy supply and demand and transportation community sectors.

- **Energy Supply & Demand.** How can overall energy system reliability, primary efficiency and GHG intensity be reduced through an integrated urban energy system approach, e.g. through use of enhanced building and industrial process efficiency, fuels switching, direct GHG intensity reductions, smart transmission and select use of combined heat and power and district energy systems? What policies would need to be implemented to encourage an integrated urban energy system approach to energy supply and demand?
    - **Possible metrics for success:** Standard metrics for success in energy supply and demand are reliability, private and social cost, air quality and carbon impacts, and political feasibility, e.g. the political implications of siting new power plants of any type.
- **Build environment (e.g., commercial, residential).** How could building and residence energy and GHG efficiency and fuel use characteristics interact with an integrated community approach to energy and carbon management? How would recent policy developments (e.g., provincial, territorial regulations/legislations in energy efficiency improvements and mandatory labelling) interact with community energy solutions (e.g., community energy systems)? What other policies may be necessary?
    - **Possible metrics of success:** reduced energy consumption; market penetration of new energy efficiency technologies; integrated building design (e.g., building able to accommodate renewable energy technologies).
- **Transportation**. How can an integrated community level approach to energy, waste, land use, buildings, transport systems contribute to reduced GHG intensity, increased energy efficiency, reduced vehicle requirements and travel time and increased air quality, all while maintaining and improving community liveability, e.g., through land use planning, community design, and provision of alternatives to single occupancy vehicles, such as faster, safer, comfortable and flexible transit? What policies may be necessary to encourage this? (Subsidies to transit, land use zoning, deliberate traffic discouragement, urban car use pricing, etc.)
    - **Possible metrics for success:** Standard metrics of success in transportation include safety, trip time and fuel efficiency - carbon intensity is typically non-existent. While maintaining the usual criteria, we would add at least carbon intensity.
- **Waste.** How can waste planning and reduction, including front end recycling and composting and back end landfill enclosure and flaring/cogeneration, contribute to reduced GHG emissions? Are regulations for capping and flaring necessary, or will carbon pricing be adequate, and how will the carbon price encourage capping flaring? (e.g. through offset eligibility)

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- **Possible metrics for success:** Reduced volumes of waste, and especially tonnes of landfill gas emissions reduced (landfill gas methane, tonne for tonne, is a greenhouse gas 23 times stronger than CO_2, and can be combusted on site to make electricity).

- **Water.** How can the needs to reduce water use, maintain system safety, and minimize GHG emissions be combined, e.g. through combined heat and power or district energy system integrated with industrial water use? What policies are needed for water management (e.g. water metering, water pricing by volume).
  - **Possible metrics for success:** Drinking water safety and reliability is paramount. Other metrics could include reduced volumes of total water used, increased volumes of water reuse

The stated intention of the RFP was that potential savings will be those attributable to the integrated community level approach, over and above those achieved by single sector energy efficiency gains. We at MKJA would also suggest that these potential savings be attributable over those above achieved by a simple carbon pricing mechanism, which beside energy efficiency investments will also induce fuel switching and direct investments to reduce carbon emissions (e.g. basic process changes, carbon capture and storage). We would also suggest that long term carbon pricing may increase the attractiveness of market driven applications of integrated urban energy systems, the impact of which has not yet been analyzed in a national study.

QUEST has divided the project into two phases. Phase I is meant to be an information gathering exercise to assess the existing capacity to quantitatively measure the impact of an integrated urban energy system approach on carbon management, including an assessment of necessary resources and project budget and plan. In a nutshell, Phase I is a study to assess the value and feasibility of assessing the impact of an integrated urban energy system approach to carbon management, including its political feasibility. Phase II, if it goes ahead, will be the actual implementation of the project plan laid out in Phase I.

Phase I is meant to include a rough estimate of the potential gains in carbon emissions reduction by 2020 and 2050, broken down by sector and region, from pursuing an integrated urban energy systems approach over a centralized approach based solely on carbon pricing with no integrated urban energy system policies; we suggest that the key in this analysis will be a clear identification of the three main scenarios:

1) Business as usual emissions without carbon pricing (tax, upstream cap & trade or hybrid)
2) Emissions with sufficient carbon pricing to meet the federal reduction goals, as per the studies that informed NRTEE's *Getting to 2050*.
3) Emissions when an integrated urban energy systems approach supplemental to the carbon price is followed. Metrics for its capacity could include:
   a. By how much does an integrated urban energy systems approach reduce the carbon price from scenario 2?

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b. What supplemental private and social co-benefits could an integrated urban energy systems approach generate (e.g. reliability, economic resiliency, employment, local air quality improvements, etc.)?

