RE-ENERGIZING CANADA

Pathways to a Low-Carbon Future

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FOREWORD

Sustainable Canada Dialogues (SCD) is a country-wide network of over 80 scholars who volunteer their time to identify positive solutions that overcome obstacles to sustainability and climate change mitigation. An initiative of the UNESCO-McGill Chair for Dialogues on Sustainability, SCD has members from every province and represents many disciplines across engineering, sciences and social sciences.

As a network, SCD seeks to motivate change and help Canada embark on the necessary transition towards a low-carbon economy, given our collective responsibility to protect future generations from the consequences of climate disruption and steer the course of economic and social development towards sustainability.

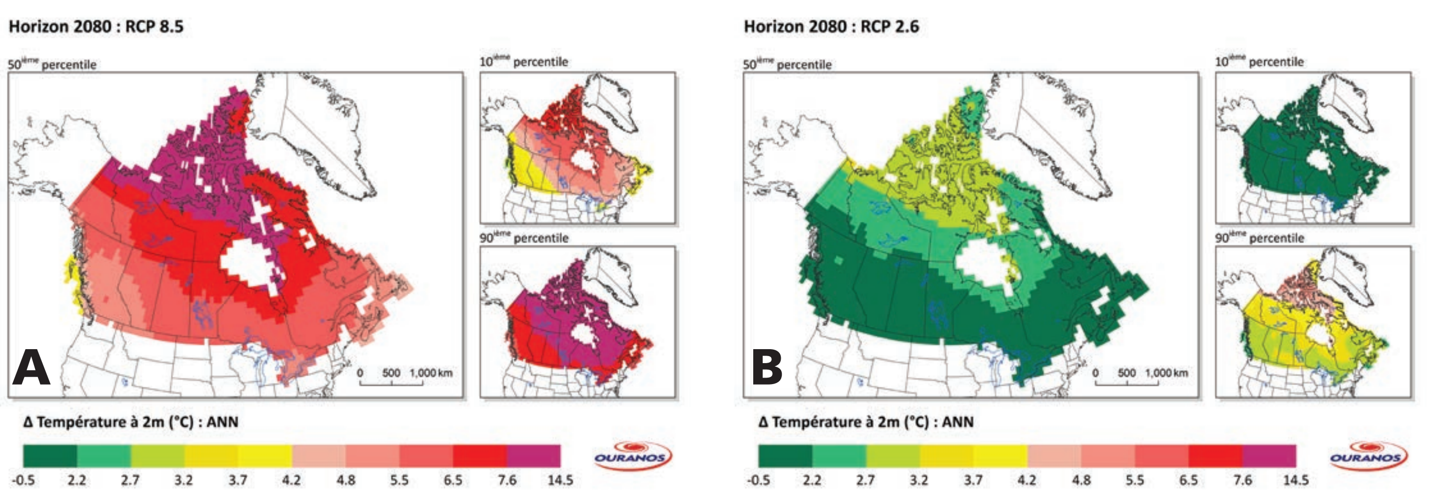
We came together as a group in 2014 because the Paris Climate Conference in December 2015 offered a critical opportunity to move action forward. Canada today is not the same as it was then. We are proud of federal, provincial and territorial governments and Indigenous chiefs across the country who came together and agreed, at the highest level of decision-making, on the *Pan-Canadian Framework on Clean Growth and Climate Change*.

This important document, however, marks the beginning of changes, not the end of the road. To succeed in the energy transition, it will be necessary to move beyond the general objectives of the *Framework* and adopt appropriate, specific policy tools and regulatory measures based on evidence and best practices. The current ambition will not allow us to reach our destination—a world that will have avoided a global temperature increment greater than 2°C (Figure 1.0).

Figure 1

PROJECTED DIFFERENCES IN TEMPERATURE

A: A business-as-usual scenario (RCP8.5) and **B:** An ambitious-effort scenario limiting the global temperature increment to less than 2°C (RCP2.6)[1] based on two Representative Concentration Pathway (RCP) scenarios used in the Intergovernmental Panel on Climate Change *Fifth Assessment Report*. The colours indicate change in annual mean surface temperature between two periods: 1971–2000 and 2071–2100.



Commissioned by Natural Resources Canada in Fall 2016, *Re-Energizing Canada: Pathways to a Low-Carbon Future* bridges decision-making and academic thought around energy and climate change, offering a number of suggestions on how Canadian governments, companies and citizens can advance the goals of the *Pan-Canadian Framework*. We draw on data, peer-reviewed research and other relevant documents to explore the challenges and opportunities in achieving a low-carbon energy transition that will form the foundation of a sustainable future. The findings of this overview and of the full report, the opinions expressed and the actions proposed come from the authors and do not reflect the opinions or policies of the Government of Canada.

At the onset, we identify governance issues as central to a successful low-carbon energy transition. While we recognize the vital role of technology, we believe that the key barriers to accelerating the low-carbon energy transition are social, political and organizational. Our report is, therefore, not as technological as could be expected in a discussion of energy. We are aware that Natural Resources Canada is developing science- and technology-focused contributions to inform discussions on the energy system transition.

After reviewing hundreds of articles and reports, and analysing much data, we are convinced more than ever that Canada has an opportunity to drive innovation and deliver benefits now and into the future by tapping our vast renewable energy potential and know-how to make the transition away from fossil-fuel-based energy systems.

Re-Energizing Canada: Pathways to a Low-Carbon Future is an independent, scholarly report on the transition to low-carbon energy produced by 71 scholars from Sustainable Canada Dialogues, a network of academics from diverse disciplines and all provinces. At the invitation of Natural Resources Canada, this report examines how Canada can decarbonise its economy while remaining globally competitive.

