LOCAL LOW CARBON AGENDA FOR NATIONAL PROSPERITY

PREPARED FOR

PROJET TROTTIER POUR L'AVENIR ÉNERGÉTIQUE
TROTTIER ENERGY FUTURES PROJECT

PREPARED BY

Boston Consulting

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TABLE OF CONTENTS

Boston Consulting

Author: Alex Boston, Principal, Senior Planner, Boston Consulting

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Front Cover: Sketch of the City of North Vancouver's waterfront in its low carbon 2100 Sustainability Vision. Diverse net zero housing choices are situated throughout highly walkable neighbourhoods supported by diverse transportation options. Local employers and services are linked to a renewable district heating network. Extensive green infrastructure, parks and urban forests are interlinked across the city. Drawing: Daniel Roehr (Design Centre for Sustainability, 2009). Patrick Condon led development of CNV's award winning 100 Year Sustainability Vision. Alex Boston led development of the CNV's award winning Community Energy and Emissions Plan (2009).

INTRODUCTION + SYNOPSIS

In the early part of the 21st century, Canada's foremost political leadership met over a series of Solution Summits in major urban centres to forge a deep carbon reduction path.

Part I lays out the genesis of the local low carbon vision for a prosperous, resilient Canada.

While elected officials from all levels of government shared a sense of urgency in heading down a decarbonization path, obstructing progress was scarce resources and competing priorities. Canada was plagued by a series of multi-facetted deficits: financial, social, and environmental.

Brilliantly, the Prime Minister sketched out five pillars to address core priorities confronting Canadians, locally, provincially and nationally. These pillars inherently advanced deep emission reductions – the foundation of their plan. Atop the pillars the Local Agenda for National Prosperity was formed.

Nine strategic directions were constructed from these pillars. These urban planning and design directions shaped where people live, work, play, shop and how they move between these places. They protected and restored their health, the economy and the ecosystems upon which they depend. The local low carbon agenda offered Canada the most affordable emission reductions, reducing national and sub-national mitigation costs by providing low-cost, local options, avoiding unproductive spending of scarce public and private resources, and generating an enourmity of co-benefits.

Laying this foundation, raising these pillars, and constructing these solutions required a governance transformation. Good Governments to Great Governance delineates this transformation.

Part II characterizes the Urban Agenda at 2050.

Qualitatively and quantitatively, the Paper characterizes the Urban Agenda's physical conditions, focusing on those variables that support the Trottier Energy Futures deep emission reduction modelling.

Local government influence in each sector, and its national and local relevance is examined. As well as the GHG management goals, the broader social, economic, and environmental opportunities for taking action in an integrated manner are outlined. The form, fit and function of the physical conditions are in each sector are described. Finally, the variables and modelling assumptions that support the CanESS and NATEM modelling teams are outlined.

Part III looks at the highlights along the Urban Agenda's journey, additional steps to define the path, and immediate next steps to get to the on ramp of the low carbon path.

An appendix discusses results of the first model run.

Key Community Emission Sectors

- Land Use + Urban Design
- Transportation Systems
- Buildings
- Building Energy Supply
- Solid Waste + Materials

I: VISION FOR NATIONAL PROSPERITY: THE LOCAL LOW CARBON AGENDA

Dateline: Canada, 2100

Almost 100 years ago, Canada's Prime Minister convened the country's foremost political leadership over a series of Solution Summits to forge a deep carbon reduction path. The impetus was a commitment by Canada and the world's foremost industrial countries to establish a zero carbon future by the turn of the century.

Serendipitously, in the same chamber where Canada hosted the first international gathering of climate scientists, and where the world's first greenhouse gas emission reduction target was set two generations prior[1], a National Prosperity Agenda for Urban Regeneration was born that would innovatively confront this challenge by simultaneously tackling a series of the day's most pressing problems. On the steps of Toronto City Hall, these visionary leaders spoke of raising five pillars that would harness the energy of federal, provincial, and local governments:

1. Fiscally Sustainable Infrastructure + Land Use
2. Public Health + Physical Activity
3. Housing Affordability
4. Natural Capital Protection
5. National Prosperity through Urban Regeneration

These pillars catalyzed a process of renewal, restoration and growth that made Canada more resilient to global economic volatility and catastrophic natural disasters, and laid a foundation in urban regions for enduring national prosperity.

Now at the dawn of the 22nd century, looking back, the legacy of these pillars is eight mutually reinforcing planning and design solutions that define Canada today:

1. Focused Growth + Productive Land Protection
2. Place-Based Planning for Good Jobs, Homes + Neighbourhoods
3. Complete, Connected Street Networks
4. Attractive Transportation Choices
5. Housing Diversity + Green Buildings
6. ABC Integrated Energy Systems
7. Smart Green Space + Smart Green Infrastructure
8. End of Waste, Beginning of Hyper Material Efficiency

An evolution in governance was necessary to lay this foundation, raise these pillars and construct these strategic directions:

1. National Prosperity Agenda for Urban Regeneration
2. Action Oriented
3. Policy and Planning Integration
4. Urban Innovation Incubation
5. Ecological Design
6. Real Costs, Real Prices, Real Choices
7. Continuous Capacity Building

[1] The first international climate change conference was held in Toronto in 1988. Convened by the government of Canada, hundreds of scientists and policymakers gathered to initiate global action on climate change. "Humanity is conducting an unintended, uncontrolled, globally pervasive experiment whose ultimate consequences could be second only to a global nuclear war," began the statement issued from the World Conference on the Changing Atmosphere. In 1989, a City, the City of Toronto, was the world's first jurisdiction to adopt a reduction target. Although it did not meet this initial target, city-wide emissions are 20% below 1990 levels and on track to meet its updated target: -30% by 2020.

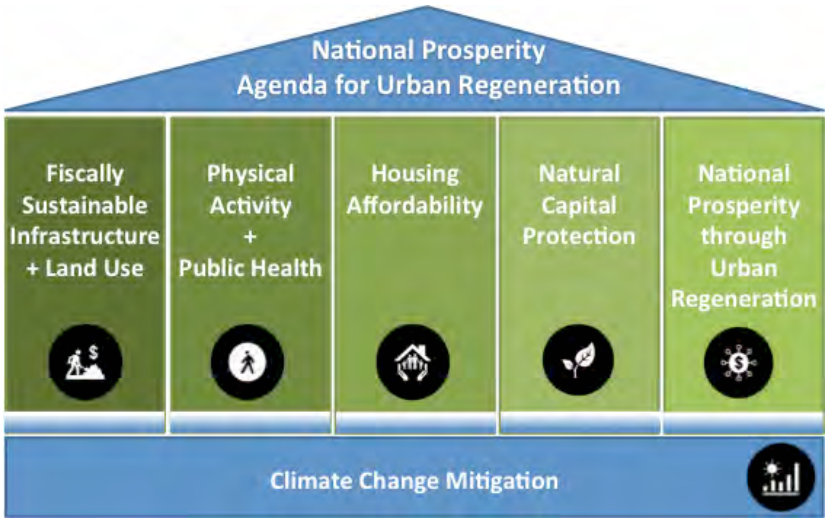
A FOUNDATION + FIVE PILLARS FOR COMPREHENSIVE DEFICIT MANAGEMENT

Over a series of Solution Summits convened by the Prime Minister early in the 21st Century, elected officials from all levels of government shared a sense of urgency in reversing emission growth and starting down the decarbonization path. Climate change was already costing Canada $5 billion annually.[2] Most impact and adaptation costs were related to property and infrastructure in urban areas, but all regions and many sectors were affected: forestry, agriculture, fisheries, hydroelectricity, transportation, outdoor recreation, and tourism (Warren, 2014). Obstructing progress on this decarbonization path, however, was scarce resources and competing priorities.

Local to national, cost-to-coast-to-coast, the country was confronting a multitude of multi-facetted, structural deficits: financial, social, and environmental. The Canadian federation, its cities and citizens were accruing, mounting financial deficits for extensive infrastructure to serve the thinly populated, far-reaching urban areas. Steadily mounting social deficits – inadequate housing, and preventable death and disease from inactivity and obesity. Environmental deficits were spiraling out of control, notably the loss of forest and farmland, polluted aquifers, and unprecedented volatility in resource commodity prices. While, the atmosphere's capacity to absorb more GHGs – the carbon deficit – was the mother of all wicked problems, these other pressing priorities could not be ignored.

At the whiteboard, the Prime Minister cautiously stepped forward to sketch five pillars:

1. Fiscally Sustainable Infrastructure + Land Use
2. Public Health + Physical Activity
3. Housing Affordability
4. Protecting Natural Capital
5. National Prosperity through Urban Renewal



Below the pillars a solid "Climate Change Mitigation" foundation was drawn. Above, the pillars supported the "Local Agenda for National Prosperity."

Rather than addressing each in isolation, Summit delegates excitedly constructed strategies that mutually supported one another and inherently advanced a low carbon future. Synergies were achieved, minimizing costs and maximizing benefits. This comprehensive deficit management agenda catalyzed a process of renewal and restoration that made Canada more resilient to global economic volatility and catastrophic natural disasters, and left the legacy of enduring national prosperity we enjoy today.

[2] Climate change impacts and adaptation estimated to cost Canada $5 billion annually by 2020 and average costs of 0.8% to 1% of GDP by 2050 (National Round Table on the Environment and the Economy, 2011).

Figure 1: Grid and building scale renewable power, district heating, diverse transportation choices, green infrastructure, and social and economic vitality are mainstreamed in Canada's Urban future. Image: Developed by Golder Sustainable Communities for NRCan OEE.

N.B. this agenda did not intend to fully solve all of Canada's problems. Complementary actions were necessary to curb financial deficits, cut health care costs and restore ecosystems. Notably on climate change and energy, major decarbonization efforts were necessary in the upstream oil and gas sector, grid-scale electricity, and many industrial sectors. The National Urban Regeneration Agenda, nevertheless, played a decisive role on many fronts, including the major part in enabling the country to achieve 80% GHG reductions by mid century while strengthening its prosperity and resilience.

Local government participation in the Solution Summits was a last minute thought and counter to prevailing wisdom on national climate change mitigation around the world. Having made the zero carbon commitment, however, the Prime Minister poured over the most critical climate change mitigation analysis and the country's emission activity. It became clear local governments must play a key role. Local actions were the most economically attractive and generated extensive co-benefits. Local governments were drivers of innovation. At the same time, Cities were major drivers in Canada's emission growth and had significant influence over half the country's emissions.

CITIES: THE BEST COST-BENEFIT BETS IN TOWN

At the time, dominant analysis by senior governments, international institutions and non-governmental organizations focused on simple cost abatement analysis of isolated mitigation strategies. A growing body of research was beginning to evaluate economic benefits, as well as costs in ways that better reflect how public and private sector finance and economies play out in the real world.

The *Global Commission on the Economy and Climate* mapped out a platform for getting on an atmospheric stability path. Low carbon cities were central planks. Rather than urbanist thinkers, the Global Commission was composed a score of hard-nosed, former finance ministers and economic thinkers, headed by the former President of Mexico – Felipe Calderón – a former World Bank Chief Economist – and Sir Nicholas Stern (Calderón, 2014). Their guiding interest was a healthy global economy.

> *…much urban growth today is unplanned and unstructured with significant economic, social and environmental costs. There is now powerful evidence that more compact and connected urban development, built around mass public transport, can create cities that are economically dynamic and healthier, and have lower GHG emissions.*
>
> Global Commission on the Economy and Climate, 2014 (see Calderón)

The industrial world's think tank also concluded urban policies as central, strategic elements in a national and sub-national strategies (OECD, 2010).

> *…urban policies can lead to a reduction of total OECD global energy demand and, consequently, of CO2 emissions at relatively low cost. Under a policy scenario where national emissions reduction objectives are implemented, the aggregate mitigation costs can be reduced if economy-wide environmental policies are complemented by urban policies, such as congestion charges or increasing spatial density. This is due to complementarities with other policy objectives, such as lower local pollution and health benefits, and the enhancement of city attractiveness and competitiveness through lower local pollution levels.*
>
> Organization for Economic Cooperation and Development, 2010

CITIES: INNOVATION INCUBATORS

A federal Zero Carbon Cabinet Committee scoured the country for the most real and resonant demonstrations of action. It discovered most emanating from city halls scattered across the country. Their market transformation impact was sending ripples across the country's largest GHG sectors.

Big cities like Vancouver and Toronto, Northern centres like Yellowknife and small towns like East Gwillimbury, Ontario, were establishing innovative standards and incentives shaping the next generation of building codes.

Halifax's solar city initiative and Nelson, BC's building energy retrofit program were driving deep carbon reductions in existing buildings with innovative financial instruments being adopted by more and more provinces, and in turn local governments (i.e. local improvement charges, and on bill financing, respectively.)

Entrepreneurial cities across were establishing district energy systems on a variety of low carbon platforms; Île-Des-Chênes, Manitoba - geothermal; Toronto – lake-water cooling; Charlottetown - wood and municipal waste; Whistler - sewage heat recovery.

Vancouver and Richmond, BC were requiring developers to integrate EV-charging into new buildings – a standard that spun out universally, but required local governments to get the ball rolling.

Montreal and Winnipeg led the country in comprehensive public transit electrification.[3]

[3] New Flyer has electric buses on the streets of Winnipeg. Société de transport de Montréal is North America's first transit authority committed to 100% electrification.

By the second decade of the century, Halifax and Greater Vancouver regional governments were diverting upwards of three-quarters of landfill waste with sophisticated green and blue bin programs, and installing advanced methane-fueled energy systems to cut GHGs from remaining waste.[4]

Right across the country local governments were colouring way outside the lines achieving large shares of zero carbon transportation. In neighbourhoods with good basic building blocks (i.e. complete, compact, connected), new infrastructure was pushing bike mode share into new North American territory. Upwards of 15% of trips were being made by bike in Fairfield (Victoria), Wolseley East (Winnipeg), The Glebe (Ottawa), Vieux-Limoilou (Québec City), Jubilee (Halifax)[5] Relative to today's 50% bike trip mode share nationally, this was modest, but reflected a trebling of rates over a mere decade.

As impressive as they were, waves generated by these cities were constrained by a sea of policy barriers inadvertently built by all levels of governments preventing a deep emission reduction groundswell.

CITIES, CARBON + THE CANADIAN FEDERATION

In light of comprehensive analysis, the Zero Carbon Cabinet Committee understood that while Canada's most rapid GHG growth at the time was in oil and gas industrial activity, the majority of emissions were emitted within municipal boundaries. Local governments had significant influence over almost half of Canada's total GHGs – double the total share of oil and gas extraction, refining and transportation.[6] Personal road-based transportation continued to be the country's largest sector and was one of the top driver's to national emission growth. Residential and commercial buildings and solid waste were also steadily growing.

Driving the enourmity of Canada's per capita footprint – amongst the world's largest – and its run away growth rate was urban form. Two-thirds of Canadians lived in thinly populated, car dependent neighbourhoods comprised predominantly of single detached homes with few, if any walkable destinations.[7] 90% of residential growth, moreover, was extending this form, modified by slight increases in multi-family and density, yet further from major employment and services.

Per capita GHGs, dominated by transportation and building activity, were conservatively four fold higher in these low density, auto-oriented residential neighbourhoods, relative to the complete, compact, connected neighbourhoods found in city, town and village centres across our urban areas

[4] These regional governments are on track to exceed these diversion targets.
[5] Based on analysis of Statistics Canada census data from 2011: http://www.cityclock.org/10-neighbourhoods-highest-levels-cycling-work-canada/#.VVwmC-s53i7
[6] Analysis by Boston of Canada's UNFCCC emission inventory submission for Federation of Canadian Municipalities to support a deep emission reduction local government program.
[7] Population distribution is based on archetyping completed by Gordon et al (2014 and 2013) using Statistics Canada data and spatial analysis. As the work focused on Census Metropolitan Areas with populations ≥100,000 (70% of Canada), extrapolations define allocations for the remaining population in Census Agglomerations (populations 10,000-100,000 - 12% of Canada) and Small Town Rural (18% of Canada).

(Boston, 2010, 2009, 2013b, 2015; Hornsweg, 2010). This was a serious problem. Rather than forward on the low carbon path, Canada was travelling backward.

Tempted to decree local government action, the Prime Minister sagely concluded collaboration and coordination was necessary amongst all levels of government to advance deep emission reductions. Building size, type and inspection, for example, were largely local government levers. Building code, building energy fuels, and retrofit programs were largely senior government buttons. Location of growth, land use mix, street design and parking policy – key transportation behaviour determinants – were largely local government dials. Senior governments largely controlled vehicle fuel economy, transit investment and major highway and bridge infrastructure.

Decision makers had an epiphany; urban land use planning and design was central to many of its goals. Canada's newly minted Minister of National Urban Regeneration declared: "We shape our cities, and then our cities shape us – our waistlines, our carbon footprints, our wealth." This understanding allowed the five pillars framework to be raised.

PILLAR I: FISCALLY SUSTAINABLE LAND USE + INFRASTRUCTURE

As well as a cornerstone to comprehensive urban climate change mitigation, compact development could help reduce mounting municipal infrastructure deficits.

While there was a web of complex revenue and spending issues, including considerable cost downloading of from senior governments, a significant contribution to the $125-billion municipal infrastructure deficit (Mirza, 2007) was low-density development.[8]

Local governments were bowed down under the weight of spiraling costs for extensive water, sewage and road infrastructure, and emergency and solid waste collection services across thinly-populated, widely-dispersed regions.

Edmonton, Calgary, Mississauga, London, Halifax: coast to coast, city after city began to look more closely at the cost of laying, maintaining *and* replacing services in low-density, automobile-oriented development to discover it was not paying for itself (Thompson, 2013). Collectively, Canadian governments were spending $29 billion annually on roads, quadruple being spent on transit (Transport Canada, 2011).

Fuelling the auto-oriented model was the transportation spending priorities of all levels of government: $29 billion annually on roads, quadruple that spent on transit (Transport Canada, 2011). That total excluded the land value of roads, let alone parking spaces, which was the single largest land use in many communities, exceeding land for housing, overwhelmingly provided free of charge (Littman, 2014). Nor did it include the social and environmental costs of driving estimated to be minimally $27 billion annually (Thompson, 2013). This value low-balled the full cost of traffic accidents estimated at $63 billion annually, largely a function of the automobile oriented urban form

[8] This value reflects the backlog of repairs and replacement of all municipal infrastructure. A large share of Canada's municipal infrastructure is at or near the end of its life.

(Transport Canada, 2013). Public revenue associated with personal automobile use picked up a small fraction of these costs – about $15.5 billion – even if all fuel tax, parking permits, and licensing costs were included (Transport Canada, 2011 in Thompson, 2013).

The dominant, deficit-making, low-density development approach was bad news. The good news, however, was the dominant, deficit-making, low-density development approach. Its fundamental fiscal unsustainability had to be resolved. And it could be – it took a decade and a half to phase out green field development, and a couple decades to modernize the existing low-density neighbourhoods.

The growth model was fatally wounded in a slow motion collision of two incompatible post World War II planning principles. 1. separate activities in people's lives (working, shopping and notably living on large, private lots) and; 2. connect people to these geographically dispersed activities by personal automobile.

Varied voices cried out about the spiraling, incompatibility. Working Canadians were spending on average close to 10 full days a years commuting to and from work (Statistics Canada, 2011). Commuting, moreover, comprised just 20% of trips.[9] Canadians lamented rising average driving times as successive waves of people moved into succeeding suburban rings, and average driving speeds sank under swelling congestion. The private sector groaned. It couldn't get employees to work and products to market on time. Public agencies bemoaned the escalating infrastructure, health and environmental costs. The planet was starting to act unpredictably due the loss of farmland, forests, aquifers, clean air and climatic stability.

Elected leaders at all levels listened, learned and led. Before the first quarter century rose, the sun set on the age of sedan socialism. The cost of roads, bridges, parking, sewage and water infrastructure, and some major accident and sedentary health injuries and diseases, pollution and environmental damages – most of which were paid directly by the state, if paid at all, were internalized into the cost of transportation and land use choices.

Sound fiscal policy by every level of government was supplemented by supportive local government zoning. Within a decade and a half, greenfield development virtually dried up. Within two decades, much of the existing, low-density fabric was modernized.

PILLAR II: PUBLIC HEALTH + PHYSICAL ACTIVITY

As well as managing carbon, compact development combined with transportation choice could address other crises afflicting Canadians. Living in low-density, automobile-oriented areas reduced the time and need to walk, fostering a sedentary citizenry.

In the early part of the century, physicians discovered the 60-year-old Swede was fitter than the 16-year-old Canadian not because of his ice time, but because of his regular walk to work and bike to the bakery. More than 40% of all trips by Swedes were by foot or bike (Pucher J. a., 1996). Personal

[9] whatIf? Technologies/NATEM data, 2014.

automobile comprised one third of trips. In Canada, only 8% of trips were by foot or bike, more than three-quarters by car.

After smoking, physical activity and obesity were amongst the leading causes of preventable death and disease at the turn of the century (Public Health Agency of Canada, 2007). For the first time in modern history, the life expectations of young Canadians was falling short of their parents due to inactivity and obesity (House of Commons Standing Committee on Health , 2007).

Higher rates of inactivity, obesity and diabetes were correlated with lower density, residential neighbourhoods (Glazier, 2014). Every additional hour spent in a car each day was associated with a 6% increase in the likelihood of obesity (Frank, 2004). Every additional kilometre walked per day was associated with a 5% reduction in obesity.

Inactivity and obesity were estimated to account for $6.4 billion in lost annual economic output annually due to short- and long-term disability and premature death. Physical inactivity alone was costing the health care system $1.6 billion annually (Katzmarzyk, 2004). Higher rates of inactivity, obesity and diabetes were correlated with lower density, single use (residential) neighbourhoods (Glazier, 2014). As well as walkers and cyclists, regular transit users were more likely to meet their recommended daily physical activity requirements than those that don't (Lachapelle, 2009).