Supplemental to point 3 will be an assessment of the impact of carbon emission actions under both an integrated and non-integrated urban energy system approach; e.g. how large is the gain of best available building technology by itself and within an integrated approach?

A key goal of Phase I will be to lay out the existing evidence for the necessity for Phase II, for judgment by QUEST. Phase II, if it proceeds, will include a modeling framework, supporting research and analysis, results and final report.

MKJA, based on the RFP, here presents it method and resources for meeting the requirements of Phase I. Methods follow the requirements, and are prefixed **"Method:".**

Phase I Deliverables

Deliverable #1: Rough estimate of the potential gains, by 2020 and 2050, from pursuing an integrated community energy system approach.

- **Task 1: Selection of the Subject Area Consultants.** The subject area consultants are the key to the success of the project – they will provide the core material by which the significance of an integrated urban energy systems approach will be assessed.
    - **Method 1:** MKJA, with advice from QUEST, will build a team to meet the requirements of the each of the following issues areas. The criteria for additional consultants will be their experience in these areas globally, nationally and regionally, their reputation for delivering quality information on time, their cost and any supplemental synergistic value they may bring to the team.
        - Energy economy and integration
        - Waste
        - Transportation
        - Land use & Buildings
        - Exergy/Energy
    - **Resources T1:** Mainly Chris Bataille contacting various candidates and interacting with Quest project management. All time resources are included in following tasks.
- **Task 2:** "The estimate should be consistent with reasonable capital stock turnover, technology and public policy assumptions but is not intended to be the result of a comprehensive modeling exercise." & "The estimate should also provide a sense of the divergence or gap in total energy (and total system efficiency) between "policy as usual" (a conventional approach to energy efficiency and the environment) and pursuing an integrated energy path?"

- **Method T2:** MKJA maintains and operates the CIMS model, which was used as the primary analysis tool for the NRTEE's *Getting to 2050* studies. While CIMS provides a highly detailed picture of the supply and end-use sides of the energy economy, its typical spatial resolution stops at the region (although a version of CIMS exists for metro Vancouver), which is insufficient to capture the potential spatially orientated benefits of an integrated urban energy systems approach. CIMS can, however, provide a common and unifying framework to integrate the scenario impacts from other modeling systems which can provide the essential spatial element. In Phase I we propose to assess how much potential carbon reduction CIMS might be missing because of the lack of a spatial element (i.e. to describe the envelope an integrated urban energy system approach may operate within), and in Phase II to take the results from specialized land use, transport, community archetype and buildings models under some prespecified carbon management scenarios, and integrate them into a unified CIMS assessment. We will also perform some basic sensitivity analysis on our Phase I assessment, especially with regard to potential energy prices and growth in residences, personal transportation and buildings.
- **Resources T2:** 5 days Chris Bataille, 4 days consultation with subject area experts, 5 days Jotham Peters

- **Task 3:** The estimate should be based upon a brief cross-disciplinary literature overview, including relevant estimates from key models within the different disciplines, both in Canada and internationally (e.g. energy-economy, integrated land use and transportation etc.).
  - **Method T3:** Quality analysis has been done worldwide on an integrated approach to urban energy systems management, especially in the UK, and should be included in this process. Task area 3 will inform and supplement Tasks 1 (subject area consultant selection) and 4 (planning the integrated modelling exercise). Several analyses have also been done in Canada (e.g. from the National Climate Change Process, Jaccard et al 1997[10]). Through consultation with the QUEST stakeholders, review of the academic and policy literatures, and consultation with key experts, we will assemble a summary of the key knowledge and literature for use to inform the final results of Phase I and recommendations for Phase II. These studies will summarized and tabulated on common theme points.
  - **Resources T3:** 2.5 days Chris Bataille, 10 days Jacqueline Sharp.

[10] "From equipment to infrastructure: community energy management and greenhouse gas emission reduction." Mark Jaccard, Lee Failing and Trent Berry. *Energy Policy,* Vol. 25, No. 13, pp. 1065-1074, 1997

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Deliverable #2: Detailed plan, budget options, analysis and research supporting the proposed approach for Phase 2 and identification of Additional Consultants.