WISDOM OF AN ELDER

We are living in an environment of chaos and uncertainty. The current reality that we are living in today is in need of change. We cannot continue to walk the current path that threatens the future for all of us. It is our opinion that the real change needed around climate change is a change of the heart. We must become stewards of our own hearts before we can become stewards of the earth.

As Elders and Knowledge Keepers we share our knowledge to provide a direction that can help us move forward to a much more sustainable earth. Technological development has advanced without a foundation of values, which has brought a great deal of dehumanization and alienation to our present reality.

We don't advise you to build a pipeline, or not to build a pipeline, although obviously we are not in support of choices that harm the earth and our future.

We have an opportunity to set a completely new narrative. We can create a new economy and new opportunities for the nation based on stewardship.

We fully realize our current structures and systems will not change overnight. We have thousands of years of knowledge and experience on how to live in peace and in balance with nature. What is needed is to form an alliance, a reciprocal relationship with the earth supporting her natural laws.

Climate change should be viewed as an opportunity for us to reflect on ourselves and to make the necessary changes that will ensure a future for all our children.

- Elder Dave Courchene (Nii Gaani Aki Inini—Leading Earth Man)

Anishinabe Elder Dave Courchene spoke at the Turtle Lodge in Sagkeeng First Nation, Manitoba, at a gathering to discuss Indigenous perspectives on pipeline development in the province on November 18, 2016 (https://youtu.be/nMt5I9gpWTk). There were a diversity of participants in attendance, including federal and provincial government representatives, energy companies, environmental organizations, and other Indigenous Elders and leaders. Elder Courchene then offered his words for this report.

1. THE TRANSITION CONTEXT

To avoid potentially dangerous levels of climate change, Canada and more than 140 other countries[2] have made commitments to reduce their greenhouse gas (GHG) emissions to keep average global temperatures "well below 2°C above pre-industrial levels".[3] The *Fifth Assessment Report* from the Intergovernmental Panel on Climate Change has concluded that this will require constraining atmospheric GHG levels to "about 450 ppm CO_2-eq" by 2100,[4] implying a 90% reduction in energy sector emissions below 2010 levels between 2040 and 2070.[5]

Canada has also joined a group of more than 100 countries known as the High Ambition Coalition[6] advocating strengthened climate action, has subscribed to the United Nations' Sustainable Development Goals[7] and participates in Mission Innovation, an initiative of 22 countries and the European Union that aims to double investment in clean energy innovation over the next five years.[8]

Domestically, one of the focus areas of the *2015 Canadian Energy Strategy* is the transition to a lower carbon economy,[9] and the *Pan-Canadian Framework on Clean Growth and Climate Change* (hereafter the *Pan-Canadian Framework*), supported by the federal government, eight provinces and the three territories, is "a commitment to the world that Canada will do its part on climate change, and a plan to meet the needs of Canadians".[10] Key decisions include pricing GHG emissions across the country by 2018 and phasing out traditional coal-fired power production from the electricity system by 2030. The transition to low-carbon emission energy systems is now a real objective.

To explore the challenges and opportunities in achieving a low-carbon energy transition that will form the foundation of a sustainable future, this report builds on our own expertise and draws on peer-reviewed research, data and other relevant documents. As we developed our arguments, we assumed that the decarbonisation of energy systems will take place in a world in which other countries are also taking decisive action to move away from GHG-emitting energy systems. In Sections 2, 3 and 4, we explore energy systems, competitiveness and low-carbon energy governance. We highlight important lessons learned as a series of key findings throughout these sections. Section 5 illustrates plausible pathways to low-carbon energy systems linking energy supply and demand-side actions. Building on the evidence presented earlier, Section 6 makes specific proposals on a way forward based on our best knowledge. Finally, four 'discussion boxes' are included in the report, each ending with an overarching question. We chose not to answer these questions, but rather identify them as central to the discussion around the vision for the low-carbon energy transition.

It is possible, although not easy, to transform the way we produce and consume energy.[11] For two centuries, coal, oil and gas have powered the rise of industrial civilization. Our technological systems and contemporary lifestyles are highly dependent on low-cost fossil energy. In 2015, fossil fuels contributed over 80% of GHGs known to be driving climate change in Canada.[12]

At the same time, there are many ways to produce low-carbon energy, including hydro, wind, solar, biomass, geothermal, waste reuse, nuclear and carbon-capture-and-storage-equipped fossil facilities.[13] Dramatic efficiency gains—getting more energy services from a given energy input—are also possible, even with technologies that are currently available.[14] Today, the cost of many renewable energy systems is falling rapidly. Solar photovoltaics, for example, have declined in cost by 6–12% per year on average since 1998.[15] Moreover, technological and social innovations are ongoing; over coming decades, we can expect the emergence of novel solutions.[16]

Shifting to low-carbon energy systems will require substantial and sustained global investments over multiple decades.[17] The costs of inaction and consequences of accelerating climate change would, however, be unprecedented.[18] Today, the obstacles to accelerating the low-carbon transition are not primarily technical or economic, but political and social.

Experience with climate change policy over the past few decades nationally[19, 20] and internationally, as well as research on energy technologies,[21] innovation systems[22] and the history of socio-technical transitions,[23, 24] point to several broad features of the low-carbon transition:

Government and policy will play a crucial role in shaping the context within which businesses, communities and households can innovate and adapt.[25] While politics and policy play a role in most socio-technical transitions, they are particularly important in the context of the low-carbon transition.[26] Previous energy transitions were largely driven by immediate benefits—in cost and convenience—of moving to new fuels or energy carriers (e.g., gas or electricity), but it is now the long-term risk of climate change, public health and the volatility of energy markets that are motivating the shift towards low-carbon energy alternatives. Governments can anticipate and manage these risks with proactive policy that cultivates innovation.