Physicians began writing prescriptions to citizens, cities and senior governments to consolidate support for an urban form and attractive transportation choices that could reduce health costs. Today, the vast majority of Canadians pass their physicals and earn 90s on their "walk scores."

PILLAR III: HOUSING AFFORDABILITY

In the early 21st century, housing affordability was a broad based crisis affecting those on income support, seniors on fixed income, and middle-income families that had not entered the real estate market, and most importantly young Canadians. One of 4 Canadians spent more than 30% of their income on housing, the county's affordability threshold. Amongst households under 25, the figure was 1 in 2. Canada's household debt was at a historic high. (Federation of Canadian Municipalities, 2013) (Statistics Canada, 2014)

Paradoxically, the dominant types of residential construction were the most expensive, namely single detached homes, followed by high-rise condominiums. On a full life cycle basis, this housing was also the most GHG intensive, the latter in part because of GHG intensive concrete construction, but also because of deteriorating thermal performance.

Insightfully, all levels of government jointly modernized housing and development policy, updating regulations and fiscal tools, reforming inadvertent subsidies that constrained housing choice and failed to meet consumer demand.

The missing middle of the housing continuum soon flourished in this fertile policy environment: multiplexes, row and town houses, laneway homes, and most significantly wood frame low rises of 3

to 6 storeys. The latter was the least carbon intensive form of housing and 25% less expensive per square foot than its concrete cousin (Teasel, 2014).

Senior governments, foresightedly, cultivated Canada as the single greatest hewer of high performance, pre-fabricated, wood frame housing in the world, meeting surging global demand for pre-fab homes in luxury and affordable markets. Production costs fell, and under prudent policy, further increased affordability. Energy efficiency surged, laying the groundwork for Canada as the pre-eminent home of net zero buildings. It is hard to believe that today's high tech factories dotted across rural Canada, abuzz with engineers, architects, computer programmers, tradespeople and robots were quiet, shuttered saw mill sites in the early part of the century.

Over and above new construction, governments realized some of the most affordable housing in the country was already built. More than half of homes at the time were single detached. Most were occupied by 1-2 person households – 60% of all households at the time and growing (Statistics Canada, 2014). A disproportionately large share of these were empty nesters looking to downsize on the short to medium term. But the market, with its missing middle, had few attractive small home options and many were reluctant to move out of their neighbourhoods.

Senior governments incentivized those who wanted to downsize in their own homes and their own hoods, providing tax credits to stratify large single detached homes into multiple units, or split large lots to build micro homes, creating, quick, liquid assets for seniors. Local governments removed barriers to secondary suites and lot splitting. Utilities incentivized secondary suites and multiplex stratas cutting household energy consumption 50%. Young people eagerly signed leases and mortgages and moved into affordable homes, eliminating the major source of angst in their lives, and restoring faith in old governments and old utilities. Older generations, older homes, and older neighbourhoods were rejuvenated.

Through the housing policy modernization process, governments acquired a fuller appreciation of affordability, seeing that after housing, which consumed 28% of average household income, transportation consumed 20% (Statistics Canada, 2014). This led to the creation of a tripartite Location Efficient Housing Framework that focused incentives for affordable housing – new construction and renovations – in and around walkable, bikeable, mixed used nodes and corridors targeted for transit investment, and car share encouragement.

PILLAR IV: PROTECTING NATURAL CAPITAL

The turn of the last millennium marked a period of global volatility in renewable and non-renewable natural resource prices unprecedented over the previous century (McKinsey Global Institute, 2011).[10] A report was tabled at a prestigious gathering of the world's business elite in Davos, Switzerland, concluding this extreme volatility with a clear background signature of rising prices was projected to continue if the dominant expression of urbanization,

[10] The McKinsey Commodity Price Index is comprised of four aggregate indexes comprised of food and non-food agricultural items, metals and energy.

resource demand, and supply constraints continued (World Economic Forum and Ellen MacArthur Foundation, 2014).

In Canada, two percent of agricultural land disappeared in the first decade of the 21st Century, most of it subsumed by development around large urban regions (Statistics Canada, 2014). This was one of the largest losses of agricultural land in decades – 1 million of 50 million hectares lost in just 10 years. The trend was projected to continue and began to startle leaders who saw growing disruptions to food production in the US – the pantry for more than half of Canada's food imports. Water scarcity, drought, extreme weather events, sea level rise were amongst the many factors reducing arable area in the US, precipitating food price increases and volatility. Urban and rural leaders saw Canada could benefit from this situation, and the world could benefit from Canada – but only if it's agricultural land base was protected.

Urbanization was Canada's third largest driver of deforestation back then, accounting for 10% of permanent forest loss annually in Canada (NRCan, 2014). This rate had been steadily rising while other deforestation activities, with the exception of oil and gas, were declining or stabilized. Globally, forest carbon loss has contributed to 30% of total atmospheric carbon accumulation since the industrial revolution (World Resources Institute, 1998). Forest loss, it was discovered, was driving up the cost of other services, notably building heating and cooling, storm water and erosion management, air quality protection. Concerned at the squandering of scarce capital, TD, a leading bank at the time, quantified the return for investing $1 dollar in urban forests as high as $12.70 (Alexander, 2014).

Canada's political leadership began to see the forest for the trees. Defending field, farm and forest, they focused growth in nodes and corridors and restored green space in cities. These visionaries sewed the seeds for today's extensive riparian forests alongside rivers and streams and brooks and creeks that started spreading out across our cities a century ago – some of which last saw the light of day as Model T Fords rolled into our cities. Not only has this reduced hard infrastructure costs and improved terrestrial, marine and fresh water habitat, this system supports today's extensive network of multi-use paths for pedestrians and cyclists penetrating into work, retail, and school destinations.[11] Larger tracts of farm, forest, and field conversely filter into cities, occupying the space between compact, corridors radiating from higher intensity residential and commercial areas.

Canada's reputation as the "Sharing Nation" also has its origins in this early 21st century eco-industrial renaissance. At the time, many high value goods sat idle for extended periods. Every household actually possessed a private car, costing $10,000 a year to own and operate, yet it sat idle 95% of the time (23/24 hours).[12] Private and social sector car shares emerged that allowed people to book cars on big computers in their homes to which they could walk down the street and pick up. Each of these share cars displaced 4 to 13 vehicles from the road, and significantly reduced driving

[11] Green infrastructure cost analysis and multi-use riparian trail network in Condon, 2010.
[12] Based on US National Household Travel Survey, 2009. http://nhts.ornl.gov/2009/pub/stt.pdf

distances and congestion.[13] With the advent of web-enabled wearables, and the emergence of young, tech-savvy cash-constrained consumers, car share rates steadily up ticked in complete, compact neighbourhoods. As an experiment, the federal Minister of Transportation of the day took the keys away from 250 self-confessed car addicts in 13 cities. They had to bike, walk, train, bus or if needed, use a car share. After one month, personal bike distances rose 132%, walking distances rose 93%, transportation spending declined 67%, collectively they lost 413 pounds, and 100 of the 250 "addicts" elected *not* to take their keys back.[14]

Along with a birthday card, it was at this time the Federal Minister of Transportation started the tradition of sending every Canadian, upon turning 16, a car share membership. Car share rates soared, and congestion, traffic accident, and emission rates plummeted. Governments saved millions of dollars annually when they replaced most of their fleets in favour of car shares. Like some of the most foresighted companies of the day, the federal government strategically saw car sharing as the emerging platform for the autonomous car.

Beating other countries to the driver's seat, Canada opened its borders to the likes of Google, Apple, Tesla and Uber. Autonomous automobiles sped into Canada for testing and roll out. Fledgling industries flourished developing superior sensory capacities for recognizing everything from weather changes to temporary, unmapped stop signs; advanced communication amongst traffic signals, cars, consumers and construction sites; smart grid interconnectivity; battery design; computer consoles; robotics….

Conservative projections estimated autonomous vehicles would displace the current share of cars 50%.[15] Pricewaterhouse Coopers' projections were 98%. With car ownership at .6 per capita (one of the highest in the world at the time) by 2100, there are fewer cars on the road in Canada, despite a doubling of the population. "Look ma no hands," said the Prime Minister of the time as he drove Canada into the future.

Car sharing was just one collaborative economy disruption. Others included bike shares, parking space shares, and collaborative work spaces. The collaborative economy was not entirely new. In fact today's network of bibliotechs had their origins in what were known as libraries housing large city-owned collections of musty paper books citizens could borrow. Bibliotechs, of course, are still great institutions for learning and sharing, but the practice of facilitating access to electronic goods, machines, tools, boats, housing, sports gear and art owned by local residents and businesses started back then.

The contribution to climate change mitigation of the collaborative economy was enormous, but not widely appreciated at the time because of the classic inventory approach in which emissions from driving, car manufacturing, metal extraction, rubber processing, etc. were all counted in isolation

[13] Metro Vancouver (2014) found each car share vehicle replaced up to four personal vehicles. In Philadelphia, the ratio was 1:11. While previously "zero" car households drive more, the vast majority drive less, with a net result of lower total driving distances (Martin, 2010).
[14] These are results of an experiment ZipCar did across 13 US cities in 2009 (News Medical, 2009).
[15] (Godsmark, 2015) 85% (Earth Institute, 2013) 98% (Pricewaterhouse Coopers, 2013).

across many jurisdictions. The embodied carbon across the full life cycle of a manufactured car, for example, typically rivaled the tailpipe carbon emitted over its operational life (Berners-Lee, 2010). Canada helped countries of the world understand it was imperative to not just manage one's own national emissions. Climate action strategies must consider the full life cycle of emissions across the planet. The collaborative economy and its big cousin the circular economy drove step changes in energy and material throughput in the economy, radically cutting global carbon emissions.

PILLAR V: NATIONAL PROSPERITY THROUGH URBAN REGENERATION

Very early in the 21st Century governments acknowledged major urban regions were the key social and economic organizing units for the country.[16] Knowledge, talent, creativity, learning and innovation were concentrated in these centres. They were the nexus where goods, people and ideas came together to connect with the rest of the country and the world. Major urban regions competed in the global marketplace to facilitate these interconnections to create, attract and retain investment, industries and jobs. The economic growth of major urban hubs resounded across larger regions and the country, determining national economic prosperity.[17]

In global rankings with competing cities, Canada's major urban centres scored high on many indexes. They scored poorly, however, on transportation measures such as congestion, commute times and public transit investment/personal transit costs.[18, 19] A partial account of the personal social and economic, and environmental costs of congestion across Canada's 9 largest urban centres was estimated at $11.7 billion annually (Transport Canada, 2006). If freight hauling and other business-related costs were accounted for nationally at ratios that held true in the Toronto-Hamilton region, the total annual cost would be closer to $20 billion, annually.[20]

While energy conservation investments were plodding along in many industrial jurisdictions, leading jurisdictions at the time began focusing on energy productivity in buildings, transportation and industry and as a central competitive advantage. Energy had become a strategic factor for 40% of global revenue, meaning it was crucial for management to know the type, quantity and cost as a key decision making variable (McKinsey + Company, 2009). As well as climate policy, the slow, steady and highly volatile price march of energy drove energy's strategic importance. At the time, Canada marched to the beat of different drummer. It was the largest per capita energy consumer in the OECD and, thus, one of the largest in the world (Conference Board of Canada, 2013). Given the great

[16] This understanding is well articulated by the Conference Board of Canada in Mission Possible: Sustainability Prosperity for Canada (2007), urban thought leader Richard Florida and Canadian urbanist icon Jane Jacobs.
[17] Analysis of nine major urban metropolitan centres across Canada shows that when their economic performance improves, the performance of the broader region also improves (Conference Board of Canada, 2007).
[18] Toronto Board of Trade's *Scorecard on Prosperity* (2011) benchmarked Toronto, Montreal, Vancouver, Calgary, and Halifax against 18 major urban centres around the world. Canadian cities scored poorly on transportation.
[19] A PricewaterhouseCoopers report, *Cities of Opportunity* (2011) ranked 26 world cities on 66 performance measures related to intellectual capital, technology, infrastructure, sustainability, business climate, cost of living, and liveability. While Toronto scored well overall, its worst grades were on transportation and infrastructure.
[20] This additional $9.3 billion is a crude extrapolation of a Metrolinx study (2008) that calculated business-related congestion costs in Greater Toronto-Hamilton at $2.7 billion annually, and personal social and economic costs at $3.3 billion, a 45/55 split.

volatility of oil and gas prices, and steadily rising cost of electricity, budgeting around public and private boardroom and kitchen tables was complicated.

Canada's ever-extending urban regions with low-density, auto-oriented residential neighbourhoods comprised of large homes made it difficult to make progress in energy productivity and congestion management. In fact, rather than declining, on a per capita basis, energy demand was growing in both building and transportation sectors (NRCan, 2013). Public and private debt was also rising to support this infrastructure, housing, and transportation regime.

Canada's political leadership was determined not to be left spiraling around this stagnant energy eddy while leading countries propelled themselves forward. As well as a suite of strategies to focus growth, Canada launched itself deep into the fastest current with the world's most ambitious electrified transportation agenda.

Inspired by North America's first 100% electrified transit authority commitment in Montreal, Canada became the world's first country to commit to 100% electrified public transit. By mid century, 2 decades after Canada, all countries had fully electrified transit systems. Many had Canadian transit infrastructure service providers – Bombardier, New Flyer, Nova and Prévost – and Canadian battery and quick charging technologies on their streets. Canada's foresighted move effectively curtailed the type of congestion that surged in many US states that opted for electric cars. This effectively decarbonized transportation but increased economic and social costs, and reduced competitiveness.

As we can infer today, Canada did not reject electric vehicles (EVs). Canada's provinces became North America's first jurisdictions to require EV charging infrastructure in new residential and commercial buildings. Cities mapped optimal locations for fast chargers and collaborated with the private sector to deploy them. The Trans Canada was the world's first fully EV viable transnational highway and remains the longest. This strategy was central to Canada's much more transformative autonomous automobile agenda, which was clearly rolling in on an EV platform.

Transportation electrification allowed Canada to overtake its industrial rivals in energy productivity. By 2020 EVs were more than four times as efficient at converting energy to the drive train than internal combustion engines and the spread was growing (Boston A. , 2013b).

STRATEGIC DIRECTIONS: 21ST CENTURY URBAN PLANNING AND DESIGN SOLUTIONS

The greatest challenges of the early 21st century were complex, deeply ingrained, interconnected and mutually reinforcing. So were the solutions! Eight planning and design characteristics characterize urban Canada in 2100. Each pillar was integral to this integrated system. Implemented together, great synergies were achieved, minimizing costs and maximizing benefits.[21]

1. FOCUSED GROWTH + PRODUCTIVE LAND PROTECTION

BIG MOVE: *COMPLETE, COMPACT CENTRES AND CORRIDORS*

Compact city centres, town centres and inter-connecting corridors underpin an efficient, competitive urban Canada. Industrial and agricultural opportunities, and ecological priorities are accommodated in strategically protected lands.

Growth has been focused in city and town centres, and along corridors in urban regions. This urban form is the foundation for many carbon management, quality of life, ecosystem protection, and cost saving measures. Intensification's double dividend includes socially and economically vibrant neighbourhoods, urban hubs and metropolitan regions, high-quality, frequent transit, and district energy systems that generate electricity and provide heating and cooling at a neighbourhood scale.

For more than half a century now growth has been evenly distributed across older urban cores, transit suburbs and what were once automobile suburbs but today are compact, economically and socially vital neo-urban areas. Focused development stabilized property taxes and stemmed a spiraling infrastructure debt crisis that once threatened the country's fiscal security.

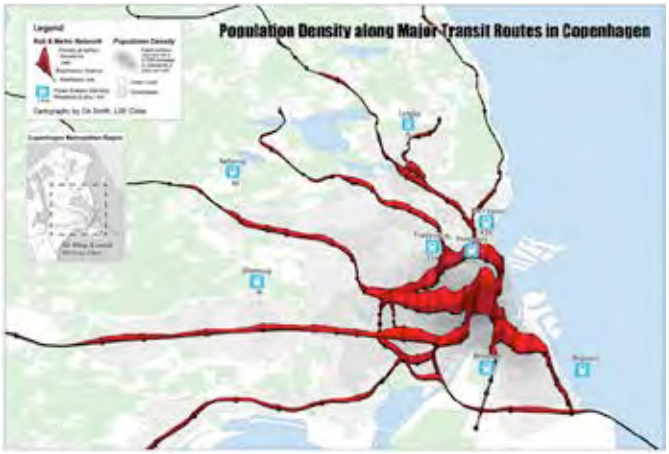


Figure 2: **Focused growth, shown here in Copenhagen**, was a central tenet in Denmark's national-local agenda with diverse economic and social objectives. Image: UCL Centre for Advanced Spatial Analysis

The urban footprint has not spread beyond limits established in the first half of the century. This has avoided the loss of agricultural land, protecting local food production that became increasingly important due to regional climate change impacts around the world, such as water shortages and higher frequency and intensity extreme weather events, disrupting food production. Habitat loss was reversed, reducing stress on important local and regional species and water supply systems that became increasingly important during periods of extended drought.

[21] The 21st century urban planning and design pillars include some important strategies and concepts from Patrick Condon. See bibliography for *Seven Rules for Sustainable Communities* (Condon P. , 2010), and *100 Year Sustainability Vision: City of North Vancouver* (Design Centre for Sustainability, 2009) which outlines a zero carbon city at 2100.

Industrial land, too, was protected inside cities and at the edge to accommodate and integrate with freight transportation. Industrial activity includes an eclectic mix of fabricating, manufacturing, assembling and processing by large and small domestic and international businesses that comprise a much larger share of the Canadian economy.

2. PLACE-BASED PLANNING FOR GOOD JOBS, HOMES AND NEIGHBOURHOODS

BIG MOVES: *FIVE-MINUTE NEIGHBOURHOODS*
VELOCITY HUBS

Most Canadians can comfortably walk from their front door to key destinations. Major employment is concentrated in vibrant multi-modal, mixed-use hubs situated along major transit corridors.

In 2100, the vast majority of Canadians in urban areas earn 90s on their "walk score." Key destinations – corner stores, transit stops, car shares, cafés, and parks – are within a five-minute walk of front door steps, approximately 400 metres. The viability of these widely available public and private services has depended on compact neighbourhoods of about 25 dwelling units per hectare[22] – about 6 dwelling units per hockey rink.

This planning principle has supported a healthy mix of land uses, and helped shift transportation planning away from mobility towards accessibility. Rather than moving lots of solitary drivers cars to dispersed places, the focus shifted to moving lots of places closer to where people live and work, establishing the basis for efficient, cost effective, and healthy transportation systems benefitting private and public pocket books.

Five-minute neighbourhoods have fostered social connectedness and local economic vibrancy. They also played a decisive role in averting a public health crisis afflicting a disproportionate share of the population living in far-flung, automobile-oriented suburbs.[23] Higher rates of inactivity, obesity and diabetes were correlated with lower density, residential neighbourhoods (Glazier, 2014). Walking and cycling have become primary transportation choices for a growing share of trips, dramatically reducing diabetes, cardiovascular disease and obesity.

Major commercial and institutional employers in metropolitan areas are located in higher density, mixed-use nodes, proximate to rapid transit stations and major transit hubs. These hubs support seamless integration of a diverse hierarchy of transportation modes based on public health, economic, transportation and environmental costs and benefits guiding all personal transportation and land use decisions:

[22] Condon, Patrick (2010). Seven Rules for Sustainable Communities: Design Strategies for the Post Carbon World
[23] According to Basset (2008) countries with higher rates of active transportation and transit use have lower obesity rates. Every additional hour spent in a car each day was associated with a 6% increase in the likelihood of obesity (Frank, 2004). Every additional kilometre walked per day was associated with a 4.8% reduction in obesity.

A. Walking
B. Cycling
C. Transit
D. Freight
E. Car Share and Taxi
F. Personal Low Emission Vehicle
G. Personal Cars

Dubbed "Velocity Hubs" for the speed at which they facilitate economic and social activity through mobility or spatial proximity, they feature attractive plazas and arcades surrounded by restaurants, cafés, shops and public services.[24] Above and around, are offices filled with educated Canadians working side-by-side colleagues from around the world, drawn to the social and economic connectedness and efficiency of Canadian cities.[25] Many companies and small business people share offices needing well-equipped business centres, hot desks and creative meeting spaces. Knowledge-based companies of all sizes from diverse sectors occupy most offices. While their scale differs across by urban context, these vibrant nerve centres are connected across urban regions, from urban cores to outer city centres by fast, frequent transit.

3. COMPLETE, CONNECTED STREET NETWORKS

BIG MOVE: *COMPLETE, CONNECTED STREETS*

A fine-grained network of streets, safely accommodating all modes delineates the basic building blocks of urban Canada.

Canada has gone back to the future to adopt block sizes that demarcated most cities up until the middle of the 20th century. Blocks are big enough to accommodate diverse commercial and residential building types, 2 to 3 dozen single detached-type homes to 2-3 mixed-use high rises and everything in between – about 2 hectares in size.

At the same time, blocks are small enough to support a density of streets and intersections to allow high connectivity and relatively direct travel from A to B in any mode, and most importantly, support rather than discourage walking.

The old suburban superblock was opened up with cross streets and greenways, connecting homes and shops. Cul-de-sacs have been connected, allowing children to cut through on bike or foot to race to school and soccer pitch.