- **Task 4:** "The plan needs to include an assessment (e.g., strengths, limitations, assumptions, previous applications) of models that are available, in Canada and internationally, to estimate savings from integrated community energy systems. Assessment should include models that take bottom up (building from archetypes or real communities) and top down approaches." & "The plan will then propose a modeling approach (or Framework) as well as a definition of the scenarios to be modeled for Phase 2. Deliverables will include a non-technical briefing regarding how the multiple modeling approaches will be combined or used and the rationale for the proposed Framework. Plan may include different proposed modeling approaches, related technical strengths and weaknesses, as well as budget and timeline implications for each alternative approach."
    - **Method T4:** Building on Tasks 1, 2 and 3, MKJA, in cooperation with the area experts, will assemble and summarize knowledge of existing subject area specific modelling frameworks (e.g., for transport, land use etc.) for possible use in an integrated analysis. Key elements of this will be their ability to capture the full impact of an integrated approach to urban energy system management, as well as their capacity to provide a metric that can be used in the integrating system (e.g., change in passenger kilometres travelled from densification policies). A core outcome of this phase is an assessment of the overall integratability of existing knowledge regarding urban energy systems; plans will be made to include important information in Phase II that does not readily translate into quantitative outcomes (i.e. liveability of urban centers). MKJA will then assemble and propose at least two modelling system options for QUEST based on criteria of effectiveness in meeting QUEST's needs, financial cost, supplemental benefits and costs, and any other criteria desired. The modelling plan will include all necessary calibration, coordination, and reporting template methodologies.
    - **Resources T4:** 10 days Chris Bataille, 5 days Jacqueline Sharp, 4 days consultation with area experts.

Timeline

Assuming a signed contract is in place by Monday November 24th, we will submit deliverable #1 by January 14, 2009 and deliverable #2 by February 27, 2009 to the Project Manager. We will also provide presentations as per the RFP (January 23rd and March 4th). Weekly phone, conference call or email updates, and presentations as necessary, will be provided to ensure the project is on target and meeting planned requirements.

Resources

The Phase I portion of the project will be managed directly by Chris Bataille of MKJA, with direct and ongoing assistance of Jacqueline Sharp of MKJA. Chris will handle client contact, and both Chris and Jacqueline will work with the subject area consultants. CIMS modelling will be carried out by Jotham Peters of MKJA. Labour calculations for MKJA are used to provide a set price; values for other consultants are estimates and could vary. Some of the MKJA, travel and consultant budget may be moved between each other. The final billed value could be lower, and any increase over the total estimate will first by checked with the QUEST project manager.

MKJA Resources and Tasks (Ph I)	Rate/Day	Days	Total
Chris Bataille – reporting and project management	1000	17.5	$17,500
Jacqueline Sharp – assistant project management, research and analysis	800	15	$12,000
Jotham Peters – modeling	800	5	$4,000
Michelle Bennett – administration	500	2.5	$1,250
Sub-total – without GST			$34,750
Other consultants by area (Ph I - all rates and times are estimates)			
Transportation	1000	2	$2,000
Waste	1000	1	$1,000
Land Use & Buildings	1000	2	$2,000
Energy / Exergy	1000	2	$2,000
Sub-total – without GST			$7,000
MKJA travel requirement, based on 3 YVR-YOW trips for 1 person			$3,600
Total without GST – Phase I			**$45,350**

Final Notes

Phase I of this project is an information, planning and assessment exercise. Information may come to light that allows a better fulfilment of QUEST's requirements that the plan here presented; MKJA will maintain ongoing contact with the project management team, and consult with them on any and all new information that may come to light that may suggest a change in plans. MKJA will not change the project plan without consulting the project team first, and all possible attempts will be made to maintain the deliverables schedule and budget in case of any major approved changes.

Appendix – Comments and Proposed Responses

Suggestions for additions to Phase I

1. The Canadian urban "market" should be segmented and sized by primary and secondary markets for urban energy systems. Once the market has been identified and sized then further segmentation should take place according to the minimum level of urban density at which there is a benefit to be realized i.e. can we expect the same relative level of GHG reductions from urban energy systems in Charlottetown as we can in Toronto?

   MKJA: This task is necessary, but will be part of the modeling approach in Phase II, and is beyond the scope of Phase 1. Our preliminary modeling approach is to model three different sizes of community archetypes, and then apply those results proportionally to and regionally appropriately to Canada.

Suggestions for Phase II

1. Expand on the policy section of the literature search, and provide an analysis of the importance of each policy, their effectiveness, and which are complements versus substitutes. If this does not fit in the Phase I scope, then make reference to the need for such an evaluation in the Phase I report, and conduct the analysis in Phase II.

   MKJA: While this is beyond the scope of Phase I, we will make reference to the need for this sort of evaluation, and ensure that in Phase II the most important policies are identified.

2. Do a sensitivity analysis using other reference case fuel prices.

   MKJA: We will propose a full suite of sensitivity analyses for Phase II, including at least a scenario analysis based on high and low energy and carbon prices and growth, and preferably stochastic Monte Carlo style analyses incorporating all major variables.