The pace and orientation of the low-carbon transition will be linked to global markets and international negotiations. A strengthening of international action on climate change empowers Canada to be more ambitious, while a weakened resolve of our key trading partners makes domestic action more difficult—particularly by heightening concerns about economic competitiveness. Moreover, the research, development and deployment and associated cost-reductions of key low-carbon technologies will play out in global markets. The low-carbon energy transition will be an international effort in which Canada can aspire to play a leading role.

Canada faces particular challenges in advancing its low-carbon transition, including:

- *A carbon-intensive economic and social structure* that is a legacy of a development trajectory based on exploiting plentiful land and resources. This has given us an enviable average standard of living but some of the highest per capita and per unit of gross domestic product GHG emissions in the world.

- *A large, export-oriented fossil fuel production sector* that has provided wealth to specific regions, and to the country as a whole, but is now facing an uncertain future.

- *Complex constitutional arrangements* involving federal, provincial, territorial and municipal governments and Indigenous peoples[27] that make coordinated action difficult, especially when regional economic interests or cultural viewpoints pull in different directions.

It is not possible to know in advance exactly how the low-carbon energy transition will unfold. We cannot tell which promising technologies will pan out and which will disappoint, how the relative cost of specific energy alternatives will evolve or which social innovations will prove most productive. What we can do today is take decisions that set us off in the right direction, retaining flexibility to adjust as circumstances evolve, and identify low-carbon pathways that best correspond to a future Canadians will want to embrace.

2. TOWARDS LOW-CARBON ENERGY SYSTEMS

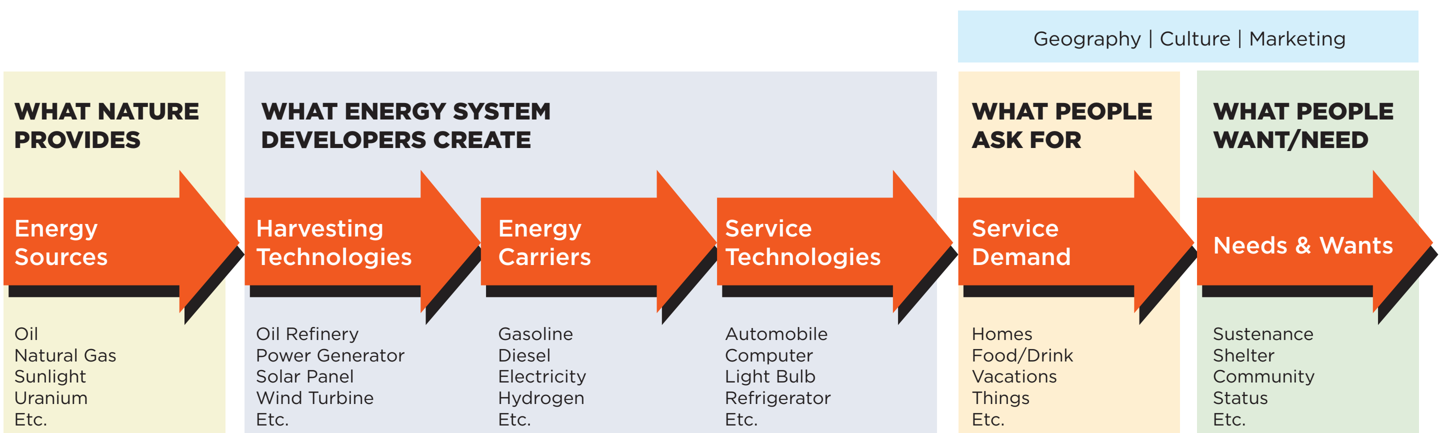
2.1 ABOUT ENERGY SYSTEMS

Energy systems link energy sources to the energy services that people demand (Figure 2.1). Those services meet our needs and wants for healthy food and water, shelter and community. They are also fundamentally shaped by geography (e.g., home heating demands are higher in colder regions), culture (one hot bath a month was once considered 'normal') and marketing (e.g., for bigger homes, faraway vacations and the latest digital devices). An analysis of national circumstances among G7 countries for 2002 showed that about 6% of Canada's per capita emissions were explained by climate and geography, suggesting that economic structure, aspirations and the level of consumption to which we have become accustomed play a powerful role in shaping both energy use and emissions.[28]

Technologies used to meet demands for energy services are often tied to a specific fuel (e.g., gasoline for a vehicle), thereby defining the harvesting technologies and energy source that must be in place. Many energy sources can be used to generate electricity, but these vary greatly in their geographic availability, environmental footprint and cost.

Figure 2.1

KEY COMPONENTS OF ENERGY SYSTEMS LINKING ENERGY SOURCES TO HUMAN NEEDS AND WANTS



2.2. ENERGY SUPPLY AND DEMAND

In 2015, Canada produced about 25.4 exajoules (EJ) of primary energy[29] and imported another 4.7 EJ, primarily as crude oil and natural gas, into eastern Canada (Figure 2.2).