Many mega-multi-lane, auto-oriented arterials from turn of the century residential areas now have sidewalks, bike lanes and bus stops along mixed-use frontages. People, for personal or commercial

[25] Velocity: from Latin *velox* (swift, speedy). Velocity Hubs shares elements of Mobility Hubs that feature prominently in Metrolinx's Regional Transportation Plan for Greater Toronto. As well as transportation attributes, the concentrated heat demand, and diversity of commercial/residential uses in Velocity Hubs supports successful district energy.

purpose, safely and comfortably travel regardless of mode – foot, freight truck, bike, bus, car, or cube van. These genuine modal choices define today's "complete" streets.

Figure 3: Complete streets transform low density arterials. Image: City of Winnipeg Master Transportation Plan

At the turn of the century, 15% of trips were less than 650 m – a comfortable walking distance for most Canadians (Littman, 2014). Half of trips were less than 5 km, a 20-minute trip for an average cyclist in average conditions (Pucher, 2005) (Larsen, 2011).[26] While people walked a large share of those short 650 m trips (60%), urban design was a barrier to growing this share. While only 5% of people actively cycled, almost 60% were characterized as "interested but concerned" (Dill, 2012).[27] Personal safety and bike security concerns associated with inadequate bicycle infrastructure stopped them saddling up.

With a better mix of land uses and more focused growth, particularly in neo-urban areas, one-third of trips today are within 650 m and three-quarters are within 5 km, making most destinations within striking distance of pedestrians or peddles. Street furniture, trees, parks, and good urban design are cost effective and customary in this urban form, dramatically increasing the share of walkers and extending the comfortable range beyond 1 km.

A dense network of bike routes designed to "Triple A" standards supports "All Ages and Abilities" interested in cycling. While Team Canada continues to trounce Sweden at the World Junior's, even more importantly an average 26-year-old Canadian, today, would, in theory, have to slow down to carry on a conversation with a 60-year-old Swede walking to work or biking to the bakery.

[26] 50% of trips under 5 km is in several sources, including: (Pucher, 2005). US has better transportation data, including trip lengths. US shares for 650 m (.5 mile) trips extrapolated to Canada from: (Littman, 2014). Walking distance propensity in: (Larsen, 2011)

[27] Researchers at Portland State University developed a methodology to categorize people's cycling propensity, regardless of current cycling behaviour. Their study, using a regional sample across Portland comprising urban core and suburbs, divided people into four categories: Strong and Fearless: 4% | Enthused and Confident: 9% | Interested but Concerned: 56%; and No Way, No How: 31%. (Dill, 2012)

On Main Street, car drivers wave to cyclists. Cyclists wave to pedestrians. Pedestrians wave to bus riders. Transportation consumers respect one another, and appreciate their respective roles in reducing congestion. The vast majority of transportation consumers, in fact, take on virtually all these roles on an ongoing basis with varying mixes over the course of their lives. The happiest commuters, nevertheless, are still those wheeling and walking without motors (Smith, 2012).[28]

Automobile accident and pedestrian casualty rates are no longer a leading cause of injury and death for Canadians (Transport Canada, 2013).[29]

4. ATTRACTIVE TRANSPORTATION CHOICES

BIG MOVES: *STREETCAR CITIES*
AUTONOMOUS ELECTRIC VEHICLE CAR COLLABORATIONS
TRANS CANADA ELECTRIC SUPER HIGHWAY

Today, Canadians have a genuine transportation choice, and freight moves efficiently to, from and around urban hubs. Transportation systems cost effectively connect people, products, and ideas.

Transportation consumers continue to make decisions on the same criteria they did 100 years ago, e.g. speed, convenience, cost, health, access to modes, access to destinations, status… Land use planning has, nevertheless, changed the calculus, concentrating so many destinations in close proximity. The other dimension of this accessibility transformation is bona fide modal choice. Rather than one dominant mode providing access to many widely distributed destinations, multiple attractive modes provide access to many clustered destinations.

Street design has laid a cornerstone for expanding attractive transportation options, i.e. walking and cycling. Market transformations have further diversified transportation choices, by leveling the financial playing field of all transportation modes.

The streetcar that shaped Canada's early urbanization shortly after Confederation to the end of World War II has made a comeback. Desire for the streetcar was driven by a rising appreciation of its formative role weaving the physical, social and economic fabric of early Canadian cities (Condon, 2010).as well as advanced European, Asian, and North American cities at the turn of the 21st Century.

Running with traffic or in a separate right of way, the streetcar has more stops than other rapid transit form, as well as prioritized signaling and rapid boarding platforms. Speed, access, and ride quality makes it attractive to users. Cost per km makes it attractive to governments, taxpayers and transit users. Compatibility with diverse housing, retail and employment zones makes it attractive to residents, businesses, employees and urbanists. As a fully commercialized electric system, light rail – the 21st century's streetcar – was also light on carbon.

[28] Cyclists were about three times happier than solo car-drivers commuting to work, and walkers were almost as happy as cyclists (Smith, 2012).
[29] Traffic accidents are the leading cause of injury and fatality for Canadians 25 and under. Rates drop with higher age cohorts affected by a range of age and lifestyle health issues, but are still high and overwhelmingly preventable (Transport Canada, 2013).

Other public transit forms play critical roles, each of which reflects its unique context. Bus rapid transit systems with lower-cost entry-points paved the way for many light rail services. Elevated rapid transit and subways with superior speeds, fewer stops but higher costs move large volumes of people through well established, high density areas with constrained road space, as well as out to neo-urban areas.

Buses remain transit fleet workhorses. Numbers have dramatically risen and so has the representation of niche bus types. Large articulated buses are common in higher density areas, and make express connections to medium-sized hubs operating along lower density corridors. Mini buses often feed into rapid transit nodes from medium density neighbourhoods, sometimes operating as share taxis driven by demand on semi-fixed routes and schedules.

Intercity electrified rail, operating at speeds of 300 km/h, connects large metropolitan areas within several hundred kilometers, specifically: Calgary-Edmonton, Windsor-Ottawa-Quebec-North Eastern US, and Vancouver-West Coast US. This rail service displaces much short haul air travel whose carbon costs have made them more expensive.

Running alongside passenger rail is freight bound for domestic and international markets. Rail transports a diverse mix of cargo across medium and long distances and this mode, too, seamlessly integrates with electric truck and ship. With a reduced emphasis on personal automobile transportation and strategically situated industrial land, goods move efficiently from farm to factory and on to food store or marine freighter.

Most urban, motor transport is powered by grid electricity with some on-board solar PV, eliminating air and carbon pollution, and dramatically cutting energy demand.[30] Long distance rail and marine transport is typically diesel-electric, using biofuel, also with on-board solar PV.

While the private automobile still exists, its dominance was displaced by an array of attractive options that emerged as the price of transportation and land use began to reflect the full costs of the activity.

The growth model was fatally wounded in a slow motion collision of two incompatible post World War II planning principles. 1. separate activities in people's lives and; 2. connect people to these geographically dispersed activities by personal automobile. (The crescendo of cries from varied voices and the pricing failures is discussed above in *Pillar I: Fiscally Sustainable Land Use and Infrastructure*).

While many drove, a large share of Canadians happily walked, biked, and bused away from this collision. It was the logical and preferred choice for many trips. The private car, however, was then rear-ended and eventually sideswiped by a convergence of digital communication, automation, and the changing attitudes of the large echo generation.

[30] In 2012, the average electric vehicle was four times more efficient at converting energy to the drive train than an internal combustion engine (Boston, 2013).

First digital networking made it easy to collaborate on the use, cost and maintenance of goods that were expensive to own and operate and sit idle for long periods. The top candidate was the private car that sat idle 95% of the time and costs $10,000 annually to keep on the road (CAA, Globe Drive, 2010). Tech savvy, change tolerant, economically constrained millennials – the largest generation since baby boomers – were the early adopters participating in hundreds of privately and cooperatively owned Car Collaborations.

Automation innovations conceived road worthy autonomous automobiles on fully electronic and electric platforms with safety and swiftness that surpassed the analogue automobile. Canada beat other countries to the AV driver's seat, opening its borders to the likes of Google, Apple, Tesla and Uber. Autonomous automobiles sped into Canada for testing and roll out. Fledgling industries flourished developing superior sensory capacities for recognizing everything from weather changes to temporary, unmapped stop signs; advanced communication amongst traffic signals, cars, consumers and construction sites; smart grid interconnectivity; battery design; computer consoles; robotics…. The Autonomous EV accelerated the convergence car shares, taxis, and car rental business models (Godsmark, 2015).

Soon publically accessible, pay-per-use AEVs rolled into every complete, compact neighbourhood for the convenient use of residents and businesses. Today, Autonomous Electric Vehicle Car Collaborations (AEV CCs) give personal mobility consumers what they want, when they want, where they want, and how they want it. Despite a more than doubling of the population, there are fewer cars on the road today than at the turn of the last century. [31]

Parked between a couple of stormwater bulges next to the sidewalk, this small bank of smart cars, odd sedan, sports car or full-size pickup now waits to be dispatched to doorsteps and lobbies at the behest of a slight of hand across the closest smart screen. Business execs to busy moms are now safely and swiftly transported to out-of-the-way work sites, and far away soccer pitches.

The collaborative economy also transformed bike ownership and mobility. Pay-per-use systems proliferated, allowing transportation consumers to exit busses or businesses and access bike banks in medium- and high-density, mixed-used nodes. Bikes are driven from one convenient location to another typically up to 5-10 km through dense, high quality bike route networks. Electric bikes humming along at 30 kmh extend this range to 10-20 km, bringing them within reach of the vast majority of destinations.

Underpinning this shift was Canada's foresighted Trans Canada Electric Super Highway – an electrification agenda for rapid transit, intercity rail, cars, and notably buses. Inspired by North America's first 100% electrified transit authority commitment in Montreal, Canada became the world's first country to commit to 100% electrified public transit. In the face of a "Grow America"

[31] Columbia University's Earth Institute estimate vehicle reduction factors of 10 (2013). Carlos Ratti, director of the SENSEable CityLab at MIT, estimates autonomous cars could take 80% of cars off roads. At the current growth rate of 0.9%, Canada's population doubles in about 80 years. With car ownership at .6 per capita today (one of the highest in the world), by 2100, there would still be fewer cars on the road today. These projections, however, precludes other significant land use planning and design improvements.

program where US cities were subsidized to purchase transit systems from US manufacturers, Canada struck a deal to accept US protectionism, as long as Canada could invest heavily in the fledgling electric bus (EB) sector, accelerating market transformation and driving down costs of products with surging demand. By mid century, 2 decades after Canada, all countries had fully electrified transit systems. Many had Canadian transit infrastructure service providers – Bombardier, New Flyer, Nova and Prévost – and Canadian battery and quick charging technologies on their streets. Canada's foresighted move effectively curtailed the type of congestion that surged in many US states that opted for electric cars that effectively decarbonized transportation but resulted in rising economic and social costs, and slumping competitiveness.

5. HOUSING DIVERSITY + GREEN BUILDINGS

BIG MOVE: *NEO-URBAN DEVELOPMENT - THE SUSTAINABLE SUBURB*

Diverse housing choices meet the needs of diverse families at diverse price points. All buildings are healthy, comfortable, low carbon and smart, connecting seamlessly to all other energy demand and supply systems.

A massive share of single-detached homes at one end of the continuum and a rapidly, growing share towers at the other once dominated the market in the early 21st Century – the two most expensive and GHG intensive building forms on a life cycle basis. Today's middle is well represented with wood frame four to six-story walk-ups, townhouses and row houses.

There is also a significant share of really small residential units in the form of detached micro homes, suites, multiplexes and units in high- and low-rises. Laneway homes were one element in a broader suite of strategies that "Re-imagined, Re-designed, and Re-invigorated" extensive single-detached neighbourhoods. Along with complete, compact, connected neighbourhoods, and diverse transportation options, the "Three R's" gently intensified single-detached neighbourhoods.

Figure 4: Missing Middle of the Housing Continuum in a variety of expressions shown above in colour, transitioning from single detached in black and white. Image: Opticos Design, missingmiddlehousing.com

Laneway housing emerged to enable aging parents to live close to their children and grandchildren, empty nesters to downsize, and young adults to rent or buy into the real estate market. Large single-

detached homes with successively smaller families, and rising household costs accelerated the duplexing and multiplexing of single-detached homes. Smaller units met demand for the fastest growing household unit in the first half of 21st century: the one-person household (Statistics Canada, 2012)

Figure 5: Gentle Intensification: housing diversity and street connectivity has been added to conventional single detached neighbourhoods as part of neo-urbanization. Image: Ron Walkey in Condon P, 2012.

Diversification and intensification of ground-oriented housing in single detached neighbourhoods was also a response to market forces as governments phased out subsidies to driving, parking, and low-density commercial and residential activity. This drove up costs of single passenger automobile-oriented areas. The allure of convenient, quick, healthy, transportation options – high quality transit, car sharing, walking and biking to nearby destinations – required a more compact form.

Senior governments, foresightedly, cultivated Canada as the single greatest hewer of high performance, pre-fabricated, wood frame housing in the world, meeting surging global demand for pre-fab homes in luxury and affordable markets. Production costs fell, and under prudent policy, further increased affordability. Energy efficiency surged, laying the groundwork for Canada as the pre-eminent home of net zero buildings. It is hard to believe that today's high tech factories dotted across rural Canada, abuzz with engineers, architects, computer programmers, tradespeople and robots were quiet, shuttered saw mill sites in the early part of the century.

Ground-oriented neighbourhoods transition to four-to-six-story wood-frame low rises – the lowest cost and lowest GHG intensity form– culminating in vibrant nodes and extensive, dynamic districts of medium to high rise residential, commercial and mixed use towers. The tower is central to the configuration of Velocity Hubs, sustaining business networks, retail vibrancy and high-speed transit.

Turn of the century glass towers were not unusually criticized as incessant environmental and social blemishes on the urban expression. The foundation of contemporary towers, however, is an understanding of local natural characteristics, starting with the local climate that defines heating, cooling and ventilation requirements, and also shapes local lifestyles. Unique social and economic factors – from history to current industrial activity – is then built in, resulting in diverse and distinctive forms.

Ceilings, floors, and walls in all buildings have exceptional insulation properties and air barriers, and improved air quality with heat recovery ventilators. Living and working spaces are organized to optimize natural light, heat, and airflow. Windows are filled with low conductivity gases and coatings appropriate for their climate and use. Windows are right-sized and located for their interior activities. Some combination of shades, awnings, overhangs, operability or other design helps regulate solar gain, heat loss and often ventilation.

Flexibility is incorporated into building design, permitting easy conversion of bedrooms to offices to support telecommuting, and a couple of rooms partitioned into home-based businesses that might employ several people and accommodate light commercial traffic. Flexibility enabled young families to convert part of their home – detached/semi-detached/or apartment – to a suite as children launched, and grandparents or renters moved in. In the commercial/institutional sector, the design of yesterday's retirement home facilitated repurposing to hotel or apartment. Many public and private spaces are designed to be easily repurposed daily or decadely to accommodate uses.

Similarly, the single use, energy/material/cost/land-intensive approach to public building design is gone. It is amusing to think that buildings were once emptied in late afternoon and evening, weekends and long holiday periods, and then other buildings filled up. Multi-use, multi-generational spaces and places now accommodate a range of long- and short-term uses that can include schools, daycares, seniors centres, BiblioTechs, medical services, pools, business meetings, pop-up outlets, farmers markets, food fairs. These learning and living hubs are financed, owned and managed by a range of public, private, social and diverse partnership models.

Outside all low and mid-rise buildings, deciduous trees on southern and western aspects obstruct the sun's heat and light in summer and filter it through in winter. Once exceptional, it is now commonplace for buildings to physically integrate nature through green roofs and walls, and sky gardens and terraces. Passive design has helped managed the size and utilization rate of mechanical and electrical systems, and overall costs.

Prices and programs, and a shift in ownership models of building components, compel owners and occupants to support continuous improvement to maintain, manage and upgrade building energy performance, as well as retrofit and re-purpose buildings to meet changing economic and social conditions.

6. ABC INTEGRATED ENERGY SYSTEMS

***BIG MOVES**: MOBILE POWER STORAGE AND GENERATION PLANTS*
SMART ABC (AUTOMOBILE-BUILDING-COMMUNITY) ENERGY SYSTEMS
COOL COMFORT RENEWABLE HEAT STRATEGY

Renewable supply and storage systems are deeply integrated into the ABCs of urban architecture – automobile, building and community – providing reliable and resilient heat and power.

With dramatically reduced demand and ample energy supply opportunities, ground-oriented buildings have been net zero for half a century, generating as much energy as they consume. Hot water, space heating and cooling loads are met with renewable heating and cooling systems, such as geo exchange, air-to-air heat exchangers and biomass stoves. Rooftop, building or site-scale solar and wind meet electricity demand. Smart meters send power to the grid during times of surplus and receive it during times of deficit. Smart buildings automatically sense time of day, occupant identity and presence, and activity-driven needs to adjust cooling, heating, lighting and ventilation to changing weather conditions.

Figure 6: Smart buildings and smart automobiles connect to smart grids with advanced information technology intuitively designed for system operators and users. Image: **Vattenfall**

Over and above buildings and backyards, renewable power is deeply integrated into urban architecture: turbine-topped bridge trusses, spray-on-solar stadium roofs, sewage-heated swimming pools, and biowaste brewery boilers.

Large buildings are net zero, too. They have met this standard for more than 50 years, starting at the community-scale, then neighbourhood, and now block scale. Residential, office, institutional, retail, etc – these large buildings still take advantage of the unique heating and cooling loads of different building uses across the day and year to cost effectively meet demand. Reduced loads in new buildings have permitted renewable district heating and cooling systems to shrink in size to a small cluster of buildings. These small systems typically exploit local energy supply through heat pumps from sewage to solar to air to ground source.

Many older, large DE networks fragmented with ever-improving efficiency in building and energy supply systems, reducing the need and expense of extensive piping networks. Large fragments of these heritage systems still exist covering neighbourhoods of predominantly older buildings. Large service areas are also co-located next to large waste heat sources such as cement plants, food and beverage processors, brewery districts, and hockey rinks – all of which are commonly found in mixed-use areas. Industrial sector plants are normally biomass combined-heat-and-power systems.

They once used direct combustion, accommodating a combination of waste from municipal, construction, forestry, and agricultural sources, as well as forestry and agricultural crops and from

marginal lands. Today, some of these feedstocks barely exist, such as municipal solid waste, which has been reduced to virtually zero. They have also transitioned to more efficient and effective biomass sources.

Most biomass today comes through the renewable natural gas network, fed by local, regional and distant plants. Gas is generated through anaerobic digestion of wet organic material such as animal waste or grass crops, or thermal gasification of dry organic materials such as waste wood, and tree or grass crops. Renewable natural gas is also the dominant cooking fuel and used for some peak heating demand in ground-oriented homes.

By 2030 all buildings – large and small - met their building heating and cooling demands with renewable heating and cooling systems. The *Cool Comfort Renewable Heat Plan* was driven by comprehensive carbon and cost management imperatives, and acknowledged that 70% of building energy end use in the early 21st century was for heating and cooling.

As well as drawing power from the grid for mobility, AEVs are important elements in the entire electric power system. They store up to 100 kWh of power, generated in part from solar-clad roofs and hoods, but primarily solar, wind and biomass from the grid. These mobile power generation and storage plants communicate with the grid when parked, drawing power as needed, but more significantly fill valleys and shave peaks across the system. They can serve as backup power for a cluster of homes or offices for several days in the event of outages from extreme weather events further afield. For the small percentage of people wanting their own, 24-7 personal automobile transport out of desire or duty, the high cost of exclusivity is partially offset by the service they provide to electricity system resilience.

Advanced information technology will be the little brain enabling information sharing amongst smart buildings, smart vehicles, and smart grids to optimize energy production and utilitization and minimize consumer and environmental costs. System operators and users share the big brain functions with intuitive tools to communicate service requirements.

The heart of the system is ecologically and socially inspired to minimize energy demand by designing with rather than against nature, and designing to enhance rather compromise the human experience, autonomously, in the community, and with nature.

7. SMART, GREEN SPACE + SMART, GREEN INFRASTRUCTURE

BIG MOVES: *RIPARIAN FOREST MULTI USE TRAIL NETWORK*
URBAN FOREST RESTORATION + PROTECTION PROGRAM

While yesterday's urban regions worked against nature, today, they work with nature. Green space and infrastructure that functions like ecosystems protects and restores natural and productive areas, or minimally mitigates the magnitude and multiplicity of impacts.

Canadians today have a strong appreciation of the impact of human activities on ecosystem health and, in turn, its importance to water quality and accessibility, agricultural productivity, marine and fresh water productivity, human health and wellness, commercial and industrial opportunity. From apple tree, bumble bee, farmyard chicken, dairy cow, salmon egg all the way to zooplankton, diverse species thrive in and around urban regions and, in turn, enable urban regions thrive.

Today, a building site is to the region, as a cell is to the human body.[32] Just as the health of the individual human cell determines the health of the human body, and in turn its family, so does the ecological function of the individual site shapes the ecological health of the region, and in turn its ecological context. Site-scale elements, when multiplied thousands and even millions of times throughout vast urban regions, define regional environmental systems. The most obvious and important, of which, is the watershed.

Figure 7: Despite higher population densities, people have greater access to green space, and green infrastructure is woven into the urban fabric. Image: (Design Centre for Sustainability, 2009)

Today's sites function like healthy cells sustaining the body of the region. The streams and rivers are veins. Rooftops, driveways, lanes and streets are capillaries. Capillaries take water to veins through a hierarchy of ever-larger channels until this water reaches big lakes and rivers and eventually ocean.