3. Because the phase in of carbon prices will occur over time, some municipalities will continue to add inefficient buildings to their stock in the near term, which could require more expensive and less efficient building retrofits in the future or the use of more alternative energy sources to meet greenhouse gas and energy end-use objectives. We suggest that it be confirmed that the inventory of new lower efficiency buildings and communities, expected to be developed during the phase in period, has been assessed in Phase II so that the concluding estimate of

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greenhouse gas reduction also includes the consequences of the development of this inventory of lower efficiency infrastructure.

MKJA: CIMS keeps track of various ages of capital stock, including buildings. The effects of different carbon prices in varying years will be automatically accounted for.

4. Incorporate a land use and built form modeler into the team along with the transportation and exergy specialist as part of a complete interdisciplinary team. The assumptions applied by transport and land use planners/modelers tend to be very different and can have significant impacts on the outcomes of models. These potential different assumptions should be addressed so that land use models maximize the potential for GHG efficiency

   MKJA: We are working to identify a land use and built form modeler to join the team for Phase II. We have at least two primary candidates, and may use one or both.

5. Connecting the work of MKJA and the Energy Mapping Study for Calgary will be critical for illustrating to decisions-makers across Canada the importance of accounting for energy in every decision and driving forward the uptake of integrated energy systems.

   MKJA: We will be contacting the Canadian Urban Institute to see the potential for this.

6. The NRTEE modeling that was used as the base for the Phase 1 estimate included "*build all new buildings to the LEED standard*". Is this aggressive enough?

   MKJA: More specific scenarios will be developed when we undertake the full modelling effort with the collaboration of other modellers. It is worth noting though that on-the-ground studies show that it is much harder to achieve practical penetration of even the basic LEED standard than technical potential studies suggest.

Requested edits, additions, and clarifications to the current report

1. In the results, the GHG implications of the proposed actions are provided. Can an estimate of the impact on grid energy use also be provided?

   MKJA: In Phase I we are only able to provide quantitative estimates of the electricity and gas demand impacts of carbon pricing in the scenarios, and not the portion driven by land use policy. Once all policies are modeled in Phase II, we will be able to provide figures for gas and electricity use, and potentially for refined petroleum products.

2. What is an IUES and does it include densification? Is an IUES part of Community Energy Planning? Are they synonymous?

   MKJA: We will add in definitions of these terms to make this clear.

3. The comments below are mostly editing requests for the Summary, to make it even more explicit and simplified. The requested edits include:

   - Explicit mention is needed of the expected impact of energy/carbon pricing on the value of property and the "market driven" densification that will follow

     MKJA: We do not have the detail at this stage to add this in to Phase I. In Phase II, the team will have to make a decision about how to proceed with this. If possible, it would be good to include it, but it may be resource intensive and non-essential to the final results. Municipal zoning and densification are public policy decisions, and the private market value of land does not necessarily feed back into the effectiveness of the densification policy. We also need to ensure that we don't add an unnecessary metric that will distract attention away from the rest of the report.

   - It is important to separate the price effect from the other factors that will lead to changes in urban form/urban energy use. Given the limitations of phase 1 a general statement like "…land use policy to encourage densification is an essential prerequisite to all GHG emissions reduction potential associated with IUES" may be the only way to cover this issue but it would be interesting to get more explicit detail of the limitations of price signals alone and a more complete acknowledgement of the significant role to be played by other measures.

     MKJA: We can add in a statement as suggested. We can also provide more detail of the impact of the carbon price signal alone versus combination with the other measures in the Phase II report, if we proceed with it.

   - It needs to be noted clearly and explicitly in the summary that, due to the time and other limitations put on the consultants by the terms of reference of phase 1, all that was able to be done was to apply the average expectation of GHG savings based on the literature studies to previous CIMS runs. This limitation is significant, but as it stands isn't clear in the report.

     MKJA: We will clarify this.

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- The summary needs to note that there has been no attempt to sort through the measures contained in the literature that has been reviewed. This point is an extension on the previous point for clarity

  MKJA: We will clarify this.

- Language clarification required in the Summary:

  MKJA: We can make edits to address all of these suggestions.

  - Explain "*at a reasonable cost*"

    MKJA: Phrase removed and replaced with a footnote discussion of equimarginal costing in the summary.