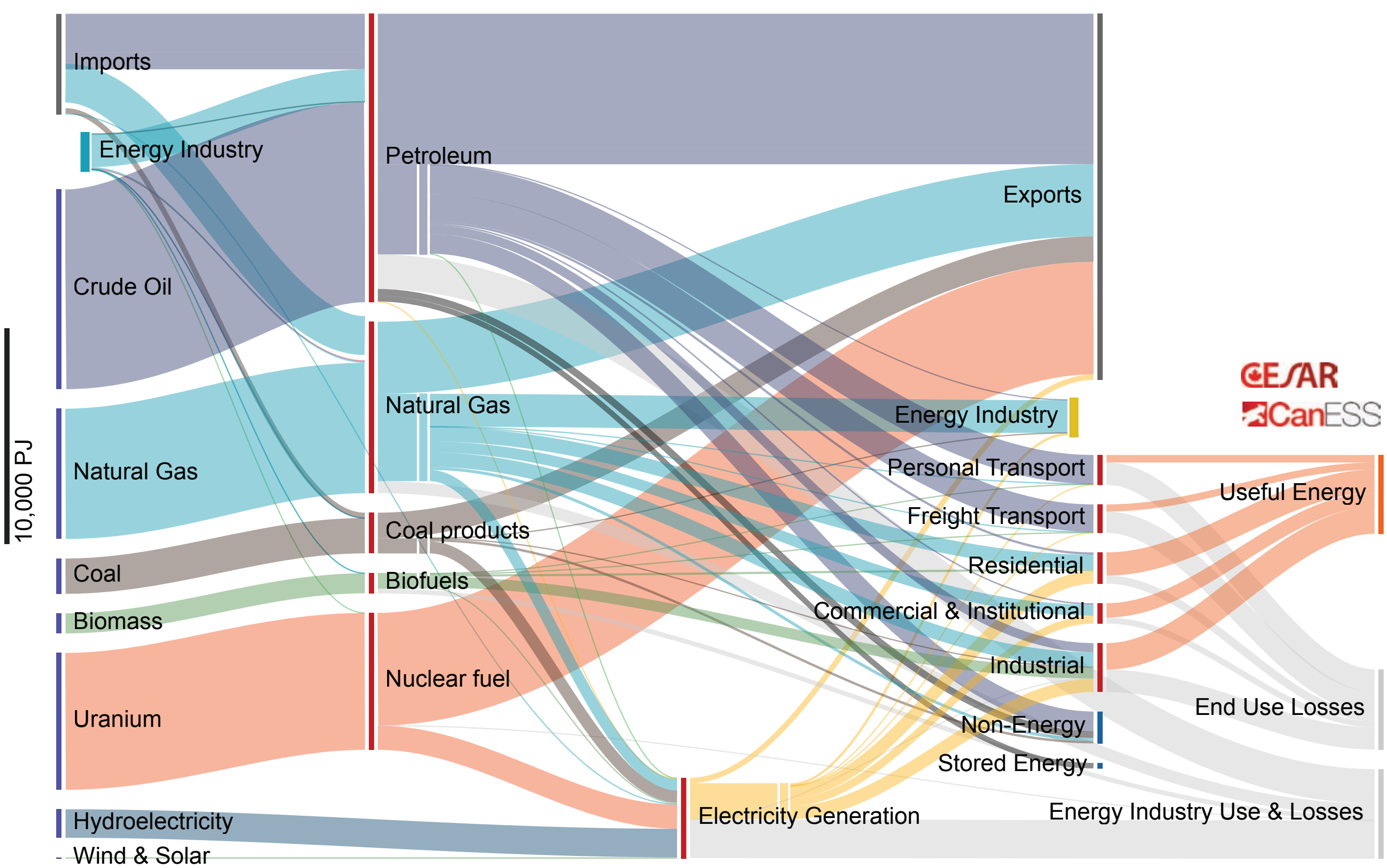
Canada is a significant energy producer on the world stage. We are currently the second largest uranium producer,[30] fourth largest oil producer and fifth largest natural gas producer.[31] Of the 30 EJ of primary energy flowing in 2015, 16.7 EJ (56%) were exported, predominantly to the USA,[32] as crude oil, uranium and natural gas.

Domestic fuel and electricity demand for transportation, buildings and non-energy industry sectors consumed another 9.1 EJ (30%) of primary energy. The remaining 4.3 EJ (14.1%) of primary energy was consumed in the recovery and conversion of energy feedstocks into fuels (e.g., gasoline and diesel) and electricity (Figure 2.2).

Figure 2.2

THE FLOWS OF ENERGY ASSOCIATED WITH FUEL AND ELECTRICITY PRODUCTION AND USE IN CANADA IN 2015

The vertical width of each flow and node is proportional to the energy processed by the energy sector, exported to other countries or used domestically in demand sectors.[33] © CESAR



In 2015, fossil fuels provided about 77% (13.3 EJ/yr) of the fuels and electricity consumed (Figure 2.2), compared to 86% worldwide.[34] The remaining 23% comes from uranium (9%), hydropower (8.4%), biomass (5.5%) and wind/solar (0.5%).[35] Expressed per capita, Canadians consume about 372 gigajoules (GJ) of energy per year. **[a]** One-third (118 GJ/capita) is associated with the recovery, processing and distribution of fuels and electricity, while the remaining two-thirds (254 GJ/capita) go to end-use demand, including:

- **Personal and freight transportation**, which are almost entirely dependent on oil products (purple flows in Figure 2.2). The average Canadian uses 76 GJ of fuel energy for this purpose, equivalent to over 1600 litres of gasoline per person per year;
- **Residential and commercial buildings**, which are primarily reliant on natural gas (blue flows in Figure 2.2) and electricity (yellow flows). Canadians use 67 GJ/capita for this purpose (about 18% of annual energy consumption);
- **The non-energy producing industries**,[36] which draw energy resources from oil, gas, electricity and biomass (green flows in Figure 2.2) and consume 63 GJ/capita (about 17% of annual energy consumption);
- Some fuels—especially oil products—which are converted to **non-energy uses**, such as plastics, fertilizer, chemicals, asphalt for roads and roofing tiles. About 41 GJ/capita (11% of annual energy consumption) are locked up in these materials.