In much of the world for most of the last millennia, cities buried this network of stream and rivers. It was still there, but in pipes and under parking lots. Of more than fifty salmon bearing streams pulsating through the City of Vancouver when BC joined the federation, only three were marginally inhabitable at the dawn of the 21st Century. At about this time, Canadian governments discovered less was more. By working with nature, rather than against it, less pipe, pavement, gutter and taxpayer "gold" resulted in more drinkable and swimmable waters for humans and fishes.

Rather than maintaining and extending this expensive infrastructure, daylight incrementally shone across more and more of this natural aquatic network, and Canada's urban fabric was increasingly woven through ecosystems. With the exception of vegetable gardens that benefit from rain collection irrigation systems integrated into buildings and gardens, smart plant selection reduces watering demand. Flood management systems improved. Broader ecosystem health benefitted. Childhood mental health improved with life-long benefits.[33]

Green roof to pervious yard and sidewalk to curbless street with infiltration boulevards, urban elements function like trees, understory plants, and forest soils, recharging aquifers. A soccer pitch is a flood plain. The park contains a wetland. The bioswale, collecting water from increasingly frequent and intense peak rain events, functions like an intermittent stream. Tree-dotted yards, streets and

[32] Patrick Condon's urban ecosystem / human body analogy was originally laid out in *Seven Rules for Sustainable Communities* (2010).

[33] Richard Louv, in his 2005 book, *Last Child in the Woods,* shows how the loss of natural surroundings in children's lives can lead to nature deficit disorder, increasing anxiety, depression and attention-deficit problems.

plazas sequester carbon and mitigate the urban heat island effect cities would otherwise confront with ever-greater frequency.

Forest-buffered brooks and creeks, feeding into larger natural stream systems branch out across a watershed. As well as healthy aquatic systems and habitat corridors, their form supports an extensive network of multi-use paths for pedestrians and cyclists penetrating into work, retail, and school destinations. Larger tracts of farmland, forest, and field conversely filter into cities, particularly the outer neo-urban areas, occupying the space between compact, corridors radiating from higher intensity residential and commercial areas.

8. THE END OF WASTE + BEGINNING OF HYPER MATERIAL EFFICENCY: 4 RS + 2CS

BIG MOVE: *REGENERATION CENTRES*

In the 20th century, Canada's economy was dominantly linear: extracting processing, consuming and wasting. Over the 21st century, Canada's economy has become dominantly circular. Biological feedstocks are designed to re-circulate and eventually re-enter the environment safely and restoratively. Technical or synthetic feedstocks nutrients are designed to re-circulate without entering the environment.

Canadians continue to be guided by a coherent 4 Rs materials management hierarchy:

1. *Reduce*
2. *Reuse*
3. *Recycle*
4. *Recover* energy from waste

The fifth "R" – *residuals management* – was relegated to the dustbin of history. Waste no longer exists, replaced by feedstock for the next generation of product or biological creation.

Energy recovery, too, once salvaged immense value from poorly designed products and short-sighted, high-cost management solutions, i.e. landfilling. Today, consumers and governments do not tolerate poor product design, and organic matter is valued for its contribution to food production and ecosystem health. Some household organic matter is, nevertheless, anaerobically digested to generate green natural gas. Tree trimmings and some construction wood endputs that have likely become successively lower value over product generations may also be combusted to generate heat and power.

There is, however, virtually no construction "waste." Firstly, few buildings are ever demolished. They are crafted with durable materials, and meet the highest fire, health, safety and energy standards. Flexible design allows residential dwellings to grow or shrink, commercial to become residential, and virtually every other transformation. Components are switched out and in to meet design or capital replacement priorities – interior walls, exterior walls, and additional stories.

The few buildings that become redundant are deconstructed. Windows become fiberglass and glassphalt. Concrete is rubbilized into roads, rip rap and retaining walls. Wood is generally re-used.

This approach to building design hints at more comprehensive changes to the economy. Rather than clunky, cumbersome goods, consumers today buy high-efficiency, high-quality, backed-up services. Hard goods from washing machines to dishwashers, windows and furnaces are no longer for sale. Instead, Canadians buy high quality services: clothing and tableware cleaning; light and sight permitting envelope openings; and home heating. This is the circular economy.

Adaptability, versatility and modularity are hallmarks applied to everything from phones to photovoltaics, computers to cars. Packaging is often repurposed; the laptop wrapper becomes the laptop messenger bag, itself made from recycled fibers. Most wrapping and packing, however, is made from compostable cellulose.

Once burgeoning local landfills have been naturalized. Their function displaced by regeneration centres taking back products, disassembling, refurbishing, or repurposing on site, or shipping to more specialized centres far beyond the city.

Although the most significant discard of the 21st century was the "buy-cheap, throw-away" global economy, commercial and social benefits were broad-based. The disappearance of complex, short-lived products advanced the efficiency of the economy, created thousands of new big and small businesses in Canada alone, eliminated superfluous environmental management costs, decimated carbon emissions, and reduced the cost of accessing many services.[34]

Many of the resource inefficiencies the circular economy couldn't eliminate were driven out by the collaborative economy, presaged by the ubiquity of collaborative cars and bikes, discussed above.

The collaborative economy is powered by idle time and enabled through digital networking. In the early 21st century the average annual cost of owning and operating a car was $10,000 (CAA, Globe Drive, 2010). The average car sat idle more than 23 hours a day.[35] Savvy financial analysts saw the car as a "voracious wealth destroyer."[36] When good options emerged, consumers swapped their personal cars for personal health and prosperity, and the atmosphere benefitted.[37]

Privately, socially, and publicly, entrepreneurs emerged to more efficiently organize and utilize costly resources across many sectors. Cars and bikes were just part of the transportation transformation.

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[34] The Ellen MacArthur Foundation (2012, 2013) delineates the business case in *Circular Economy: an economic and business rationale for an accelerated transition.* The cost of remanufacturing mobile phones, for example, can be reduced 50% per device if the industry made phones that were easier to take apart, improved the reverse cycle and offered incentives to return phones. High-end washing machines could be accessible for most households if they were leased. Customers could save roughly a third per wash cycle, and the manufacturer would earn roughly a third more in profits. Over a 20-year period, replacing the purchase of five 2,000-cycle machines with leases to one 10,000-cycle machine would also yield almost 180 kg of steel savings and more than 2.5 tonnes of CO2 savings.

[35] US National Household Travel Survey, 2009. http://nhts.ornl.gov/2009/pub/stt.pdf

[36] Rob Carrick, Oct 21, 2013. *A money pit on wheels: The real cost of owning a car* in http://www.theglobeandmail.com/globe-investor/personal-finance/household-finances/the-real-cost-of-owning-a-car/article14974498/

[37] ZipCar took the keys from 250 self-confessed car addicts in 13 US cities (News Medical, 2009). They had to bike, walk, train, bus or if they really needed to, use a ZipCar. After one month, personal bike distances rose 132%, walking distances rose 93%, collectively they lost 413 lbs, transportation spending declined 67%, and 100 of the 250 "addicts" elected *not* to take their keys back.

Passenger seats and parking spaces followed shortly after. All sorts of spaces, in fact, were enabled: working spaces, living spaces, recreational spaces, restaurant spaces and food growing spaces. Similarly were hard goods: machines, tools, electronic goods, sports gear, and art.

With public leadership and stewardship, collaborative and circular economies massively cut energy and material throughput in the economy, drastically cutting global carbon emissions.

THE INTEGRATION IMPERATIVE

Each of these 8 urban planning and design strategies played an important role in an integrated system. Analysis showed that failing to implement one was at the expense of others.[38] Analysis also showed many traditional approaches to address carbon management or siloed sustainable priorities had limitations.

Widespread electric vehicles – using renewable grid power – operating in the same, low-density urban form was physically inconceivable due to road space limitations. Over and above gridlock, fiscally unsustainable infrastructure and ongoing agricultural and habitat land loss, it was also a high-energy demand approach, increasing marginal costs, relative to a transportation choice approach.

Figure 8 - "It's Okay. They're all Electric!": Some US states tragically discovered a focused electric vehicle strategy, relative to a transportation choice strategy, had limitations. Over and above gridlock, fiscally unsustainable infrastructure and ongoing agricultural and habitat land loss, it was a high-energy demand approach that increased marginal public and private costs relative to a transportation choice approach.

A focused high-rise solution wouldn't have allowed the gentle intensification and dramatic decarbonization of suburban areas that would've otherwise dominated and drove building energy demand until beyond mid-century. The easiest way to cut household building emissions in half in

[38] Doubling density reduces distances driven in order of 5%, but research suggests doubling density in combination with other policies, including land-use diversity, neighborhood design, access to transit, and accessibility, could reduce distances driven in the order of 25 to 30 percent.

those areas was by adding a suite to a single detached home, a huge opportunity for many houses given demographic shifts.

While high-rise buildings were integral to the feasibility and success of rapid transit systems and multi modal enterprise hubs, they couldn't have been a universal solution. A high-rise oriented approach wouldn't have allowed the gentle intensification and dramatic decarbonization of suburban areas that would otherwise dominate building energy demand until beyond mid-century.

While attractive to many, glass high rises at the time were also generally expensive, relative to some other options. Additionally, they typically required extensive mechanical and electrical energy to support elevators, heating, cooling and lighting hallways and common areas, and compensate for energy loss and gain through their curtain windows. Concrete construction added to their GHG intensity. Wood-frame, three to six story wood frame buildings, in contrast, were the most cost-effective low carbon homes. Good design had the potential to even further reduce energy demand in these buildings: eliminating and minimizing elevator use with smart stairway construction; single loaded corridors vs double corridors, permitting excellent cross ventilation and eliminating air conditioning demand, which was growing rapidly at the time.

High density development without grocery stores, green spaces and a fine grained pedestrian networks and nearby jobs would not have achieved the same modal shifts to transit and walking that were necessary for deep carbon reductions, as well as public health and neighbourhood social and economic vitality (Abt Associates Inc, 2010).

Omitting urban green space renewal and green infrastructure would've increased infrastructure costs, and compromised ecosystem services, seriously compromising water quality and accessibility, species viability, and carbon sequestration. Many green spaces also became critical links in active transportation networks.

Omitting the circular economy would've comprehensively undermined the decarbonization of goods, from AEVs, to buildings, clothing, and landfill methane management.

GOVERNANCE: GOOD GOVERNMENTS TO GREAT GOVERNANCE

The magnitude of Canada's financial, social, environmental deficits at the beginning of the 211st Century may suggest a federation governed by bad governments – local to federal. On most accounts, however, Canada's governments scored solidly good grades.

Good, however, was not good enough. As was illustrated in a best selling management book at the time "From Good to Great," there are a lot of good companies, but only the best are multi-generational survivors.

Governments – local to federal – in the early 21st Century were conceived in much earlier eras with less global trade, less communication, less technology, lower national and global populations, greater resources… The challenges at the time were more complex, interconnected and wicked. To be multi-generational survivors and thrivers, new approaches were necessary to strengthen Canadian competitiveness, improve public health, increase housing affordability, protect productive land, and, most importantly advance deep emission reductions.

A set of principles emerged from the Agenda's foundational goals to shape the urban planning and design pillars.

1. NATIONAL PROSPERITY AGENDA ON LOCAL REGENERATION

Stronger, more responsive formal structures were reinforced with flexible informal governance structures, all of which function and focus scarce resources at the appropriate scale of activity.

The central initiative driving this transformation was the *National Prosperity Agenda on Urban Regeneration,* involving national, sub-national and local government collaboration on a shared prosperity agenda comprised of five major policy pillars built atop a decarbonization foundation.[39]

Other complementary multi-level governance regimes were necessary to enable all levels of government to collaborate on agendas that once conflicted, but were now coordinated. Active collaboration with the major urban regions, and focused engagement with other cities was critical to its success.

Stronger regional planning authority (i.e. a level above municipalities and below provinces/territories) was necessary to steward the integrated land use, transportation, energy and waste and material planning agendas central to Canada's economic, social and environmental future.

A wide diversity of organizational actors outside government were essential to engage in planning and implementation: energy utilities, real estate developers, home builders, first nations, universities, foundations, health agencies…

[39] Similar initiatives exist in many jurisdictions (e.g. Denmark, Netherlands, Sweden, Japan, Korea, UK, China). The Global Commission on the Economy and Climate, headed by former Mexican President Felipe Calderon and World Bank Chief Economist Sir Nicholas Stern, at the time were also calling for such an initiative.

2. ACTION ORIENTED

Putting a U-turn on carbon emissions by 2020, and achieving 80% reductions by 2050 required immediate action from local to national levels.[40] As was typical of the time and culture, big agendas were frequently sidelined or delayed by Royal Commissions, the Local Agenda for National Prosperity, in contrast was an organic action plan. A federal Minister of Urban Regeneration and National Prosperity was appointed to drive the agenda. Each province and territory had a similar counterpart. Targets and timetables, benchmarks and milestones were established to focus intellectual, social and financial capital. Policies and programs were aligned around the agenda.

3. POLICY + PLANNING INTEGRATION + ALLIGNMENT

Policy priorities at every level of government and within each level once were overwhelmingly advanced in isolation of one another: public health, housing, economic development, energy conservation, energy supply, mobility, water safety and supply, species protection. While it was then and continues to be impossible to achieve absolute alignment, in the early 21st century the conflicts and counterproductive efforts were incredibly costly.

Lower costs, greater synergies, and higher benefits were achieved with integrated planning that brought together the right disciplines, departments, levels of government, private and social stakeholders to solve specific complex, interrelated policy priorities.

Canadian decision makers began to realize that a deep carbon reduction agenda that does not effectively address a range of core community priorities was not going to be viable.

4. URBAN INNOVATION INCUBATION

In the 20th and early 21st centuries, cities were centres of innovation, and partnership amongst local government, private and social sectors, driving development of new industries with local, regional and national benefit. They innovated around regulatory barriers to strengthen land use planning and advance demand and supply solutions in buildings and transportation. Despite their contribution, their role in market transformation was typically uncoordinated with and often opposed by senior governments.

Under the *National-Urban Prosperity Agenda*, the central role of local government in market transformation was acknowledged and fostered. Virtual space – the urban innovation incubator – was created for local leaders to work with public, private and social sectors to accelerate market transformation on many critical agendas for communities and the country. This involved coordinating market transformation processes amongst levels of government, and creating the regulatory and financial space for it to happen. Unique spaces were created for the gateway urban regions, major urban centres as well as smaller communities.

[40] This is a dominant interpretation of the targets and timetables necessary for OECD countries to contribute to atmospheric stabilization based on IPCC stabilization scenarios in Assessment Report 4 (IPCC, 2007, Box 13.7)

All levels of governments collaborated on a Disruptive Technology Red Tape Reduction Action Plan. They acknowledged many policies, processes and plans constrained, typically inadvertently, old and new disruptive technologies and practices. This Action Plan updated policies to guide and enable demonstrated successes enter the marketplace.

Building policies were updated to require EV charging infrastructure. Building floor space calculations made allowances for thick walls and renewable heating equipment so as not to discourage better thermal performance. Parking policies were reviewed to ensure they did not constrain market penetration of AEV CCs. The collaborative economy and the circular economy were on top of the Disruptive Technology Red Tape Reduction Action Plan.

5. ECOLOGICAL DESIGN

Elegant, beautiful, dynamic, adaptive, regenerative, enduring - the planet's ultimate designer is nature. While there are always costs, aspiring to nature's greatest design achievements while maintaining and restoring natural and physical systems became a principle shaping design in the economy and across cities at every scale and within and across scales: building, street, neighbourhood, community, region, country, planet.

6. REAL COSTS, REAL PRICES, REAL CHOICES

In the early 21st century, subsidies and externalized costs reduced choice. A wide variety of financial tools were introduced and existing ones transformed to level the playing field and provide Canadians with the transportation, and residential and commercial building choices they deserved with real prices that reflected real costs. One form of development no longer subsidized another. One transportation mode was no longer subsidized over others. Social and environmental costs, notably carbon emissions, were reflected in the price of goods and services. Developers, homeowners and businesses responded to price signals, re-defining urban form and design, mobility systems, and resource intensity.

To reflect the true costs of service delivery, property taxes, development charges and service fees were updated and innovative financial tools were mainstreamed such as road pricing and feed in tariffs.

Tools such as revolving funds were introduced to hurdle the first cost barrier of green buildings that were more expensive to construct but less expensive to operate and maintain and had lower environmental costs. Private sector green loans were introduce to hurdle the split incentives that existed between developers, for example, who typically build and sell and aren't incented to incorporate high performance products, and building owners who would benefit from lower high efficiency products.

7. CONTINUOUS CAPACITY BUILDING

Building skills, knowledge and capacities of individuals and institutions has been central to the *National-Urban Prosperity Agenda*.

One of the major reasons for missing a litany of GHG reduction targets established at federal, provincial and local levels in the late 20th and early 21st century was that the public, private and social sectors did not have the skills, knowledge and capacities to make deep emission reductions.

New energy codes in buildings, for example, were being established, however, the vast majority of new buildings were not meeting these codes. Senior governments set codes but limited insight into how industry and the local government "regulator" operated. Organizations and individuals had to learn and apply new approaches to enable continuous adaptation to higher and higher standards.

Knowledge, moreover, was central to the economic success and social well being.

Working across sectors, governments – at all levels – established a policy context that fostered the interest and the institutions to build this capacity through businesses, primary and secondary and post-secondary schools, government agencies, and social organizations. Large urban regions and small cities all played unique roll

Cities, already the centres of learning and knowledge creation and transfer, became more conscious of their pivotal role and adjusted planning and design to facilitate this activity. Mobility and access was fostered between classrooms, research centres, enterprise areas, placing great importance on Velocity Hubs and high speed, high frequency transit corridors and intercity rail.

Pre, early, mid and end of their serial careers, private, public and social sectors created opportunities for Canadians to survive and thrive in the 21st century. Knowledgeable and knowledge-hungry Canadians were central to the success of realizing the vision for a prosperous, resilient, low-carbon Canada.

II: 2050 HORIZON: URBAN AGENDA CHARACTERISTICS, MODELLING ASSUMPTIONS

This section qualitatively and quantitatively outlines the Urban Agenda's physical conditions at 2050. It is organized in 5 parts, which are the key sectors driving energy and emissions in cities:

- Land Use and Urban Design
- Transportation Systems
- Buildings
- Building Energy Supply
- Solid Waste and Materials

Transportation Systems and *Buildings* are overwhelmingly focused on managing energy demand. Emissions from these sectors, along with *Building Energy Supply,* are energy-related, generating primarily carbon dioxide from the combustion of fossil fuels.

Land Use and Urban Design is also focused on managing energy demand. It does this very directly in some cases such as determining building size and type. It also does this extensively but indirectly, ultimately determining many aspects of transportation and building energy demand and supply opportunities in other sectors. Land use planning also addresses forest and soil carbon management opportunities in and around urban regions, only lightly explored in this paper.

Solid Waste and Materials is traditionally a non-energy sector focusing mostly on managing methane emissions from anaerobic digestion of organic matter in landfills. However, the potential for deep emission reductions through better utilization of products and moving from linear to circular economic models is tremendous.

Each section contains the following components:

- Relevance of each sector to a national low carbon future and its relevance to the urban agenda and local government influence
- Goals, delineate the carbon and energy management objectives, as well as broader social, economic, and environmental objectives to met by the planning and design solutions
- Form, Fit and Function - describe each condition shaping the urban form, how the conditions fit with one another, and their purpose (the function)
- Synopsis of Variables and Modelling – highlighting the assumptions and parameters

Variables and Modelling

To help navigate the quantitative variables used by CanESS and NATEM in modelling the Urban Agenda, this content is highlighted in blue boxes.

CanESS and NATEM incorporated inputs from the *Land Use and Urban Design* and *Transportation Systems* sectors. Inputs generated from the *Building Energy Supply* sector were not incorporated. Variables for the *Waste and Materials* sector were initially explored, but unable to be incorporated into the modelling process.

LAND USE + URBAN DESIGN

COMPLETE + COMPACT, CENTRED + CORRIDORED

Relevance

Land use planning and urban design are not a typical emission sector, in that rather than directly generating emissions, these urban form policies, plans and practices drive emissions in the transportation and building sectors, which are amongst the top emission sources in Canada. Urban form is also a fundamental determinant of district energy viability.

While considerably smaller in annual contribution, urbanization also contributes to 12% of permanent forest loss in Canada, releasing biogenic carbon. Cities with strong urban tree and forestry policy and practice, however, are protecting and restoring these carbon sinks.

Land use planning and urban design are local governments' area of paramount authority. Local governments have determined where commercial, residential and institutional activity is currently, and where it will go in the future. This settlement location, situated on parcels, separated by streets fundamentally powerfully influences transportation activity. Building types, sizes and uses, situated on these parcels, are the starting point for building emissions. Local government land use decisions are amongst the most influential decisions in the country shaping greenhouse gas emissions.

Goals

- Efficient land use and attractive urban design supports high efficiency building and transportation systems and diverse public priorities:
  - Integrated land use and transportation systems maximize access between origins and destinations at neighbourhood to regional scales
  - Building size and type reduces energy demand, and density supports district energy
  - Focused development supports agricultural, forest and natural land protection and restoration
  - Focused growth supports fiscally sustainable municipal infrastructure development, operation, maintenance and replacement
  - Land use planning supports active transportation, healthy people and vibrant neighbourhoods alive with people and diverse businesses
  - Housing choices accommodate diverse families and households
  - Reduced housing and transportation costs due to locational efficiency, and a larger share of more affordable housing forms, e.g. wood frame multi unit residential
  - Building types, sizes, tenures and uses accommodate demographic change such as growing cohorts of seniors, 1 and 2 person households, home-based and telecommuting workforces
  - Industrial and commercial land use and location supports efficient transportation and employment and is attractive to local and global business

Fit, Form + Function

Three overarching characteristics define efficient and effective land use, development and urban design in Canada's low carbon urban future.