  - Clarification of the relationship between land use measures and sector specific measures. Current wording: "*The GHG emissions reductions from land use policy and the reductions from the transport and buildings regulations cannot be directly added, however, as the regulations would reduce the emissions impact of densification (i.e. the GHG intensities of vehicles and buildings would have fallen, reducing the impact of densification).*" Perhaps the difficulty of doing this can be introduced more clearly with reference to the fact that work will be done as part of Phase II to clarifying how CES measures can complement sector specific ones…

  - Qualification for the statement "*Political considerations will also likely constrain Canada from sustaining domestic carbon pricing higher than international levels.*"

  - Defining what is meant by "*welfare costs and benefits*"

    MKJA: Phrase modified to "total financial and welfare costs and benefits", and a footnote explaining this was added in the summary.

  - Paragraph on respective role of municipalities, provinces and federal government should be more explicit about the fact provinces ultimately set the rules by which municipalities operate, plan, set property taxes, etc.

4. In reference to the sentence that our governing bodies need to *"[Discourage] use of GHG and CAC intense energy forms in buildings, transport and energy*

supply", it is important to be careful of implications of focusing on GHG intensity of building energy use."

MKJA: Reduction of both energy and GHG intensity will be goals in this analysis, although we expect guidance from the Quest project committee if we find situations in which the two goals conflict, e.g. if fuel switching were to lead to signifcant overall increases in the use of some energy form.

5. In reference to the statement "*We have not included urban freight in this analysis, which may be affected by land use policy*", what impacts are expected?

   MKJA: A portion of freight transportation is within urban centres. If our cities densify, urban freight kilometres per tonne may fall, but there may also be local air quality issues, depending on the character of the urban freight fleet. This will be directly addressed in Phase II.

Questions about CIMS, how the model works and how the Scenarios were Run

1. In reference to the statement in the methods section that "*In other words, strong carbon pricing will induce fuel shifting, energy and GHG efficiency in CIMS, but will not induce spatially related GHG reduction actions, such as a shift from suburban single home living based on personal vehicles to urban multi-occupancy townhouse living based on transit. This uncaptured component is included in the remaining emissions after carbon policy has been applied*", at $200/tonne, a carbon tax would add about $0.50 per litre to gas prices. Wouldn't this create some shifting from suburban to urban living, and/or increased transit ridership?"

   MKJA: At it stands, prior to any modifications potentially made for Phase II, CIMS includes some endogenous capacity for mode shifting between single and high occupancy vehicles, transit and walking and cycling, but this is within a fixed urban form, i.e. the size, density and layout of cities are fixed. CIMS can however incorporate a changing urban form in the form of scenarios, which is one method by which we anticipate including the inputs of the bottom up modellers. In Phase I we used the literature to estimate the potential scope of what the scenario changes might indicate, and in Phase II, if it goes ahead, we will directly incorporate inputs from the bottom up modellers to change our scenario details.

2. In reference to the statement about how CIMS runs "*A competition also occurs to determine whether technologies will be retrofitted or prematurely retired. This is based on the same type of considerations as the competition for new technologies*", are interventions in the market, e.g. utility company DSM programs and incentives, accounted for in the model?"

   MKJA: They can be, and usually are if there is reason to include them in the reference case. This tends to be project specific, however. Announced *government policy regarding appliance standards, etc., is usually incorporated in the reference case.*

3. In reference to the statement "*CIMS is non-spatial below the provincial/regional level*", does this mean the results are not meaningful at the community level?"

   MKJA: No. What it means is that while CIMS captures all the component energy efficiency, fuel switching, process and energy supply and demand responses to a policy, it cannot capture the spatial changes at the community, i.e. market driven densification. That is why we used the literature estimates for Phase I, and hope to use the bottom up modellers for Phase II. There is also a logical reason for not doing economic modelling at this scale as well; CIMS is an economic model, whereas the long run spatial layout of the city is as much a public policy as market choice.

4. In reference to the statement: "*We have assumed that any amount of gas produced not used in Canada will be sold to the US*" how are higher exports of low/no carbon electricity as a result of decreased domestic consumption accounted for in the models, and could that generate either carbon offsets for use domestically and/or a price premium to allow for greater investment in GHG reduction measures?"

   MKJA: These are very good scenario assumption questions that will be addressed in Phase II. We have assumed constant electricity imports and exports in the Phase I analysis. We look forward to having this discussion with the participants.

5. In Table 1 (*BAU and Policy Emissions in the NRTEE Economically Optimal World, with land use policy to encourage densification*), Line X "*Reductions from aggressive land use policy*", how should the numbers be interpreted? What are the "reductions"? Why do reductions decline over time? Why is the biggest reduction between 2030 and 2040?"

   MKJA: The reductions fall over time because over time the carbon price is gradually driving the component (e.g. vehicle, building and appliance) GHG intensity lower and lower, reducing the scope of impact of densification land use policy.