2.3 INTERPROVINCIAL DIFFERENCES

The provinces and territories vary in the energy resources at their disposal, and in the way that they have developed and used these resources to support their populations and economy. Expressed per capita,[37] fuels and electricity consumed to provide energy outside the energy sector (i.e., for transportation, for buildings and by industry) varied among provinces by a factor of two (yellow bars in Figure 2.3A). However, larger interprovincial differences exist for other components of our energy systems (Figure 2.3A). For example, in 2013:

- Imported energy ranged from 141 GJ/capita (British Columbia) to 949 GJ/capita (New Brunswick)
- Non-energy uses of fuels (e.g., for chemical and materials) ranged from 0 GJ/capita (Newfoundland and Labrador) to 189 GJ/capita (Alberta)
- Energy use by the energy sector ranged from 17 GJ/capita (Manitoba) to 340 GJ/capita (Alberta)
- Primary energy production ranged from 23 GJ/capita (Prince Edward Island) to 6098 GJ/capita (Saskatchewan)
- Energy exports ranged from 7 GJ/capita (Prince Edward Island) to 6192 GJ/capita (Saskatchewan)

As a result, per capita GHG emissions (Figure 2.3B) varied widely around the national average of 20.6 tCO_2-eq/capita (tonnes of CO_2-equivalent per capita)[38], with Quebec showing the lowest emissions and Saskatchewan the highest (10.1 and 67 tCO_2-eq/capita, respectively).

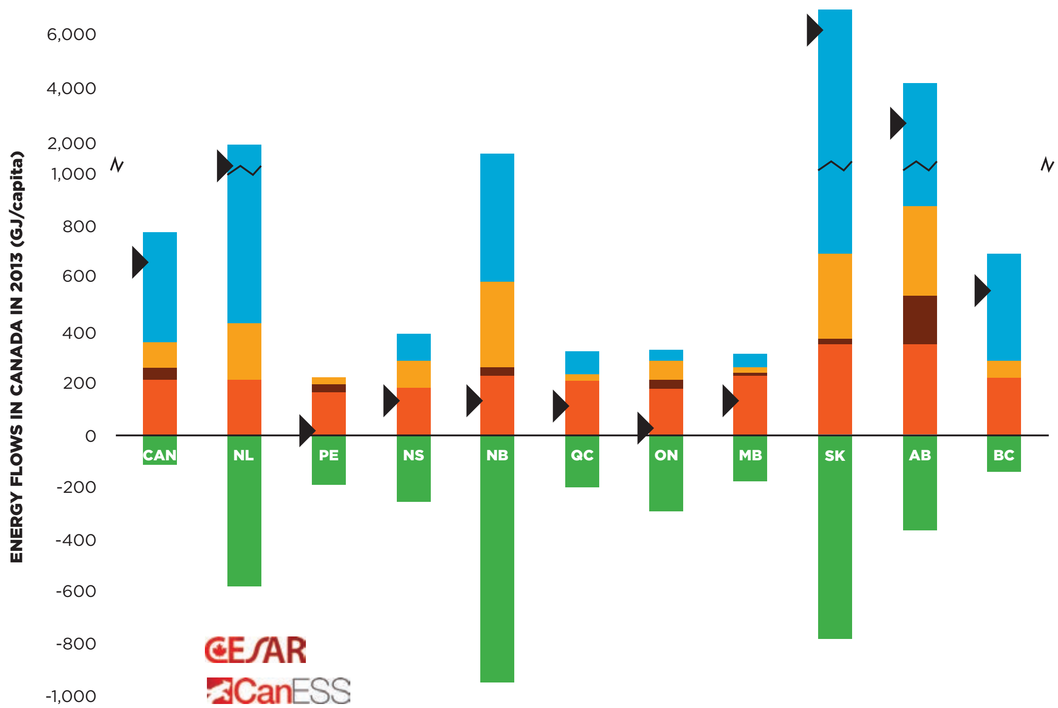
[a] By comparison, global energy use is about 80 GJ/capita.

Figure 2.3

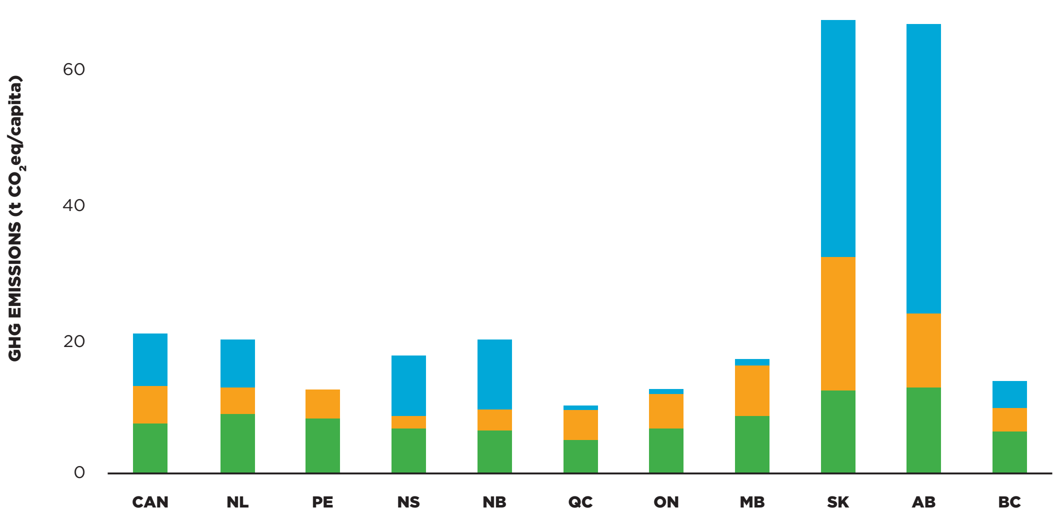
COMPARISON OF A: PER CAPITA CANADIAN AND PROVINCIAL FLOWS OF ENERGY IN 2013 AND B: PER CAPITA GREENHOUSE GAS (GHG) EMISSIONS IN 2014[39]