1. Focused residential and commercial development across urban areas

- Focused residential development (i.e. growth) in hubs, nodes and corridors supporting high quality, frequent transit and maximizing district energy opportunities
- "Five minute walkable neighbourhoods" with access to key commercial services, parks and schools from residential origins for vast majority of Canadians (excluding a small minority of the population living beyond urban areas)
- Major commercial and institutional employers located in higher density, mixed-use nodes, served by high quality transit
- Gentle intensification of former single detached neighbourhoods
  - Extensive "invisible" density characterized by suites in single detached including duplexes and row houses, "hidden" density in the form of laneway houses and garden suites, and "gentle" density in the form of duplexes, row houses and town houses
- Urban growth boundaries limit inefficient land use and transportation systems, and protect land for agriculture and ecosystem services
- Strategic location and protection of industrial land to support efficient goods movement

Growth Location and Form Variables and Modelling	
BC Quantified CanESS + NATEM do *not* model these variables, but they do model transportation and building energy activity that is strongly influenced by these variables.	These variables define the general location and form of growth in urban regions. These conditions establish the basis for other key variables, notably building typology, district energy share, transit/active transpo mode shifts, and trip length reductions.

Synopsis of Variables and Parameters

Location of Growth

The cornerstone of the Urban Agenda is allocating future population to urban geographies conducive to lower carbon intensity transportation activity and building forms. Five urban typologies were created representing *current* urban geographies, defined by key urban form variables, e.g dwelling types, commercial/residential land use mix, transportation regime, and proximity to central business district (for large urban areas).

	Urban Agenda Growth Share	**Current/BAU Growth Share**	**2010 Population Total Share**	**2050 Population Total Share**	**2050 Urban Typology Transformation**
Active Hub/Urban Core	*23%*	6%	10%	15%	Active Hub
Transit Suburb	*18%*	4%	8%	11%	*Neo-Urban* w Active Centres + Transit Suburbs
Auto Suburb	*51%*	76%	55%	53%	
Exurb	*5%*	9%	9%	7%	Exurb
Small Town/Rural	*3%*	5%	18%	14%	S Town/Rural

Canada's current population distribution across these urban typologies, with >70% in suburban areas, is a major contributor to Canada's current emission intensity. These areas are characterized by very high automobile mode shares and personal driving distances and very high shares of single detached homes, defining characteristics of high to very high personal carbon intensity transportation and building profiles. The current share of population growth going to Automobile Suburbs and Exurban Areas is 85% of all growth,

further exacerbating Canada's carbon intensity. (This growth share doesn't account for suburban-type growth in Small Town/Rural Areas or the Transit Suburbs.)

The basis of the 2010 urban typologies and population allocations was strongly informed by archetyping completed by Gordon et al (2014 and 2013). As this work focused on Census Metropolitan Areas, extrapolations and informed judgments defined allocations for the remaining population residing in Census Agglomerations (which share similar trends to CMAs) and Small Town Rural which became a new heterogeneous typology.

The transportation behaviour and building forms of the typologies for urban areas (excluding Small Town/Rural) are similar to other analysis on neighbourhood/urban travel/building form and carbon intensity, notably work completed by CMHC and IBI (2000) and many others (Abt Associates Inc, 2010) (Boston, 2009, 2010, 2011, 2013a/b, 2014) (Condon P. , 2010) (OECD, 2010) (Thompson, 2013).

These typologies are rarely if ever representative of any single municipality. Most communities feature more than 1 typology, and many have 3 or 4.

Under the Urban Agenda growth is shifted away from "Auto Suburbs" towards today's "Active Hubs" characterized by mixed-use, higher density, high walkability fabrics – e.g. village and town centres – distributed across urban regions. The share of growth towards "Transit Suburbs" also grows. "Exurban" growth is halved. "Small Town/Rural Area" growth modestly declines in line UN/Stats Canada projections (UN Department of Economic and Social Affairs, 2014).

While the name of these typologies is static for modelling reasons, the characteristics of these typologies change over time. This is especially true for "Transit Suburbs" and "Auto Suburbs." Under the Urban Agenda, growth in these areas is infill focused, multiplexing some single-detached homes, adding laneway houses and integrating ground-oriented multi-unit residential buildings. Moreover, key destinations are added, such as grocery stores, cafes and parks and significant employment is added to hubs. These areas become "neo-urban" with significant transit suburb fabric and many "active centres"

For details, see "TEF Urban - Population Growth by Urban Typology" spreadsheet.

2. Diverse housing to support diverse families and households

- New construction is oriented towards multi unit residential buildings (MURBs)
- A modest share of single family dwellings are annually multiplexed to accommodate demographic changes and affordability imperatives with the co-benefit of reduced personal carbon intensity in buildings and transportation, achieving a compactness that supports active transportation and public transit investment
- The missing middle of the housing continuum with single detached at one end and the condominium tower at the other is filled out with significant ground-oriented residential such as row/town house, 4-6 story walk up
    - This housing type has the potential to be highly efficient, more affordable, and more amenable to density opponents
- Housing types include small format, flex housing, work/live, diverse tenures, as well as multi-bedroom MURBs in higher density frequent transit corridors
    - Small format housing includes: Secondary Suites, Laneway + Coach Houses, Small Lots, Flex Housing including *lock*-off suites in MURBs

- Housing meets diverse and dynamic demographics, including rapidly rising share of single-person households, seniors, empty nesters, as well options for family-friendly frequent transit, medium to high density corridors

Housing Type and Size Characteristics Variables and Modelling	
BC Quantified CanESS + NATEM modeled	These variables define the form and size (i.e. building type and floor area) of residential development in urban regions, establishing the basis for building energy demand.

Synopsis of Modelling Inputs

These building form variables and parameters drive significant building energy demand reductions.

Building Split

Dwelling splits to 2050 were informed by current new construction trends according to provincial archetype:

- AB, PEI, SK historic trend: Stable/Modest Declining Apt Growth rate, Modestly Growing Semis, Stable/Modest Declining Single D
- BC, ON, QC historic trend: Very High Apt Growth rate, Modest Declining Semis + Single D
- MB, NB, NS, NF historic trend: Steady Apt Growth Rate, Declining Single D, Stable/Modestly Growing Semis

These trends influenced dwelling splits by a matter of degrees. Generally about 80% of growth was split between "apartments" and "semi-attached." The remainder, approximately 20%, was comprised of "single detached." In all situations, "single detached" share dropped significantly relative to BAU. "Single *attached*" (duplexes, multiplexes, row/town houses) are a small share of existing dwelling stock and BAU future. However, they are an important part of the Urban Agenda's future building mix as they are generally more affordable and lower carbon intensity per capita than high rises and single detached, and are more palatable than high rises in many neighbourhoods. In the "apartment" category, a greater share was allocated to low rise for the same reasons – this dwelling type has *the* greatest potential from low carbon/high affordability measures.

A couple of new building "sub" classes were created to address smaller family sizes and affordability as well as manage carbon and energy:

- **"Annual Retrofit of (2010) Single Detached to Single Detached w Suite(s)" increased the number of families in single detached dwellings, essentially halving per family building energy demand in those homes. The retrofit rate is expressed as an annual percent of 2010 units starting at 1% of stock in 2030 and declining to .5% in 2050**
- **The "Laneway House" is a micro single-detached dwelling. The share of new construction grew from ~5% in 2030 to ~10% in 2050 depending on the urban typology. From a modelling perspective, this was managed by reducing the average single detached floor area.**

Building splits were reflective of their urban typology, with progressively more Multi Unit Residential Buildings (MURBs) towards "active hubs" and fewer single detached.

Building Floor Area:

The Urban Agenda reversed the half-century trend in increased floor area, notably for single detached homes that comprise the largest share of Canada's building stock. Growth in home size has coincided with contractions

in family size, exponentially increasing per capita energy demand.

Under the Urban Agenda, single detached homes average floor area returns to 1980 levels. Average "apartment" and "semi-detached" floor areas fall slightly, although in reality this average obscures greater diversity in size with more micro units and more larger, "family-oriented" apartments.

For details, see "TEF Urban - Dwelling Split and Floor Area" spreadsheet.

3. Strategic urban design in hubs, nodes and corridors

- Vibrant and attractive city and town centres with plazas, community centres and parks that meet diverse demographic needs including families
- High quality urban design along frequent transit corridors to encourage walking, cycling, and access to transit

Urban Design Variables and Modelling
These variables were qualitatively assumed to achieve the public transit, and active transportation mode shifts.

Additional Opportunities (not quantified or modeled)

- **Diverse commercial building development**
  - Diverse commercial building development to support diverse commercial activity, including eco-industrial networks, and home-based businesses

- **Urban Forest and Tree Protection and Expansion**
  - Climate resilient trees and forests on private land, streets and parks protect and expand carbon sinks.

*TRANSPORTATION SYSTEMS

Efficient + Extensive Networks + Vehicles

Relevance

While Canada's most rapid emission growth is in oil and gas, personal road-based transportation, is still the largest emission sector and has grown 25% since 1990 – significantly higher than the national rate (18%).

Personal transportation emission growth is primarily attributable to rising vehicle kilometres travelled and reduced automobile fuel economy. The direction of land use and transportation systems are the major growth factor in vehicle KM travelled at the household level, notably low density, residential development remote from employment centres.

The primary determinant of transportation behaviour is land use planning which defines the location and mix of commercial, residential and institutional activity, as well as the location and density of street networks. Street design, including lanes, sidewalks and pedestrian and bike networks and parking policies are also local government responsibilities. Local governments may not deliver public transit services, but are typically actively involved in policy and planning where such services exist and certainly in large urban regions where the overwhelming majority of Canadians reside.

For more than half a century, local governments with senior government support, focused on mobility, moving lots of solitary drivers in cars from dispersed living areas to dispersed working, shopping and recreational areas. In the early half of the 21st Century, the focus shifted to accessibility, moving lots of shopping, work and recreation closer to where people live and vice versa. This establishes the basis for efficient, cost effective, and healthy transportation systems benefitting private and public pocket books.

Freight emissions, while a smaller share overall, have grown even more rapidly. Despite a significant rise in stock efficiency, the total number of heavy trucks rose 20%, and average distance travelled rose 16%, increasing GHGs 67% since 1990. Trucking growth is driven by just-in-time shipping, a shift towards trucking freight at the expense of rail (about 10 times more efficient per tonne/kilometre), increased material throughput in the economy, and increased local delivery demand.

While a large share of freight emissions is between large urban regions. A significant amount is local, e.g. local/regional freight, school/public transit buses, waste/recycling/compost hauling, cement/gravel trucks, and construction material hauling. Even medium and long haul trucking can be strongly influenced by LGs. While a larger share of freight tonne km is on open highway, a disproportionate share of time at lower fuel economies is within urban regions slowed by congestion worth billions of dollars annually in losses.

Goals

- Efficient transportation systems based on sustainable land use support diverse public priorities:
  - Efficient movement of people and goods
  - A hierarchy of personal transportation choices reflecting public health, infrastructure cost, competitiveness, and climate change mitigation imperatives
  - Liveable neighbourhoods, vibrant businesses and globally competitive cities
  - Affordable transportation in the face of volatile and steadily rising fuel costs
  - Sustainable transportation innovations with domestic and global market opportunities

Fit, Form + Function

Four overarching characteristics define the high efficiency transportation system in Canada's low carbon urban future. These characteristics are fundamentally integrated with and enabled by the land use and urban design characteristics.

1. Fine-grained, complete, connected street networks support efficient movement and seamless integration of modes

- Street networks are organized around a coherent transportation hierarchy:
  a. Pedestrian
  b. Bike
  c. Transit
  d. Freight
  e. Car Share
  f. Personal LEVs
  g. Personal automobile
- Transportation networks, land uses, urban design and smart technologies support multi-modal transportation

2. Extensive public transit infrastructure networks reflecting urban context

- Extensive rapid transit in the form of subway, elevated rail, light rail, and bus rapid transit as appropriate for the context
- Extensive bus service with context appropriate types, articulated bus, midi-bus, mini bus
- High speed (~300 kmh) intercity rail for regions with multiple, proximate large urban regions, specifically: Windsor-Toronto-Ottawa-Montreal-Quebec City, Calgary-Edmonton

3. Widespread autonomous electric car share systems

- Extensive AEVs available through collaborative economic models in medium to high density mixed used areas (comprising the majority of Canada's urban fabric by 2050, and the overwhelming majority of the population)
- Extensive distribution of fast charging infrastructure (e.g. Level 2) in commercial/institutional building parking areas, on street parking areas, and public parking lots
  - Minimum basic charging infrastructure is required (i.e. 120 volt) in residential building parking areas

4. Extensive bike share systems

- Extensive public, private, and social bike/electric bike share systems of various forms in medium to high density mixed used area (comprising the majority of Canada's urban fabric by 2050)

- Systems are safe, low cost, dependable, user friendly, and widely accessible in in medium to high density mixed used areas

5. Strong transportation demand management

- Extensive pedestrian commercial zones and meeting places
- Advanced parking systems manage supply and incorporate full costs, and facilitate efficient use of high value land
- Underutilized, historic parking space land has been sold or re-purposed for higher value uses such as retail space notably small restaurants and grocery stores, parks, terraces,
- Advance transit priority measures such as transit lanes, queue jumpers, bus bulges, bus activated traffic signals

Transportation System Variables and Modelling	
BC Quantified CanESS + NATEM modeled	The four transportation system characteristics outlined above, combined with the land use characteristics determine the parameters for key transportation variables: mode share, automobile ownership rates, trip length, and trip frequency.

Synopsis of Modelling Inputs

Automobile Ownership Rates

Automobile ownership rates dropped 25% by 2030 and 50% by 2050, going from .5 vehicles per capita in 2010 to .25 in 2050. This decline is attributable to two multi-facetted developments that make the convenience, cost and speed of other modes and automobile access models more attractive. The first is the Urban Agenda's complete, compact, connected integrated transportation and land use approach. Reduced car ownership is consistent with neighbourhood and urban form analysis (Abt Associates Inc, 2010) (CMHC , 2000) (Boston, 2009, 2010, 2011, 2013, 2014) (Condon P. , 2010) (Thompson, 2013). The second is the combined disruptive social and technological force of the autonomous electric vehicle accessed under some kind of a collaborative economic model. Each car share vehicle is estimated to displace 4 to 13 vehicles and reduce overall driving distances (Metro Vancouver, 2014) (Martin, 2010).[41] Autonomous vehicles are expected to be accessed predominantly through a collaborative economic model and displace the current share of vehicles on the road anywhere from 50-98% (Godsmark, 2015) 85% (Earth Institute, 2013) 98% (Pricewaterhouse Coopers, 2013) -- higher rates than assumed for this paper.

Mode Split

Mode shares were established according to provincial archetype determined by census metropolitan area size and transportation/transit characteristics:

- Provinces with *smaller urban regions* and characteristics to support rubber tire rapid transit jurisdictions to 2030 and rail beyond that (SK, MB, NB, NS, PE, NF)
- Provinces with *larger urban regions* and characteristics to support rail rapid transit (BC, AB, ON, QC)

Under both archetypes active transportation mode share rises from 7% in 2010 to 16-18% in 2050 for

[41] Metro Vancouver (2014) found each car share vehicle replaced up to four personal vehicles. This is a conservative estimate; Philadelphia found 11 vehicles displaced. While previously "zero" car households drive more, most households – the vast majority of users – drive less, with a net result of lower total distances driven (Martin, 2010).

commuting and 18-20% for personal trips from 7% (e.g. retail, social, recreational, health). This shift can be attributed to the fine-grained, complete street network and "Five Minute Neighbourhood" planning for residential-oriented areas, and the complete, compact residential/employment hubs and nodes. These conditions place people close to destinations and destinations close to people.

The transit share rises from a 5% average in 2010 to 34-37% in 2050 for commuting and 37-40% for personal trips. Commensurately, light duty vehicle mode shares were 45-50% commuting and 40-45% for personal. These differences by provincial archetype reflect the extent and speed of transit infrastructure, which in turn is shaped by urban form, notably density. Different transit use propensities are associated with speed, convenience, and accessibility.

The parameters are very equivalent to or slightly more aggressive than modal split targets already established by Canada's largest CMAs (Toronto, Montreal and Vancouver)[42], comprising 35% of the Canadian population. These CMA targets are on shorter timelines, nevertheless. These Urban Agenda parameters, nevertheless, apply to the entire country, where the car mode share is generally higher, and they include the much more transformative land use agenda integrated with diverse transportation choices, including car share autonomous vehicles.

The active transportation and transit mode shares are close to some of today's leading European jurisdictions with highly integrated and efficient transportation and land use systems, such as Netherlands, Denmark, Sweden, Switzerland, and Germany. At least one-third of all trips are taken by active transportation modes in these jurisdictions, measurably lower than the Urban Agenda's estimates. It will take significant time and effort to achieve similar mode shares in Canada when 70% of the current population resides in low-density, single use suburban fabrics with relatively few proximate destinations (Gordon D. a., 2014). Cost effectively extending, high quality high frequency transit to these areas is also challenging. This is why the Urban Agenda places such great emphasis on gentle intensification of existing areas, and five-minute neighbourhood planning that introduces key destinations.

Once again, neighbourhood scale analysis of transportation behaviour and mode shares is consistent with the parameters (Abt Associates Inc, 2010) (CMHC , 2000) (Boston, 2009, 2010, 2011, 2013, 2014) (Condon P. , 2010) (Thompson, 2013)

Inter City Mode Share

Jurisdictions with high-speed (300 kmh) inter-city rail displaced automobile trips by almost 30% by 2050 from the base year (2010), and short haul air travel by 50%. These jurisdictions had several proximate large urban regions within 500 km (Alberta: Calgary-Edmonton; and Ontario-Quebec: Windsor-Toronto-Ottawa-Montreal-Québec). These corridors also included other medium to large cities.

Trip Length

Average trip lengths by light duty vehicle declined for both commuting and personal trips declined 22% by 2050. Transit trip lengths declined by 15-20%. This is attributable to a greater distribution of employment in regional town centres, as well as greater key destination access at neighbourhood and sub-regional scales. **Active transportation trip lengths for commute and personal, in contrast, increased 3 to**

[42] Sociéte de Transport de Montréal is aiming to achieve a Car/Transit/Active mode split of 45/37/18 by 2020; MetroLynx is aiming for a 47/33/20 Car/Transit/Active mode split by 2035 in greater Toronto. TransLink is aiming to achieve a Car/Transit-Active mode split in Metro Vancouver of 50/50 by 2045.

5 fold, respectively, from 1 km in 2010. (Active mode includes walking, cycling, electric-assist cycling and bike shares.) This is attributable to more key destinations proximate to homes, improved pedestrian/cycling infrastructure, and better urban design (enhanced street connectivity, as well as street trees, street furniture, etc.). Neighbourhood design increases active transportation propensity and trip lengths (Frank, 2004) (CMHC , 2000). Walking lengths for work are higher than personal (Littman, 2014). These trip length reductions are consistent with analysis of similar changes to integrated land use and transportation (Abt Associates Inc, 2010) (CMHC , 2000) (Boston, 2009, 2010, 2011, 2013, 2014) (Condon P. , 2010) (Thompson, 2013).

Trip Frequency

Commuting trips per capita declined 24% by 2050 from 2010 due to the rise in home-based employment, as well as liberalized telecommuting policies permit some or all trips from home. These projections are only slightly below the trend and attributable to home design and local government policy that supports home based employment. **Personal trip frequency remained constant.**

For details, see "TEF Urban - Transportation" spreadsheet.

Additional Opportunities (not quantified or modeled)

- **EB (Electric Bus) Market Transformation Strategy**
  - LGs, Transit Authorities, Provincial and Federal Governments, industry and supportive national organizations can collaborate, potentially with US counterparts, on accelerating market transformation of EBs (electric buses)

- **Local Green Freight Strategy**
  - As well as reducing personal automobile dependence, and, in turn, congestion, LGs have a variety of tools to manage freight and commercial vehicle emissions and improve transportation efficiency, e.g. expand truck access in HOV lanes, permit freight in HOV/transit lanes and cue jumpers, establish toll lanes for freight, expand PU/delivery hours in urban areas, establish better truck delivery parking design and access standards, reduce residential development around freight hubs, such as hubs. LGs can have significant influence over standards at construction projects – small and mega. They have strong convening powers that can be used to deliver green fleet/green freight programs. Freight needs to be appropriately situated within a transportation planning hierarchy.

BUILDINGS

Liveable, Affordable + Near Net Zero

Relevance

Buildings are the country's fourth largest source of emissions, however, if the Building sector's share of electricity generation emissions are included, buildings emissions are on par with the Transportation and Oil and Gas sectors as the country's top 3 emission sectors. In the urban context, building and transportations share almost equally more than 90% of emissions.

Local governments play a central role in managing building carbon and energy starting with zoning that determines building types and sizes and uses, followed by permitting and inspection and then extensive engagement with builders, developers and building owners in new construction and renovations/retrofits. These authorities and relationships position local governments to play key roles in establishing the baseline of building emissions through building type and size, as well as help build capacity to meet codes, accelerate market transformation, and improve efficiency in existing building stock.

Goals

- Low energy, low carbon intensity new and existing buildings support diverse public priorities:
  - Liveable and affordable housing options
  - Improved building durability
  - Significant savings from energy conservation, redirected towards spending with higher socio-economic benefit
  - Clean tech/green building industry growth with domestic and global market opportunities
  - The growing share of one and two-person households with reduced space requirements
  - Attractive and healthy commercial buildings for local and international businesses

Fit, Form + Function (additional Opportunities – not quantified or modeled)

Three primary characteristics, outlined below, define low carbon buildings in Canada's urban future. They complement the land use and urban design priorities that manage carbon through more efficient residential building types and efficient floor areas.

- **Diverse, near-net zero housing**
  - Passive design exploits local climatic conditions to maximize solar heat gain in the winter and minimize in summer, and facilitate day lighting, natural ventilation, and cooling, enhancing occupant comfort and reducing mechanical and electrical energy demand
  - A large share of low heating, cooling and electrical loads can be met through building or site integrated or neighbourhood energy systems, with an emphasis on renewable heat, supplemented by low carbon grid electricity
  - Diverse housing typologies offer genuine choices to accommodate diverse interests, including luxury, affordability, household size, and stage in life
    - As well as affordability, a significant share of ground-oriented, wood frame MURBs offer inherently lower energy demands than mid/high rise as they can be designed with low to no mechanical and electrical loads for heating, lighting and operating elevators, corridors and interior common areas

        - A small and important share of micro single detached homes in rental, strata, and free hold tenures offer ultra low carbon, high affordability to 1 and 2 person households
    - Flex design permits easy re-purposing living areas to offices to suites, accommodating different family sizes, employment types, and aging in place
    - Extensive modular construction supports quality control for high-efficiency, flex use, affordable buildings, notably in the residential sector
    - Smart design supports durability as well as deconstruction simplicity, minimizing GHG throughput in the economy

- **Low carbon commercial-institutional buildings**
    - Commercial-institutional sectors share similar approaches with residential in terms of passive solar, flex, modular, and durable design
    - Block, neighbourhood and community scale heating and cooling, i.e. district energy, has a higher share than in residential
    - Institutional services – education, recreation and leisure, daycare, library, health, etc. – are integrated in different configurations, often with complementary commercial services, e.g. professional medical, to maximize building space and energy utilization as well as program delivery, and minimize extensive periods of underutilization, redundant capital costs
    - Commercial and institutional office space per capita is reduced and optimized (and significantly lower per worker than the early 21st Century) due to high rates of home-based employment, full and part-time telecommuting, and extensive space sharing in diverse arrangements, hot desking, desk sharing, shared offices
    - Brick and mortar retail spaces operate side by side mobile and stationary pop-up stores, pick up points, and home delivery services, reducing retail space, and increasing warehouse space per capita
        - 3-D print shops and laser cutting cafes provide specialized manufacturing services, replacing some goods previously available in retail shops
        - The collaborative economy has reduced demand for some retail products, such as specialized tools, sports equipment and electronics, reducing GHG throughput in the economy and some retail space requirements

- **Continuous carbon improvement in existing buildings**
    - Ongoing carbon tune ups, integrated into capital planning and ownership/lease changes, minimize carbon emissions associated with envelope, glazing, lighting, plumbing, equipment and appliance inefficiency and/or fuel type
    - Multiplexing of large single detached homes doubles or even trebles per household carbon intensity
    - Commissioning and ongoing re-commissioning of larger, complex buildings

BUILDING ENERGY SUPPLY

Low Carbon Community Heat + Power

Relevance

Approximately 60% of building energy demand is for space and hot water heating. While the grid supplies almost all lighting and plug load services in Canada, and this includes significant low carbon, renewable electricity; a large share of heating services are met with natural gas, making heating services the biggest source of carbon in the building sector by far.

Cost effective, low impact renewable heat can be provided at the building or site scale with diverse technologies, e.g. heat pumps (geo/ground, water or air), and biomass combustion. It can also be provided at the neighbourhood or community scale with one plant generating heat distributing hot water to and collecting cooled water from local buildings. Where biomass combustion is the optimal district energy (DE) fuel, there is tremendous potential for combined heat and power systems.

Delivering heat through electricity for electric resistance heating can have higher social and environmental impacts, and does have inherent inefficiencies across the electricity system: generation (particularly combustion technologies), transmission, distribution, and (re)-conversion to heat. These inefficiencies are smaller with renewable heat, which is local and distributed.

Thermal density – i.e. the concentration of space and hot water heating services over a given area – is a fundamental determinant of district energy viability. Thermal density is determined by urban form and local government land use policy. The low carbon Urban Agenda dramatically increased the potential for district energy by focusing growth in nodes and corridors.

While urban form and local government policy are less imperative for building and site scale renewable heat, this opportunity complements district heating, as buildings not on DE networks are candidates for building/site scale technologies.

While there are important urban form and local government policy considerations that can maximize community-scale power, they are not as pervasive as for district heating and combined heat and power. Local governments can enable community-scale, renewable power, by removing obstacles like height restrictions for wind turbines to building-scale solar access, and land use and urban design policy to appropriately accommodate renewable power on land and infrastructure.

Goals

- Community-scale renewable heat and power supports diverse public priorities:
  - Resilience to changing commodity prices, and extreme weather and power instability, notably for critical energy supply needs (e.g. hospitals and emergency management services)
  - Management of energy transmission and distribution infrastructure costs, complementing decarbonization of grid electricity and natural gas
  - Resolution to public opposition over siting new transmission and distribution infrastructure
  - Optimized energy supply matching for energy end uses, specifically heating
  - Local participation in renewable energy development

Fit, Form + Function

Two characteristics define the residential, commercial and institutional building energy supply systems in Canada's low carbon urban future.

1. Extensive low carbon, district energy systems in higher density neighbourhoods

- Diverse low carbon district energy technologies provide heating and cooling services and, in many cases, generate electricity in combined heat power systems for high-rise, mid-rise and low-rise and some higher density ground oriented multi family neighbourhoods
    - Expand and decarbonize existing district energy systems

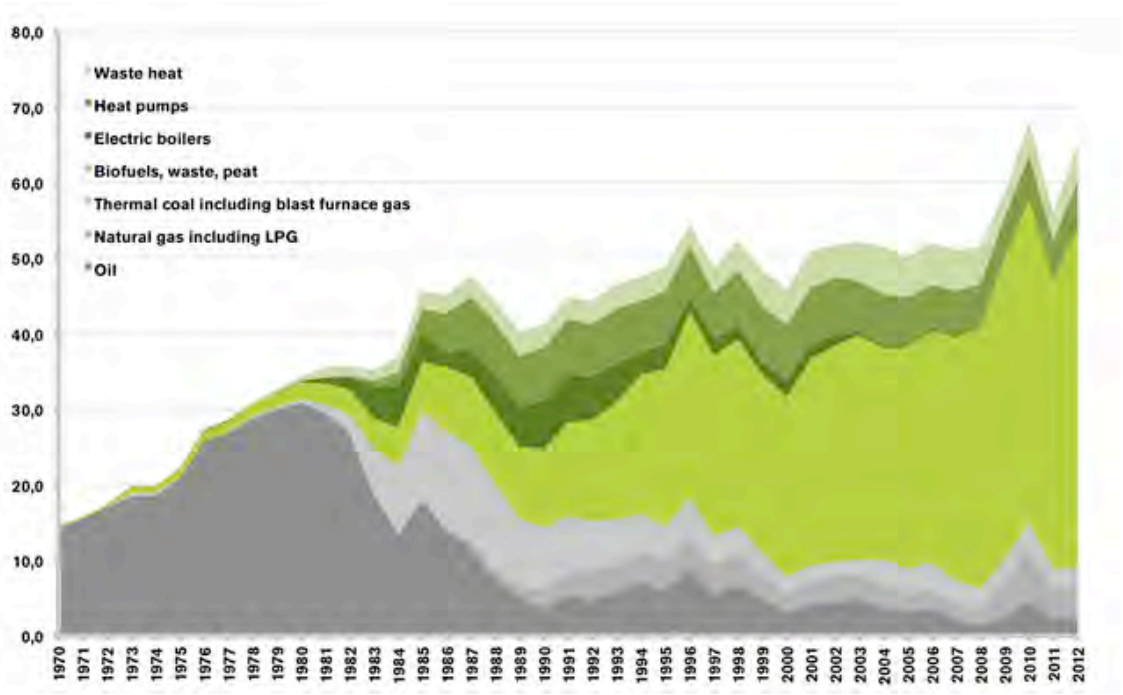


Figure 9: District Energy – Platform for Fuel Flexibility and Decarbonization: Over the past 40 years, Sweden's district heating fuel mix has transitioned from 98% fossil fuel (grey scales) to a range of resources dominated by renewables that comprise upwards of 85% of fuels (greens). Image: Swedish Energy Agency - www.svebio.se/english/bioenergy-data

2. Extensive building and site scale renewable heat in lower density areas

- Building scale renewable heat such as air source heat pumps, geo exchange provide the majority of heating and cooling services in lower density and single detached neighbourhoods

Renewable Heating Variables and Modelling	
BC Quantified paramaters CanESS + NATEM do *not* model these variables	The two renewable heating characteristics outlined above, combined with the land use characteristics determine parameters for the renewable heating variables: DE technology, and floor space penetration by building type in each urban typology.

Synopsis of Variables and Parameters

The share of district energy and building scale renewable heat in new construction is incrementally ramped up. By 2040 all new buildings have the majority of thermal loads met by either district energy or building/site-scale renewable heat. A small percentage of existing buildings are annually retrofit with district energy or building scale renewable heating. 100% of existing fossil fuel DE systems are converted to biomass heat and biomass cogeneration/trigeneration by 2020.

DE is concentrated in higher density neighbourhoods, notably city and town centres and major corridors. This urban form is necessary to justify the capital cost associated with larger heating systems and thermal distribution networks. Effective growth management planning has enabled extensive DE development.

Building-scale renewable heating, such as geo-exchange and heat pump technologies, is higher in urban areas and dwelling types where DE feasibility is low, i.e. exurban areas and single-detached dwellings.

By 2040, the share of building-scale renewables accelerates relative to district energy in new construction. A growing number of micro "district" energy systems emerge at the block scale. This is attributable to falling thermal loads due to rising building energy efficiency, making smaller building-scale technologies more cost effective than district energy systems with their higher cost thermal distribution piping networks.

District Energy and Combined Heat + Power Technical Assumptions

District energy systems currently provide 5.2 million MWh (19 PJ) of heating and cooling services in Canada, meeting 1% of total energy demand (Natural Resources Canada's Comprehensive Energy Use Database). Systems are based on diverse renewable and fossil feedstocks. While most new systems are low to hot temperature hot water systems, many older ones are lower efficiency, steam based systems.

In Canada's low carbon future, district energy meets a growing share of space heating and cooling and hot water services, and also provides a growing amount of electricity with cogeneration systems.

To justify the heat distribution network, district energy systems require minimum thermal demand densities, e.g. a concentration of medium-sized buildings (e.g. ≥1000 m2) across a multi block area (e.g. ≥500-800 MWh per hectare across several hectares).

Higher density, low rise and high-rise neighbourhoods (residential and/or mixed use) achieve these thresholds. Some medium density neighbourhoods (e.g. multiplex, row house, townhouse dwellings) may achieve these thresholds, and could certainly be within district energy

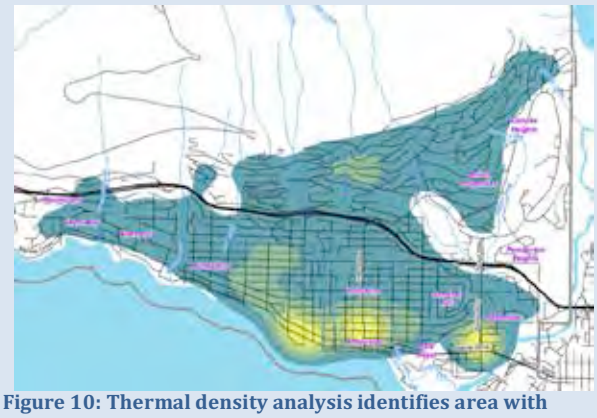


Figure 10: Thermal density analysis identifies area with high concentrations of space heating and hot water demand. Thermal density is amongst the most important factors in screening for district energy potential. Mapping: Golder and Associates for District of West Vancouver (Boston, 2015)

service areas if they are adjacent to higher density areas. Lot sizes (i.e. smaller) and building location on lots (i.e. clustered) strongly influence feasibility in neighbourhoods with ground-oriented dwellings.

Given these thermal density requirements, district energy take up is higher in active hubs and transit suburbs than in auto suburbs and exurbs. Medium to high-density corridors and nodes, nevertheless, across all of today's and tomorrow's urban areas achieve some district energy penetration. Take up is naturally more rapid in new growth. District energy retrofits for existing buildings are influenced by capital replacement plans and compatibility with existing heating systems.

District energy systems may only meet a minority of peak demand, yet typically meet a large majority of annual space heat and hot water demand, and cooling where required.

Generally peak heating demand is met with gas boilers. This could be conventional natural gas (fossil fuel) or renewable natural gas (biogas or biomethane from wastewater treatment, anaerobic digesters using agricultural or organic waste, or landfills, although this source will decline over time). In some circumstances, typically beyond the gas network, peak demand would be met by propane or diesel, ideally biodiesel.

Many parts of Canada (generally BC, Northern Canada, Atlantic) will have very low cooling requirements, even as the climate warms, as good passive design and/or high building efficiency requirements would eliminate cooling demand needs, notably in the residential sector.

District energy technologies and feedstocks are diverse and strongly influenced by demand and supply variables, as well as site, community, regional and provincial context. For the purpose of this study, new district energy systems used one of three representative technologies.

Biomass Heat (Bio Heat)

Biomass-based district heating systems typically combust or gasify wood and other types of biomass. Zero carbon feedstock includes forest industry wood residues, source-separated organic municipal solid waste free of plastics, trimmings from urban trees and urban-forest interfaces for fire management, source-separated construction and demolition waste, and energy crops (switch grass, willow). Some lithospheric carbon (i.e. fossil) may be associated with some fuels for transport, energy crop inputs, and processing, e.g. pelletization.

As combustion technologies, biomass systems are hot water based (vs steam). Cooling services may provided in smaller systems with parallel air source heat pumps that can provide a portion of space heating, or absorption chillers through a second set of pipes. Both of these cooling approaches require electricity.

Performance Assumptions that could be used for modelling:

- Energy Services: space heating and hot water
- Capacity Factor: 30% (ratio of energy generated relative to system capacity)
- Base load: 75% of annual energy demand met by system
- Energy Utilization:
    - Heating: 85%
    - Thermal Loss: 15%

Biomass Co + Trigeneration (Bio Cogen)

Biomass cogeneration DE systems generate heat and electricity. Trigeneration systems provide cooling services. Due to thermal loss, typical fossil fuel thermal power systems operate at efficiencies of 40% (simple cycle) to 60% (combined cycle). Typical bio-power plants can operate at only 25% efficiency. Cogeneration

plants, in contrast, can achieve 85-95% efficiency if paired with a well-matched thermal energy consumer such as a district energy system or continuous industrial process heat load.

A typical plant uses a rankine cycle turbine – often with organic fluids rather than water and steam, permitting lower temperature operation and a wider diversity of inputs. These systems become justifiable with larger loads, i.e. more building energy and/or bigger commercial/industrial process heat demands. The smallest system capacities start at approximately 2,000 kW of heat and 500 kW of electricity.

Co/trigeneration systems are often phased onto established district energy systems when sufficient heating loads are achieved.

Feedstocks are the same as biomass district heating systems.

Performance Assumptions that would support modelling:

- Energy Services: space heating and hot water, electricity, and cooling where required
- Capacity Factor: 30% (ratio of energy generated relative to system capacity)
- Base load: 75% of annual energy demand met by system (some systems are higher with cost implications)
- Energy Utilization:
    - Electricity: 20%
    - Heating and Cooling: 70%
    - Thermal Loss: 10%

Ground Source Geo Exchange Heat Pump (Geo HP)

Ground source geo-exchange is the dominant heat pump-based district energy technology assumption. Other heat pump technologies have similar performance metrics that could comprise a share of new DE systems including ocean or lake water systems and sewage heat recovery. Geo exchange is a low to medium temperature system that can provide hot water, as well as space cooling and heating through the same pipes.

As a carbon management measure, because electricity is required to power heat pumps, these technologies are preferable in jurisdictions with low carbon intensity electricity grids.

Site-specific geology influences efficiency and outright viability. Ground source geo exchange potential is, nevertheless, widespread.

Geo-exchange retrofit rates are slower than biomass district energy due to the complexity and cost of extending geo-exchange fields for many existing building sites.

Performance Assumptions that would support modelling:

- Energy Services: space heating and cooling, hot water
- Capacity Factor: 50%
- Base load: 85% of annual energy demand met by system
- Co-efficient of Performance: 3.5 (avg units of heat energy output for each unit of electricity energy input)

Building-Scale Renewable Heat: Geo Exchange & Air Source Heat Pump

Two heat pump-based technologies represent the take up of building-scale renewable thermal systems: ground source geo-exchange and air source heat pumps. In reality, building scale renewables will be much more diverse, these selected technologies are generally viable in all Canadian jurisdictions. Other technologies, such

as building-scale biomass and solar thermal, are more location sensitive.

The demand side management gains of heat pump technologies are reasonably consistent across all jurisdictions with average co-efficients of performance of 3.5 (average units of energy – heat – output for each unit of energy – electricity – input to power heat pump). Carbon management gains are correlated to the carbon intensity of their respective provincial/regional grid.

Take up of building-scale renewables is higher in urban typologies and dwelling types where district energy feasibility is low, i.e. exurban areas and single-detached dwellings.

While there is considerable variation in system sizing and performance amongst and between geo and air source heat pump systems, for modelling simplicity, performance assumptions for both should be held constant. In most parts of Canada and where most Canadians live, today's heat pump technologies can generally meet close to 100% of annualized space heating and cooling demands in the residential sector. Colder climates have greater auxiliary heat demands, notably for air source heat pumps. In the commercial/institutional sector, heat pumps are more typically sized to meet something in the order of 80% of annualized thermal loads with auxiliary systems for peak periods. Auxiliary systems are typically gas boilers

Performance Assumptions that would support modelling:

- Energy Services: space heating and cooling
- Capacity Factor (ratio of energy generated relative to system capacity):
    - residential: 90%
    - commercial/institutional: 50%
- Base load
    - residential: 95% of annual space conditioning load is met by system
    - commercial/institutional: 80% of annual space conditioning load is met by system
- Co-efficient of Performance: 3.5 (average units of energy – heat – output for each unit of energy – electricity – input to power heat pump)

For details, see "TEF Urban – DE, CHP + Building Scale Heat" spreadsheet.

Additional Opportunities (not quantified or modeled)

- **Small and medium-scale, community-driven renewable power development**
    - Renewable power, notably solar photo voltaics and wind for:
        - critical energy users in higher penetrations such as hospitals, senior's homes, sewage/water systems, major computer servers, and stationary and mobile police/emergency management services
        - other residential and commercial building owners in lower penetrations such as farmers, co-ops, municipalities and First Nations

SOLID WASTE + MATERIALS

Zero Waste + Dematerialization

Relevance

While methane emissions from anaerobic landfill waste decomposition comprise the smallest emission sector, this sector is associated with considerable emissions for hauling, processing recyclables, as well as the immense carbon embedded in the economy's material throughput.

Local governments have significant authority and influence over waste emissions, notably waste management practices, and, in particular diversion and land fill management. These activities can be characterized as standard, short to medium term GHG management solutions. Because they deal with the end result of inadequate packaging and product design policy by senior governments and the linear economy (take, transform and trash), local governments have unique insights into more transformative approaches to materials and "waste" management that better utilize products and support circular economic models. Local governments have become central players in facilitating circular and collaborative economic activity with the potential for dramatic step changes in the economy's carbon metabolism.

Goals

- Enhanced waste and material management to virtually eliminate landfill methane and reduce GHGs; and transformative economic models to decarbonize the economy while supporting:
  - Cost effective landfill and waste management on behalf of taxpayers
  - Maximize value from material traditionally discarded as waste
  - Manage scarce resources more efficiently
  - Support economic development with domestic and international market opportunities

Fit, Form + Function (additional opportunities – not quantified or modeled)

- **Comprehensive methane capture and energy generation in existing landfills**

- **Extensive re-use, recycling, and composting in residential, commercial, institutional and industrial sectors**
  - Prioritized diversion of organics, notably food, to composting
  - Prioritized diversion of plastics to higher value uses
  - Enhanced product design and packaging practices to minimize "waste"
  - Zero waste construction & deconstruction

- **Energy recovery from residuals under an adaptive management approach that optimizes waste and resources by management practice on GHG life cycle basis**
  - Strategic diversion of wood from construction, deconstruction and land clearing
  - Optimized energy recovery from waste site/facility selection with an emphasis placed on high emitters that can utilize heat and power, e.g. cement plants

- **Expanded collaborative and circular economies across all sectors guided by a long-term carbon reduction imperative and active intervention by all levels of government**

III: HIGHLIGHTS + NEXT STEPS ON THE PATH TO LOW CARBON CITIES

Top take homes from the National Prosperity Agenda for Urban Regeneration are organized in three areas:

- Urban Agenda Highlights
- Additional Steps to Define the Path
- First Steps to the Low Carbon Path On Ramp

URBAN AGENDA HIGHLIGHTS

Highlights along the Urban Agenda's low carbon path.