A: Imports are shown as negative values (green), while domestic consumption of fuels and electricity for energy services (orange), non-energy uses (brown) and energy use by the energy sector (yellow) are positive. Embedded energy in exported fuels and electricity is also positive (blue). The arrowhead shows the national or provincial production of energy.
B: Per capita emissions are shown for the energy sector (blue), non-energy industries (yellow) and transportation and buildings (green).

A



B



2.4 BRIEF REVIEW OF MODELING STUDIES THAT EXPLORE LOW-CARBON ENERGY PATHWAYS

The structure and nature of future energy systems have been modelled by multiple groups focused on decarbonisation, including:

a. **Deep Decarbonisation Pathways Canada Project [DDCP]** 2015. *Pathways to Deep Decarbonisation*[40]

b. **Council of Canadian Academies [CCA]** 2015. *Technology and Policy Options for a Low-Emission Energy System in Canada*[41]

c. **Trottier Energy Futures Project [TEFP]** 2016. *Canada's Challenge & Opportunity: Transformations for Major Reductions in Greenhouse Gas Emissions*[42]

d. **Energy & Materials Research Group [EMRG]** 2016. *Is win-win possible? Can Canada's government achieve its Paris commitment… and get re-elected?*[43]

e. **Environment and Climate Change Canada's [ECCC]** 2016. *Mid-Century Long-Term Low-Greenhouse Gas Development Strategy*[44]

Recently, Bataille (2016)[45] reviewed three of these studies (DDCP, CCA and TEFP) to identify lessons for stakeholders and policymakers. Building on his review, the following insights can be gleaned:

Deep decarbonisation of 60% or more is possible. TEFP and EMRG achieved 60–70% reductions; the DDCP concluded that it was possible to achieve up to an 88% reduction. Cost estimates ranged from \$200/tCO_2 [EMRG] to \$350/tCO_2 [DDCP] and \$650+/tCO_2 [TEFP].

Energy efficiency and conservation are critical. Scenarios with more energy efficiency and conservation, such as those achieved with transformed urban design, are essential to achieving more decarbonisation and at a lower cost.

Electrification with low-carbon power is essential. Electrification of distributed stationary energy uses (e.g., building space and water conditioning) and transportation (especially personal and urban freight vehicles) are essential pathways for decarbonisation, but could increase electricity generation demand by 150% to 200%. Existing fossil-fuel-based sources of power must be replaced and new generation demands met with very low- or zero-carbon alternatives like wind, solar, hydro, nuclear or fossil-fuel-based combined heat and power coupled to carbon capture and storage. Energy storage for backup renewables will be needed.

Heavy freight and aviation may be best served by biofuels. While mode shifting—more trains and fewer trucks, and high speed trains or hyperloops replacing aviation—could contribute to decarbonisation of heavy freight and aviation, there will likely be an ongoing demand for high density, carbon-based fuels. Biofuels could play a critical role in 'closing the carbon cycle' on this portion of future energy systems.

Meeting needs for intense heat in industry is challenging. Iron, steel, cement, chemical and fertilizer industries all require high temperatures that are now served through fossil fuel combustion. In the short-term, combined heat and power could be important in some provinces but, in the longer term, the emissions will need to be coupled to carbon capture and storage or to the heat provided by non-emitting sources like nuclear power or electricity.

KEY FINDING 1:

Models exploring energy futures agree that sustainable energy systems will rely on three key components: energy efficiency and conservation, enhanced low-carbon electrification and deploying alternative fuels.

Despite general agreement among models on the insights identified above, they differ markedly in the assessment of optimal pathways, policies and costs. Comparing the models is difficult, in large part because virtually all are proprietary, fully understood by very few individuals and, therefore, not transparent to others in how they work or what assumptions are made. This undermines efforts to inform decision-makers in government and industry about how best to set and meet climate change commitments while also achieving socio-economic objectives.

There is a need for technology-rich, open source, well-documented scenario and optimization models that will attract a wide range of users from across the country to add features, argue about assumptions, compare results and explore numerous possible energy futures. To feed these models, reliable data resources on the energy systems of provinces and sectors are needed. Such data are severely lacking.

KEY FINDING 2:

Improvements are needed in the quality of, and access to, data on energy systems. Federal and provincial governments should also support the establishment and improvement of technology-rich, open source, well-documented scenarios and optimization models that can be used by researchers to explore energy pathways and inform policy and investment decisions.

2.5 A MAJOR TRANSFORMATION OF ENERGY SOURCES

Canada's per capita demand for energy is among the highest in the world, similar to that of the USA and Australia but more than double that of the European Union.[46] No single sector of the economy is responsible for our high per capita energy use and emissions. We tend to drive large vehicles long distances, live in spacious homes in a cold climate and move freight by truck rather than by more efficient trains. Canada is also a large country with many natural resources—including oil, gas, minerals and agricultural and forest products—that require large amounts of energy to produce, extract and process. In the context of international climate agreements, Canada is responsible for emissions from energy used domestically, including emissions associated with the production of energy for export. Below are key elements of possible pathways to a low-carbon energy future.

2.5.1 INCREASING ENERGY EFFICIENCY AND CONSERVATION

Roughly one-third of domestic energy use is associated with fuel and electricity recovery, processing and distribution; one-third provides 'useful' energy services and one-third is a conversion loss associated with the service technologies (Figure 2.2, right-hand side). Even the fraction considered 'useful' energy is determined by lifestyle. For example, between 1990 and 2013, Canadians bought more light trucks or SUVs and average house size increased.[47]

There are many opportunities to promote energy conservation and improve energy efficiency. According to the Intergovernmental Panel on Climate Change, "scenarios with the greater efficiency and other measures to limit energy demand… show less pervasive and rapid up-scaling of supply-side options." Similarly, the International Energy Agency indicates that "energy efficiency, as well as structural changes and targeted energy conservation, are critical instruments to reduce emissions while supporting… economic growth."[49]

World markets invested US$130 billion in energy efficiency in 2014.[50] GHG cost-abatement curves suggest that energy efficiency measures like switching lighting to light-emitting diodes, insulation retrofits and improving motor system efficiency are most cost-effective.[51] Bashmakov et al. (2009)[52] provide a list of 15 major technical options to implement energy efficiency, including combined cycle natural gas turbines, efficient gas boilers and hybrid vehicles.

Energy efficiency in part rests on 'rediscovering' engineering to save energy. For example, industrial ecology examines how waste energy outputs can be turned into useful energy inputs, akin to coupling a heat-generating industry with an energy-hungry industry.[53]

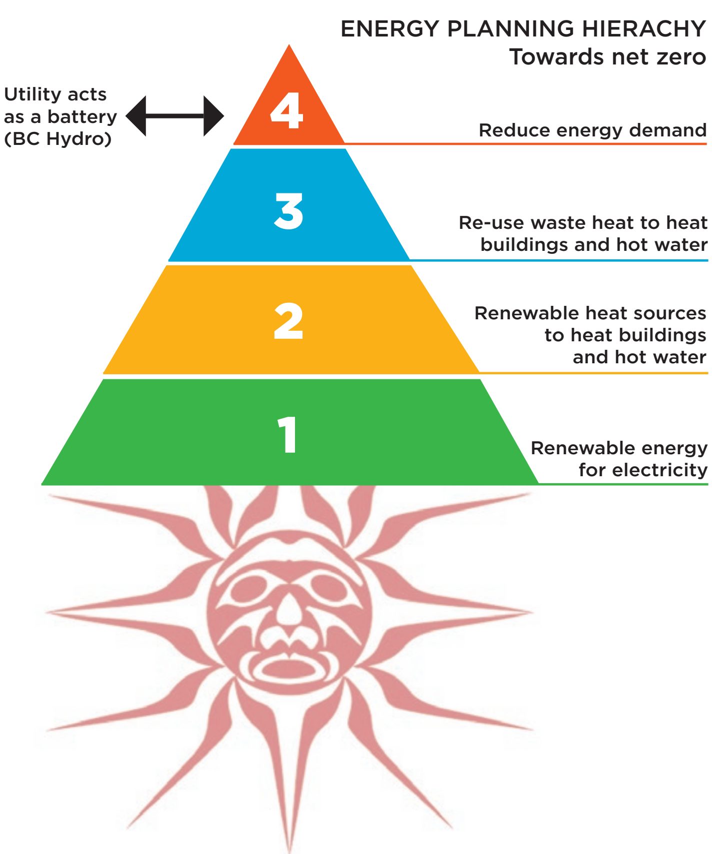
Energy efficiency measures also include making low-carbon options more readily available, as with safer and more convenient cycling infrastructure, and/or relatively straightforward technology like sensors that turn off lights when no one is in a room, or devices that learn for us (e.g., the Nest thermostat[54]). Zero tillage farming systems, for example, have been shown to reduce energy use compared to conventional tillage systems when annual crops are considered.[55] Searching for energy-efficient products can orient future technological development, for example intelligent technologies and innovations in management.

Forward-thinking energy efficiency paradigms proposed by Indigenous peoples have been recognized under the concept of indigenizing energy, which emphasizes the need for "connectedness, reciprocity and respect for the natural world".[57] Understanding the link between land and energy can guide resource development activities in support of the energy transition. For example, T'Sou-ke Nation's 'energy triangle' combines reduced energy consumption, re-use of heat and waste energy and low-carbon electricity. It illustrates the integration of technological action and behaviours when developing net-zero energy buildings in the most affordable way (Figure 2.4).

Energy efficiency and conservation are critical strategies for reducing or avoiding energy consumption and cutting costs at the same time. One such scenario developed for France, for example, which makes simple assumptions regarding the number of people per household, house size, kilometers traveled, speed limits on roads, number of passengers per vehicle and more, suggests that energy efficiency measures could reduce energy use by 49% for heating and cooling buildings, 67% for mobility and 48% for electric usage in appliances, electronics and computers.[58]

Figure 2.4

T'SOU-KE NATION'S INTEGRATION OF LOW-CARBON ENERGY SYSTEM ELEMENTS. ©T'SOU-KE NATION



KEY FINDING 3:

Improvements in energy efficiency and conservation are among the most cost-effective strategies to achieve low-carbon energy systems.