THE BEST COST BENEFIT BETS IN TOWN

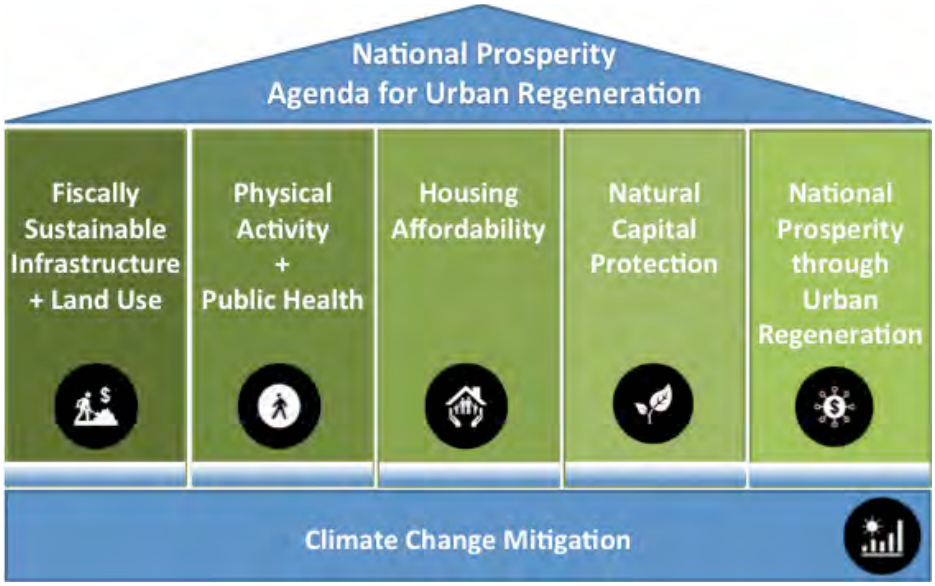
- **The Urban Agenda offers extensive lower cost carbon management opportunities**. Some low cost opportunities are shown in the NATEM modelling results.
- A growing body of research is evaluating economic benefits, as well as costs in ways that better reflect how public and private sector finance and economies play out in the real world.
- **Smart urban policies reduce national mitigation costs** (OECD, 2010), **are amongst the lowest cost mitigation measures** (Replogle, 2014), **accrue significant public and private savings due to avoided infrastructure spending** (Calderón, 2014), **and offer many no-regrets strategies because of their extensive co-benefits such as investment attractiveness, congestion management and public health.**

CANADA'S HIGH CARBON URBAN GROWTH MODEL

- **While there are many challenges confronting LGs and the country in achieving deep emission reductions, one of the most complex, technical, social, and economic challenges is the dominant growth model of Canadian cities.**
- **More than two-thirds of Canadians live in thinly populated, car dependent neighbourhoods comprised predominantly of single detached homes with few, if any walkable destinations**. Today, right across the country, 90% of the growth, by population, is extending this form. **This form is the major contributor to the enourmity of Canada's community GHGs, the major driver of community GHG growth, and one of several major drivers to Canada's overall GHG growth.**
- **Per capita personal transportation and residential buildings emissions are conservatively four fold higher in low density, auto-oriented residential neighbourhoods, in contrast to complete, compact, connected neighbourhoods. Most communities, nevertheless, feature both neighbourhood forms.** (Boston, 2009, 2010, 2011, 2013a,b, 2015) (Hoornweg, 2010)
- This growth model is not sustainable in any manner. Municipal infrastructure deficits, physical inactivity and public health, congestion, commute times, combined housing and transportation costs, agricultural land loss – Canada cannot afford this growth model.

URBAN AGENDA PILLARS UNDERPIN NATIONAL DEEP REDUCTIONS

- Decarbonization can be achieved by addressing core policy priorities that resonate locally, sub-nationally and nationally. Realistically, this may be the only way. Canada is confronting a multitude of multi-facetted, structural deficits: financial, social, and environmental. They are complex, deeply ingrained, interconnected and mutually reinforcing. The solutions must be, too.
- **The National Prosperity Agenda for Urban Regeneration is comprised of five pillars that offer comprehensive deficit management for the country.** The foundation of each is deep emission reductions.



- **By laying this foundation, and raising these pillars together, synergies can be realized, costs minimized, benefits maximized. From this architecture, eight mutually reinforcing planning and design strategic directions can be built** to make Canada more resilient to global economic volatility and catastrophic natural disasters, and lay a foundation for enduring local, regional and national prosperity.

1. Focused Growth + Productive Land Protection
2. Place-Based Planning for Good Jobs, Homes + Neighbourhoods
3. Complete, Connected Street Networks
4. Attractive Transportation Choices
5. Housing Diversity + Green Buildings
6. ABC Integrated Energy Systems
7. Smart Green Space + Smart Green Infrastructure
8. End of Waste, Beginning of Hyper Material Efficiency

- Failing to form any one of these pillars, or any one of these strategies is done at the expense of others. Siloed approaches in and beyond urban regions compromise carbon reduction potential.

CRITICAL REGIONAL + NATIONAL PRIORITIES

- **The Urban Agenda reinforces critical regional and national priorities**:

- ***Public health***, specifically improved air quality and greater physical activity reducing obesity, cardiovascular disease and diabetes with significant lost economic output estimated at $6.4 billion annually (Katzmarzyk, 2004).
- ***Housing affordability*** through more affordable residential building types and construction methods and reduced transportation expenditures cutting the affordability shortfall experienced by 25% of Canadians, and the historic household debt loads.
- ***Mobility and accessibility***, enabled by greater transportation choice underpinned by more strategic and efficient land use systems designed for accessibility amongst origins and destinations and efficient transportation networks and infrastructure.
- ***Competiveness*****,** regionally and nationally, by enabling more efficient networking amongst public, private and social players, faster transportation of people and freight, and socially and economically vibrant urban hubs and attractive urban regions to attract and retain domestic and international talent.
- ***Infrastructure deficit management*** by creating an urban form and ecologically designed management strategies that lighten infrastructure demands and reduce band aid solutions. Most municipalities do not have the revenue to pay for the cost of laying, maintaining *and* replacing services in low-density, automobile-oriented development where 80% of today's growth is focussed. Modest shifts in housing typology and land use can reduce infrastructure servicing costs 75% (Condon P. , 2010), bringing numerous co-benefits and filing a void in ground-oriented multi-family housing highly sought after in Canada.
- ***Sustainable productive capacity*** **protection**, reversing the loss of agricultural land and ecosystems.
- ***Demographic Change Management:*** Single family home multiplexing and micro residential units can address some of the needs of Canada's fastest growing family types (one and two-person households), including young adult singles, couples, and parents priced out of current markets, as well as downsizing empty nesters and widows/widowers.

NO URBAN AGENDA = DANGEROUS, RUN AWAY CLIMATE CHANGE

- **In the absence of a strong urban agenda, deep emission reductions will be onerous if not physically impossible**, e.g.

    - ***EV Limitations + Integrated Transportation and Land Use Imperative:*** Electrifying personal LDVs is an attractive, and important strategy. There are, however, practical limitations, notably congestion. An aggressive EV strategy in the absence of public transit, transportation demand management and active transportation could exacerbate congestion, undermining competitiveness, health and safety, productivity, and quality of life. In many cities, there is simply not enough space to allocate more lanes to accommodate similar per capita automobile ownership rates with another 5 million people concentrated in Canada's biggest urban regions. The complete, compact,

connected Urban Agenda supports mobility and more importantly access to destinations in a cost effective and efficient manner with diverse transportation choices.

The autonomous EV has great potential to overcome some of these limitations, but is not in itself a solution if the low density, distributed form persists. AEVs under the expected collaborative economy model will penetrate suburban areas at much slower and lower rates, similar to the relative absence of car shares in genuine suburban areas. The potential for congestion management is compromised as the urban form demands driving. On top of this, many of the other co-benefits are dampened, e.g. no reduction in urban infrastructure costs, and lower health and safety benefits.

- ***Low Cost, Zero Carbon Transportation + Urban Form****:* The lowest carbon, cheapest transportation modes, for consumers and governments, are walking and biking. High active transportation mode share is also a key indicator of neighbourhood vitality and personal health. At least one of three trips in many European jurisdictions is made by foot or bike. In Canada the rate is one of 15. Improving access between origins and destinations with focused, mixed-use growth, and providing good infrastructure and urban design can allow the active transportation mode share to rapidly grow.

- ***3 R's for High Carbon Canada - Re-imagine, Re-design, Re-invigorate Suburbs****:* The most carbon intensive neighbourhoods in Canada are automobile oriented suburbs with large single-detached homes on large lots. Two-thirds of Canadians live in these areas today, and 90% of new growth is going into this urban archetype (Gordon D. a., 2014). The vast majority of residential greenhouse gases beyond 2050 are from buildings already standing in these urban areas. Standard home retrofits will not be sufficient for an 80% carbon reduction agenda, and that approach ignores the transportation carbon, congestion and other costs.

  Decarbonizing existing suburban homes and transportation systems can be achieved with a multi-pronged approach involving gentle intensification of the existing urban fabric with ground oriented multi family buildings, multiplexing and laneway homes, "five-minute neighbourhood" planning with parks and shopping, and focussed growth along corridors and in nodes that become higher density, mixed use hubs, bringing and focussing employment in the suburbs. Adding suites in single-detached homes halves household carbon intensity, and addresses very real demographic change and affordability priorities. To access the plethora of new local destinations as well as regional ones, street networks need to be enhanced and diverse transportation choices created – all of which are more cost effective than today's approach to mobility provision, involving highly subsidized personal vehicle travel.

- ***High Rise Limitations + the Gentle Intensification of Low Density Urban Fabric***: While there is a critical role for high rises in the Urban Agenda, notably enabling high quality transit, there are limitations. An over emphasis can undermine the gentle intensification and dramatic decarbonization of suburban areas that will otherwise dominate and drive

building energy demand until beyond mid-century. The anti high-rise movement, furthermore, is mobilized and further mobilizing in all major urban regions of the country. The Urban Agenda strategically establishes a wide mix of housing types, notably including significant shares of ground oriented multi-unit residential buildings that are more broadly accepted, in high demand, but are in low supply. They are also more affordable and capable of higher energy performance. The gentle intensification of suburban neighbourhoods by multiplexing many single detached homes, and adding micro, laneway homes, can halve energy demand relative to a conventional single detached household.

These critical low-carbon solutions are only viable with active local government engagement and urban strategy integration in national and provincial climate change mitigation planning.

GOOD GOVERNANCE – STEWARD ON THE LOW CARBON PATH

- Evolving from **good to great governance is key to advancing the Urban Agenda and forging the larger low carbon path**. This involves several elements:

    - ***Strengthened Multi-Level Governance:*** To survive and thrive in the 21st century, stronger multi-level governance regimes are necessary to enable local, provincial and federal players to collaborate on agendas that can currently conflict. This involves active collaboration across the Federation, federal-provincial and major urban regions, and focused engagement with other cities.

        - **The central initiative driving this transformation is the *National Prosperity Agenda on Urban Regeneration,* involving national, sub-national and local government collaboration on a shared prosperity agenda comprised of five major policy pillars built atop a decarbonization foundation**

      Stronger regional planning authority and governance amongst municipalities is needed to steward regional integrated land use, transportation, energy and waste planning agendas central to Canada's economic, social and environmental future.

    - ***Policy and Planning Integration and Alignment:*** Policy priorities locally, provincially and federally must be better integrated and aligned not only in traditional energy and emission sectors, e.g. energy, transportation, and housing, but also around other mutually reinforcing policy areas, e.g health protection, affordable housing, food security and agriculture, forestry, economic development, infrastructure management.

      Lower costs, greater synergies, and higher benefits can be achieved with integrated planning that brings together the right disciplines, departments, levels of government, private and social stakeholders to solve specific complex, interrelated policy priorities.

    - ***Urban Innovation Incubation:*** Federal and provincial governments must take advantage of the innovation enabled by local governments in transportation, buildings, energy

supply, economic development, high tech, green tech and beyond. Despite local government's role in market transformation and economic development, local efforts are typically uncoordinated with and often opposed by senior governments.

Virtual space must be created for local leaders –*Urban Innovation Incubators* – to work with public, private and social sectors to accelerate market transformation on many critical agendas for communities and the country in coordination with senior governments rather than in opposition.

All levels of governments must collaborate on a Disruptive Technology Red Tape Reduction Action Plan. This Action Plan would be focused on removing and updating policies and processes to accelerate innovation, maximizing benefits and minimizing costs. The inadvertent barriers are myriad for innovations associated with electric vehicles, autonomous vehicles, the circular economy, the collaborative economy, green buildings, and renewable energy generation.

- **Real choices will emerge when the real costs of transactions are reflected in real prices.** Fiscal policies and financial tools need to be transformed to level the playing field and provide Canadians with the transportation, and residential and commercial building choices they deserve. One form of development should not be subsidized over another. One transportation mode should not be subsidized over others. Social and environmental costs, notably carbon emissions, should be reflected in the price of goods and services. To compensate for a half century and more of subsidies, an adjustment period may be needed to phase out some subsidies and invest in some disadvantaged priorities.

Real Costs, Real Prices and Real Choices in the Transportation Sector

The $29 billion spent annually on roads and bridges should begin to be integrated into the cost of personal vehicular travel using a variety of mechanisms from road pricing to distance based insurance. The $7.5 billion spent on transit should be topped up to ensure greater transportation choice, along with significant investments in pedestrian and bike infrastructure. Public revenues would grow from better utilization of today's extensive "free" public parking spaces (parking comprises the single largest land use in many communities, and a large share of it is on public land and available for "free."). The $27-63 billion accrued annually for the social costs of driving (e.g. congestion, traffic accidents, air pollution) should appear on the ledger, internalized into the cost of vehicle operation. These transportation price adjustments will result in significant collateral benefits. The shift towards public transit and active transportation combined with more efficient land use should, should reduce personal transportation spending (the second highest household cost after housing), increasing housing affordability and re-allocating spending towards goods and services with greater economic and social benefit. Focused growth, driven by both policy and market forces, will also dramatically reduce the cost of water, sewage, road, energy, and communications infrastructure and many municipal services.

ADDITIONAL STEPS TO DEFINE THE PATH

MULTIPLE ACCOUNTS COST-BENEFIT ANALYSIS

Carbon and cost are two essential criteria to select technology and practice preferences. Developing a cost effective, meaningful agenda that will be driven down and across a multitude of line departments federally, provincially and locally requires the evaluation of additional criteria. Ideally a climate change mitigation agenda will emerge that reinforces other broad-based public priorities, e.g public health, housing affordability, mobility and accessibility, global competiveness, infrastructure deficit management, and agricultural land protection.

The approach to costing carbon management technologies and practices should be redistributive rather than additive. Spending on new measures will often result in less money spent elsewhere and the avoidance or reduction in many other costs, over and above energy. (See box above for insights into modelling considerations: Real Costs, Real Prices and Real Choices in the Transportation Sector.)

The Global Commission on the Economy and Climate[43] takes a comprehensive cost-benefit approach (Calderón, 2014). Top actions identified in their cost-benefit abatement curves, it should be noted, are urban carbon management priorities.

Multiple accounts cost-benefit analysis can enhance the current technology and practice selection and modelling approach, strengthening screening and optimization. Such analysis can help take the climate change debate out of the atmosphere and place it meaningfully in homes, businesses, farms, hospitals and main streets

CARBON REDUCTION TECHNOLOGIES + PRACTICES

A number of additional modelling opportunities could enhance the Trottier Energy Futures low carbon path.

Renewable Heat and Combined Heat + Power

The vast majority of building energy demand is for space and hot water heating. Meeting this demand with electric resistance heating has inherent inefficiencies across the electricity system from losses in generation, transmission, distribution to end use (re)conversion, sometimes with high socio economic and environmental costs. While renewable heat deployment at building and neighbourhood scales has unique institutional challenges, there is great carbon reduction potential and the levelized cost of many renewable heat opportunities is competitive with many renewable electricity opportunities (IPCC, 2011) (International Energy Agency, 2012).

Under the physical conditions created by the Urban Agenda, district heat and combined heat and power systems offer energy services that are already cost effective in North America and Europe with the advantage of a platform for flexible feedstocks, reduced need for electricity transmission system upgrades with its associated costs and siting challenges, and the resilience provided during electricity system failures.

[43] Chaired by Felipe Calderon, former President of Mexico and comprised of former ministers of finance/state leaders, and notoriety in economics, business and finance, including former World Bank Chief Economist Nicholas Stern.

Canada has much to learn from Northern European jurisdictions that have the lowest carbon intensity buildings amongst advanced OECD economies. While they share comparable climates (heating degree days) with Canada, they have the highest penetrations of renewable heat while Canada has amongst the lowest.

Renewable heating would be worthy of further investigation.

Waste + Materials: Standard Solutions + Disruptive Innovations

While methane emissions from anaerobic waste decomposition in landfills are relatively small, they still amount to 27 Mt of CO2e annually, of which 25% are captured (the equivalent of removing about 5.5 million cars from the road).[44]

The potential for virtually eliminating landfill methane through standard solutions is immense, and making even deeper carbon reductions with disruptive interventions will involve a full matrix of action by all levels of government with a central local government role.

- ***Standard, short to medium term solutions*** have the potential to cost effectively reduce the majority of methane emissions by mid century, reducing costs for landfills and material inputs and generating new products and services. These solutions include composting, recycling, paper and packaging reductions, methane capture and energy generation, and combusting residuals in energy recovery from waste facilities to generate heat and electricity. As per many other sectors and technologies, energy recovery from waste demands a strong adaptive management framework to ensure better waste and material management practices in the future are not undermined by today's investments.

More significantly, the waste and materials sector has huge potential for **disruptive solutions that dramatically reduce energy and material throughput in the economy, drastically cutting global carbon emissions.**

- ***The Circular Economy****,* driven by resource constraints and economics, is displacing the dominant linear economy, which has gained steam since the industrial revolution and could be at its climax with decisive public sector leadership. Driven by a circular model, Interface flooring for example, has reduced waste 99.7% relative to other manufacturers, and reduced carbon emissions 90% while expanding production. (Gould, 2014)

- ***The collaborative economy****,* accelerated by digital networking tools, can also make an important decarbonization contribution. This is best exemplified by car sharing in which total car ownership and distances driven amongst users has dropped, fully acknowledging that for a small percentage of users car use and distance driven has risen, sometimes significantly (Martin, 2010). The City of Seoul (Korea) dubbed the Sharing City, has started more than 20 initiatives, and there

[44] Environment Canada values based on the National Inventory in *Municipal Solid Waste and Greenhouse Gases* from: https://www.ec.gc.ca/gdd-mw/default.asp?lang=En&n=6F92E701-1

are hundreds of others enabled by private and social sector entrepreneurs in the capital of this canny Asian Tiger.[45]

Standard, short to medium term solutions and disruptive solutions to waste and materials would be worthy of further investigation.

Urban Forest Protection and Expansion

Reversing the loss of forests due to urbanization and expanding forests and tree cover in urban areas can make a measurable contribution to climate change mitigation in two ways:

1) ***Reduce energy demand*** at a neighbourhood scale by improving pedestrian comfort and enjoyment, reducing personal vehicle travel; and lessening the urban heat island effect minimizing the need for air conditioning. Similarly at a site/building scale, appropriate tree selection, e.g. deciduous trees on S and W aspects, can reduce air conditioning demand in summer and lighting loads in the winter.

2) ***Protect and Enhance Carbon Sinks:*** Halifax Regional Municipality's forest and tree cover, for example, removes 120 Mt of carbon from the atmosphere annually, equivalent to 80,000 vehicles or about one-third of the region's total vehicle stock.[46]

Depending on climate, forest type, local energy prices amongst other assumptions, the relative value of energy savings and carbon sequestration differ according to a recent TD Economics report. (Alexander, 2014) There are also significant benefits to air quality and storm water management. Depending on the City, TD Economics estimates that every $1 invested in urban trees realizes $1.88 to $12.70 of benefits. (Alexander, 2014)

The impact of urban expansion on deforestation is significant, accounting for 12% of permanent forest loss annually in Canada (resource development accounts for the largest loss).[47] The potential is immense for avoiding ongoing losses to low-density development, and enhancing forest and tree cover within existing urban areas.

Urban forest protection and expansion would be worthy of further investigation.

"Distributed" Renewable Power

There is likely an important role for renewable not just because it is "distributed," but because a comprehensive cost benefit analysis complimented by strong multi-criteria analysis, some distributed power generation is likely to emerge as part of the optimal supply mix, and some large-

[45] CollCons (Collaborative Consumption) visits South Korea: http://www.collaborativeconsumption.com/tag/collconskorea/

[46] TD Economics estimate of tree and forest carbon sequestration (Alexander, 2014). Boston Consulting estimate of vehicle stock based on Canadian average of .6 cars per person from World Bank Motor Vehicle Data.

[47] Natural Resources Canada estimate in *Deforestation in Canada: The Facts* in http://www.nrcan.gc.ca/forests/inventory/13419

scale hydro, for example, may be too costly from a habitat/species loss/local community/First Nations perspective.

Like renewable heat, small-scale power strengthens resilience during electricity system failures and reduces the need for electricity transmission system upgrades with its associated costs and its siting challenges. The cost of land and opposition to power plant and transmission line development, notably in large urban regions where most Canadians live, is a top concern for utilities and provincial governments in some parts of Canada.

The strategic role of unique end users needs to be considered because of the significant leveraging opportunity. End users that require "110%" reliability are ideal candidates for some kind of oversized distributed energy system (heat, power, or CHP) that provide surplus power to surrounding areas, and/or store surplus power from the grid on site. These unique energy users (e.g. hospitals, senior's homes, sewage/water systems, major computer servers, and police/emergency management stations) can offset the premium paid for reliability by providing heat and power to the broader neighbourhood.

While provincial governments and utilities should play the lead role in advancing renewable power, significant local government policy and planning tools can enable community-scale, renewable power, including removing obstacles like height restrictions for wind turbines to building-scale solar access, and land use planning to accommodate small to medium-sized renewable power development.

Distributed renewable power would be worthy of further investigation.

Autonomous Vehicles

Accelerated networking and security tools are starting to disrupt car ownership trends, with a rapidly growing share of privately and socially owned car shares. A range of similar and complementary technical innovations is promising the autonomous vehicle, almost inevitably an EV and likely accessible through a collaborative economic model. Autonomous vehicles are projected to displace the current share of vehicles on the road anywhere from 50-98% (Godsmark, 2015) 85% (Earth Institute, 2013) 98% (Pricewaterhouse Coopers, 2013). This kind of disruption to personal vehicle travel would have diverse carbon implications, including vacant garages (a share of which may be new living or working spaces), reduced on street parking demand and concurrent new municipal assets (for anything from retail space to bike lanes), profound disruption to public transit, potentially exacerbating sprawl, and potentially significantly greater mobility for seniors, the disabled and minors.

At the current growth rate of 0.9%, Canada's population doubles in about 80 years. With car ownership at .6 per capita today (one of the highest in the world), by 2100, there would still be fewer cars on the road today in Canada under any of these projections of car displacement by AVs. These

projections, moreover, preclude other significant land use planning and design improvements.[48] Deeper analysis could inform better modelling inputs and shed insights into regulatory priorities to maximize carbon reductions amongst other socio-economic priorities, and minimize costs.

The autonomous vehicle may be worthy of further investigation.

Urban Scenario Exploration

With comprehensive cost and multi-criteria analyses, results for the urban agenda would likely be markedly different, notably with much more extensive renewable heat and much lower deployment costs. Moreover, with such screening and strategy optimization, it would be instructive to do further urban agenda modelling. This could include alternative scenarios, capacity assessments to quantify new dwelling unit potential in different urban forms (including old active hubs and suburban areas), and an integrated land use/development and transportation sub-model to generate robust personal vehicle, transit and active transpo mode share and distance travelled inputs.

It would be useful, also, to begin mapping out strategy synergies amongst different levels of government. Local government engagement on residential and commercial retrofits has shown substantial increases to utility and provincial utility energy conservation programs. Central strategies in accelerating building energy code updates include senior government loop closing with local governments given their immense insight into actual construction derived through inspections; and collaboration with builders and developers to build capacity to meet the code.

More granular urban scenario analysis would be worthy of further investigation.

STRATEGIC POLICY DEVELOPMENT

Where the rubber really meets the road on the Urban Agenda and the broader low carbon path is in policy design. For example, design of a phase-out in public subsidies to personal vehicles will be critical to the long term success of focusing growth, investing in public transit, reducing transportation sector GHGs, controlling low density greenfield development, and thus, also managing building carbon.

Additionally, it is necessary to attribute a level of government or a public institution (e.g. transit authority) or regulated organization (e.g. utility) to an emission (and energy) management target and associated suite of policies and actions to meet it.

Articulating the synergies across departments and levels of government and coordination with private and social sector institutions will help in policy and program design and roll out, and reduce overall costs.

Strategic policy development can provide ground truth and give life to the technologies and practices in the Trottier Energy Futures project.

[48] In Self-driving cars could reduce city traffic by 80% in http://www.nationmultimedia.com/aec/Self-driving-cars-could-reduce-city-traffic-by-80-30235414.html

ON RAMP TO THE LOW CARBON PATH – FIRST CRITICAL STEP

The most important step that can be taken to advance low carbon urban regions is launching the National Prosperity Agenda on Urban Regeneration:

- Convene key players in the federation from national, sub-national, and local levels to explore development of a national urban agenda with atmospheric stabilization as a primary goal.
- Focus agenda development on climate change mitigation measures that complement other national priorities that are shared regionally and locally.
- Establish a multi-level governance regime that strengthens policy and planning integration and alignment, acknowledges the unique role of Canada's large urban centres in the economic and social development of the entire country, and at the same time updating public investment opportunities to benefit all communities – *Prosperity through DiverCity*!
- Support agenda development and implementation using full cost accounting, acknowledging social and environmental costs, benefits as well as life cycle costs.

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APPENDIX I: URBAN AGENDA MODEL RUN 1.0 RESULTS ANALYSIS

Variables and parameters provided to CanESS and NATEM models as part of the Urban Agenda scenario addressed urban form, and complimentary transportation, and building energy demand and supply measures. More granular waste management and dematerialization variables could not be integrated into the modelling process. While CanESS was able to accommodate the building energy supply inputs, NATEM appears to have been unable.

This analysis compares the Urban Agenda Scenario inputs with NATEM outputs, and compares the Urban Agenda inputs and outputs with the Low Carbon Technologies Scenario. The Trottier Project identifies the Urban Agenda Scenario as Scenario 4 (S4). Scenario 3 (S3) is the Low Carbon Technologies Scenario.

This analysis also includes a discussion on Urban Agenda co-benefits.

BUILDING ENERGY DEMAND

MODEL INPUTS

The Urban Agenda was characterized by smaller floor area per capita and improved thermal performance from a higher percentage of shared walls in more attached dwellings and apartments, and a small, but important share of micro detached residential buildings. The attached dwellings included both *new* residential (multiplex, row house, town house) units as well as the multiplexing of a significant share of single-detached home stock existing in 2010. Multiplexing approximately halved per household/family building emissions in a single detached home where a suite was established, or where a large single family home was split into several residential units.

MODEL OUTPUTS: ACCURACY AND ALIGNMENT

The Urban Agenda's (S4's) smaller total floor area and higher thermal performance appears to be well represented in the NATEM results as reduced building energy demand, when compared to the Low Carbon Technologies scenario (S3).

There is, nevertheless, a possibility that the Urban Agenda energy demand reductions are *underestimated* in the building energy demand results for a couple of reasons:

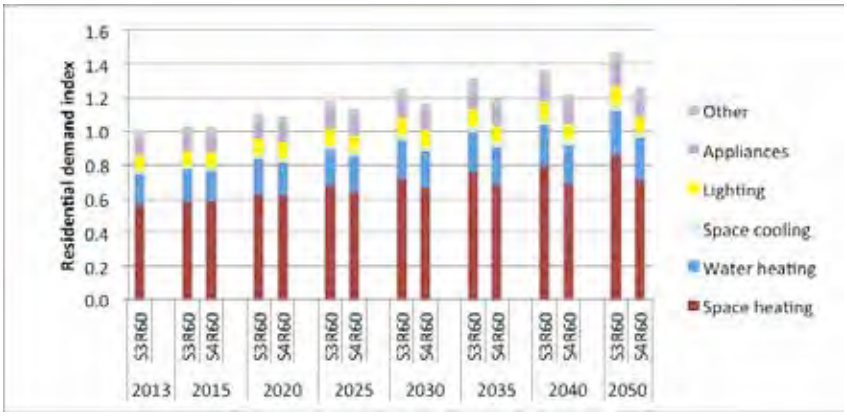

Figure 11: TIMES Building Energy Demand Scenario Comparisons

- The share of "semi-attached" dwelling units in the Urban Agenda (S4) was significantly larger than in the Low Carbon Technologies scenario (S3), and the efficiency of "attached buildings" *may* have been underestimated relative to "apartments" for the reasons outlined, below.
- Common assumptions about building energy intensity (e.g. NRCan National Energy Use Database) often overestimate the efficiency of contemporary of mid and high-rise buildings (classified as "apartments" in CanESS/NATEM models) (RDH Engineering, 2012). Common area heating and ventilation systems often have higher energy use in practice than assumed by building-scale modelers and designers in Part 3 apartments, largely due to poor thermal efficiencies and inadequate air barriers between common areas (corridors) and residential units in building *interiors.* The absence of sub-metering in a large share of apartments has resulted in inefficient, amenity gas fireplaces being used as primary heating systems, inconsistent with building modelling and design. The dominance of the curtain wall in contemporary design has further compromised energy performance. All told, energy performance in Part 3 apartments built from 1990 to present has been found to be inferior to older buildings (1970s and 1980s). Many of these inefficiencies could be addressed through improved design, and these improvements should be assumed over time. There are, nevertheless, some inherent inefficiencies in mid and high-rise apartments (i.e. common area mechanical and electrical loads for heating, lighting, and operating elevators, corridors and common areas) that constrain ultra-low carbon potential. Town house and row house (classified as "semi-attached" in CanESS/NATEM models) and three-six storey wood frame apartments do not necessarily have these same inherent energy demands. Concrete construction is additionally more GHG intensive relative to wood frame on a life cycle basis due to the high GHGs associated with cement production.

APARTMENT BENEFITS AND CO-BENEFITS

While Part 3 apartment efficiency may be overestimated (see above), apartments have many important benefits and are part of the synergies within the low carbon Urban Agenda. Firstly, average apartment floor area is significantly lower than average single detached houses and typically (but not necessarily) lower than ground-oriented multi-family, making household carbon/energy intensity much lower relative to single detached and likely equal to ground-oriented multi-family. The high rise is also integral to the feasibility and success of rapid transit systems and multi modal enterprise hubs, under the Urban Agenda. Apartment towers support a high concentration of destinations and services in close proximity, allowing very high active transportation modal shares. The thermal demand density of high-rise apartments, establishes the preconditions for feasible low carbon, district-heating systems. Beyond carbon and energy benefits, the smaller building footprint per dwelling unit can support integration of parks and green space into the urban fabric, improving ecosystem functionality and reducing demand for costly stormwater management systems. A sizeable share of the real estate market, importantly, wants high-rise condominiums.

TRANSPORTATION DEMAND

MODEL INPUTS

The Urban Agenda focused growth in city and town centres, and along corridors. Major employment is concentrated in multi-modal, mixed-use hubs situated along major transit corridors. Residential areas intensified and acquired key services and amenities, e.g. grocery stores and parks. The form supported cost effective, high quality public transit services. Complete, compact, connected neighbourhoods and regions supported a dramatic shift towards walking, cycling and transit modes, and reduced distances travelled (PKM), number of trips, and car ownership. Convenient, cost effective car share vehicles also rolled onto neighbourhood streets, further reducing car ownership.

Intercity rail, operating at speeds of 300 km/h, connected large metropolitan areas within several hundred kilometers, specifically: Calgary-Edmonton, Windsor-Ottawa-Quebec. This service increased rail mode share at the expense of short haul air travel and personal automobile.

Input Limitations

While school bus travel inputs were not generated through the Urban Agenda, per capita school bus demand would've dropped and trip distances reduced, notably because of better access (proximity) and optimized modes, walking and cycling, as well as transit. While inputs for freight were not generated, short haul freight and urban commercial travel distances and trip numbers would've also been reduced.

MODEL OUTPUTS: ACCURACY AND ALIGNMENT

The reduced distance travelled (passenger kms) appears to be well represented in the Urban Agenda S4 results.

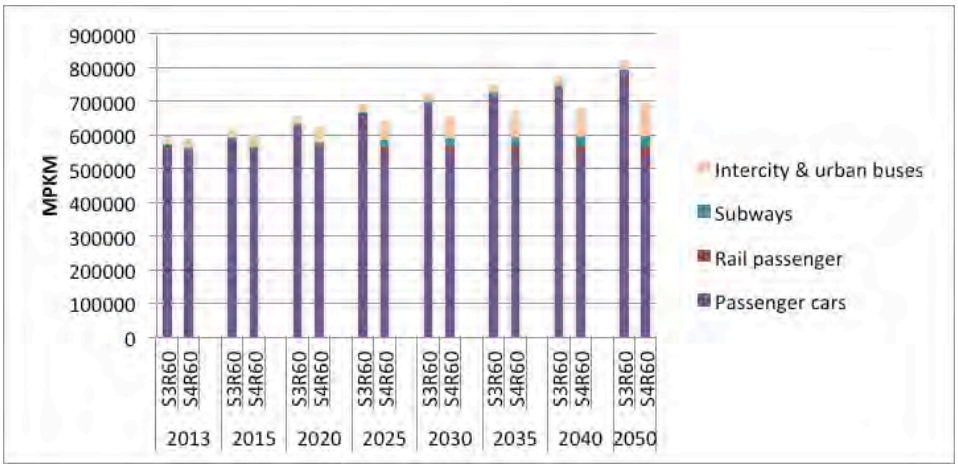

Figure 12: TIMES Transportation Demand Scenario Comparisons (passenger km)

The chart showing this reduction relative to the BAU and S3, nevertheless, includes inter-city rail distances that were displaced from short-haul air travel. (This chart also omits active transportation modes, potentially (mis) communicating a loss of mobility or access to key destinations.)

The modeled energy demand, and in turn GHG emission results may have some limitations as discussed below.

Potential Transportation GHG Underestimates under the Urban Agenda (S4)

- Load factor assumptions used for the future, modeled public transit system were not accessible. If load factors did *not* rise significantly over time under S4, the results shown make sense. While load factors today are high in most active hubs, load factors are typically low on many suburban routes. These geographies are much larger and populous than urban core areas. The urban form transformations would support a significant increase in average load factors, thereby reducing CO_2e/PKM under the Urban Agenda.
- The focused urban form, similarly, would support a more focused, high-occupancy, efficient transit network relative to a transit-supported, traditional suburban development with more extensive, lengthy, low occupancy routes and higher CO_2e/PKM. Thus, depending on the model's transit network assumptions, CO_2e/PKM under the Urban Agenda may be lower.

Practical Constraints and Costs to the Low Carbon Technologies Agenda (S3)

- Electrifying personal LDVs is an attractive, and important strategy. There are, however, practical limitations to the extent to which EVs can be utilized to support deep emission reductions, and potentially were assumed in the Low Carbon Technologies scenario (S3): notably congestion. Congestion is already greater in Canada's largest cities compared with competing cities in other jurisdictions (Transport Canada, 2006). An aggressive EV strategy in the absence of public transit, transportation demand management and active transportation could exacerbate congestion, undermining competitiveness, health and safety, productivity, and quality of life. In many cities, there is simply just not enough space to accommodate the volume of new vehicles. The complete, compact, connected Urban Agenda supports mobility and more importantly access to destinations in a cost effective and efficient manner.

  The autonomous EV has great potential to overcome some of these limitations, but is not in itself a solution if the low density, distributed form persists. AEVs under the expected collaborative economy model will penetrate suburban areas at much slower and lower rates, similar to the relative absence of car shares in genuine suburban areas. The potential for congestion management is compromised as the urban form demands driving. On top of this, many of the other co-benefits are dampened, e.g. no reduction in urban infrastructure costs, and lower health and safety benefits.

BUILDING ENERGY SUPPLY

MODEL INPUTS

The Urban Agenda parameters defined extensive renewable heat delivered through district energy systems for higher density neighbourhoods comprised of apartment towers and large commercial/institutional buildings, and at the building/site scale in neighbourhoods with lower density, ground-oriented buildings. These locational distinctions were determined by the neighbourhood typology population projections undertaken as part of the Urban Agenda. By 2040, 100% of new buildings met most space and water heating demand with renewable heating technologies (e.g. biomass combustion, or some kind of heat pump technology or renewable combined heat and power).

Input Limitations

Although the potential should be evaluated, the Urban Agenda did not develop community-scale renewable power variables and parameters. Firstly, this was not within the Urban Agenda's scope. Second, it is more appropriate that small-scale, community renewable power technology/policy options are explored in tandem with grid-scale technology/policy options. While there are "urban form" considerations that can maximize community-scale power, they are not as pervasive as the considerations for district heating and combined heat and power.

There are nevertheless, significant local government policy and planning tools that can enable community-scale, renewable power, from removing obstacles like height restrictions for wind turbines to building-scale solar access, and land use planning to accommodate renewable power. Combined heat and power, for which there is considerable potential, has been addressed as part of the Urban Agenda's renewable heat opportunity, discussed below.

MODEL OUTPUTS: ACCURACY AND ALIGNMENT

The NATEM model did not include a significant share of district heating, combined heat and power nor building-scale renewable heat, although some heat pump technologies may be represented under electricity demand. More granular building energy charts may exist that break down the source of electricity generation (e.g. nuclear, wind, solar, biomass CHP, etc.) as well as the end use technologies, e.g. (ground source heat pumps, air source heat pumps, etc.). It does not appear, nevertheless, that renewable heating is comprehensively integrated, as there is very limited biomass combustion.

The relative absence of renewable heat seems incongruous with the experience of Northern European jurisdictions with the lowest carbon intensity buildings amongst advanced OECD economies, and who share comparable climates (heating degree days) with Canada.[49] A brief discussion of the rationale, and technical and financial merits is outlined below.

[49] Sweden meets 70% of residential/commercial/industrial heating requirements with renewable heat. Finland and Denmark meet about half.

Approximately 60% of building energy demand is for space heating and hot water. To meet this heating demand with electric resistance heating has inherent inefficiencies across the electricity system: generation (particularly with combustion technologies), transmission, distribution, and (re)conversion to heat. These inefficiencies are smaller to non-existent with renewable heating technologies, which are local and distributed in nature.

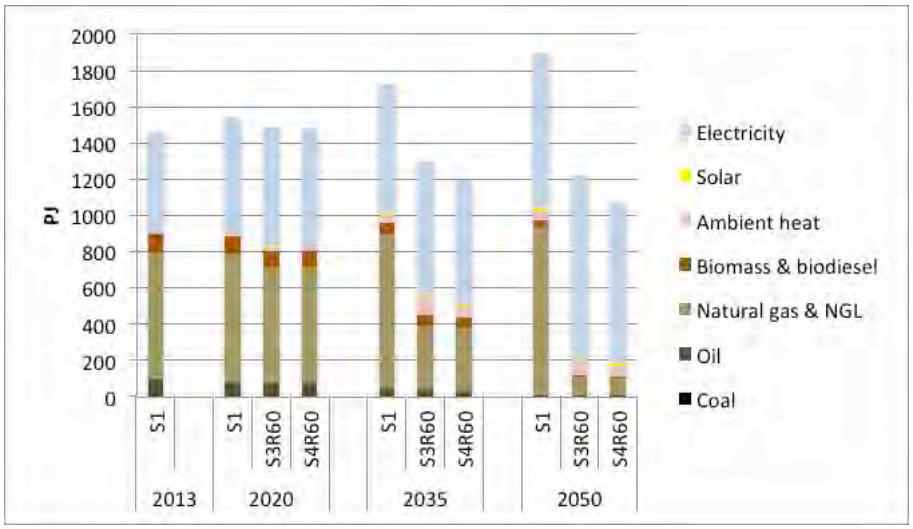

Figure 13: TIMES Building Energy Fuel Consumption by Scenario

The levelized cost of renewable heat is competitive with renewable electricity sources (IPCC, 2011) (International Energy Agency, 2012). Under the physical conditions created by the Urban Agenda, district heat and combined heat and power systems offer cost competitive energy services in North America and Europe with the advantage of a platform for flexible feedstocks, reduced need for electricity transmission system upgrades with its associated costs and siting challenges, and the resilience provided during electricity system failures. The latter is particularly important for critical energy users such as hospitals, senior's homes, sewage/water systems, major computer servers, stationary police/emergency management services, some industries, etc. The premium these users pay for "100%+" reliability can be offset to provide heat and power to the broader neighbourhoods in which they are situated.

Those jurisdictions enabling district heating have benefited from active local and senior government policy support to overcome many of the barriers associated with aligning stakeholder interests, up-front capital costs, and split incentives unique to district heating and combined heat and power systems.

Most European countries are now placing even greater emphasis on renewable heat, setting renewable heat generation targets for 2020 and policies and programs to meet them as part of an EU directive (International Energy Agency, 2012).

URBAN AGENDA CO-BENEFITS + COMPLEMENTARITIES

Over an above the carbon and energy management benefits, the Urban Agenda has been designed to reinforce other public policy priorities shared nationally and regionally. Co-benefits are essential to consider in consolidating support for a deep reduction agenda. Indeed, where deep emission reduction strategies are successful, almost invariably they dovetail other jurisdictional priorities. Resonant co-benefits will be necessary in realizing any deep emission reduction agenda.[50]

- ***Positive Cost-Benefit Abatement Curve:*** While there are costs associated with the Urban Agenda, a growing amount of analysis by a range of prestigious bodies recognizes that Urban Agenda climate change mitigation measures offer amongst the lowest cost per tonne because of the value of the benefits, often completely offsetting costs (Calderón, 2014) (OECD, 2010) (Replogle, 2014).
- ***Affordability:*** The Urban Agenda fills the missing middle of the housing continuum. The large share of attached wood frame buildings, notably row/town house and four-story walk up, as well as micro residential units, create greater affordability in the housing marketplace, where condominiums and single-detached homes do not. The complete, compact, connected Urban Agenda reduces demand for automobile ownership, today's second largest household expenditure after housing.
- ***Public Health:*** The active transportation mode shares achieved under the Urban Agenda provide the basis for a dramatic improvement in public health and, in turn, reduce health care spending.
- ***Infrastructure Deficit Management:*** Focused development, realized under the Urban Agenda's locational population projections, will significantly reduce Canada's spiraling infrastructure deficit.
    - *Similarly, focused development and five minute neighbourhoods permit cost effective public transit investment, mobility and accessibility, supporting social and economic priorities.*
- ***Competitiveness:*** The Urban Agenda's congestion management, mobility and access, and strategic investment create a foundation for competitiveness for urban regions and in turn the country.
- ***Anti Density Movement Management:*** The anti high-rise movement is mobilized and further mobilizing in all urban regions. The Urban Agenda strategically establishes a wide mix of housing types, notably including significant shares of ground oriented multi-unit residential buildings that are more broadly accepted, and further gentle intensification of suburban neighbourhoods by multiplexing many single family homes, and adding micro, laneway homes.
- ***Step Changing Carbon in Current Single Family Stock:*** The majority of energy demand and carbon in buildings at 2050 will come from single-detached homes that exist today. A strategy for step changing energy and carbon performance in this building stock is necessary for 80% emission reductions – multiplexing a sizeable share of existing single family homes is a viable strategy to contribute to these reductions and simultaneously address affordability and demographic change imperatives.
- ***Demographic Change Management:*** Single family home multiplexing and micro residential units address the need for Canada's fastest growing household types (1-person households; and empty nesters), and young singles, couples, and parents unable to buy into the inflated real estate market.

[50] These co-benefits are outlined with references in the first section of the paper: "The Foundation: Goals for Comprehensive Deficit Management.