2.5.2 ELECTRIFYING WITH LOW-CARBON ELECTRICITY

Even though 80% of Canada's electricity is low-carbon, reliance on coal-fired power generation in some provinces leads to 2.6 tCO_2-eq of average per capita emissions associated with electricity generation (Figures 2.2–2.3). National statistics hide important differences among regions, however; understanding regional similarities and differences is crucial when considering the technology or policy options necessary to guide energy system transformations.

In 2013, Newfoundland and Labrador, Prince Edward Island, Quebec, Ontario, Manitoba and British Columbia generated electricity with emissions of less than 1 tCO_2-eq/capita, while New Brunswick weighed in at 4.7, Nova Scotia at 7.2, Alberta at 12.5 and Saskatchewan at 17.2 tCO_2-eq/capita (from Figure 2.3 data). The decarbonisation of energy systems will require high-emitting provinces to transform their technologies for electricity generation.[59]

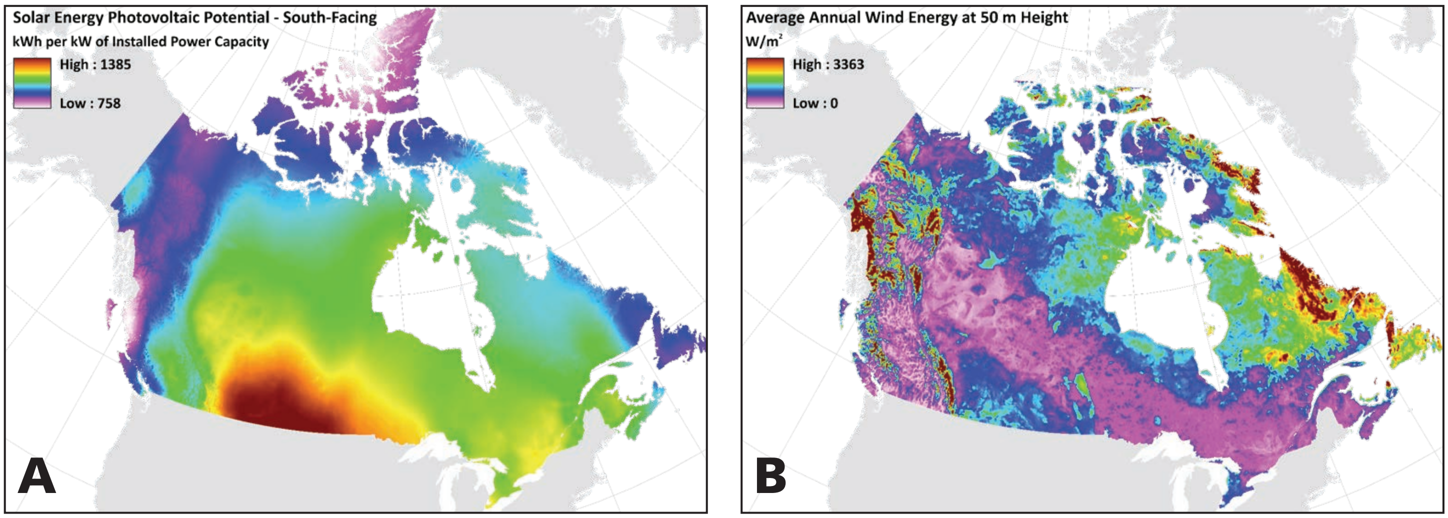
Renewable energy resources abound in Canada (Figure 2.5). Germany is working to build its electricity system around wind and solar; the country enjoys 1500–1800 sunny hours per year.[60] In contrast, Canadian cities that currently rely on high-carbon sources of electricity (Calgary, Edmonton and Saskatoon) receive over 2200 sunny hours per year.[61]

The Pan-Canadian Wind Integration Study indicated potential for increased wind generation in all regions, with 65 GW of installed wind capacity, providing 35% of annual system load energy.[62] Prince Edward Island already meets more than 25% of its electricity needs through on-island wind generation.[63]

Figure 2.5

SOLAR AND WIND ENERGY POTENTIAL

A: Annual solar energy potential based on daily average solar radiation from 1974–1993.[64] **B:** Wind potential. Data are average wind power densities at 50m height above ground level based on observations recorded every six hours from 1958–2000.[65]



In addition, tidal and wave energy might become part of future energy mixes. Nova Scotia hosts North America's sole tidal-barrage generating station at Annapolis Royal (20 MW) and a MW-scale in-stream tidal turbine (2 MW) in operation since November 2016. This turbine's potential impact on sea life is being monitored. In British Columbia, modelling suggests that hydropower and wave/tide power may be important for future electricity supply.[66]

Since variable renewables fluctuate hourly, seasonally and regionally, their deployment requires a storage strategy to ensure that power is provided when needed. Variations can also be balanced by combining energy sources in the same location.

Storage through hydroelectric dams can help to match energy production with demand. Norway's vast hydro reservoirs, for instance, enable high levels of wind power in Denmark and neighbouring countries.[67] Existing hydroelectric reservoirs in British Columbia, Manitoba, Quebec and Newfoundland and Labrador, which represent hundreds of terawatt-hours altogether, could serve a similar function.

One possible energy transition pathway would require interprovincial cooperation to strengthen grid connections within and between provinces and territories. Modelling suggests that in Saskatchewan, for example, importing electricity is the least-cost option.[68] Greater regional interconnectedness in the electricity grid can smooth out fluctuations across different regions.

Large hydro dams have significant environmental and social impacts. Calls for adopting environmental best practices in renewable energy development have been made following local populations' loss of access to pre-existing rivers[69] and new environmental health risks[70] (Box 1).[71] More recent large-scale hydro dams also show rapidly increasing costs well above current wind and solar energy prices.

1

For Discussion:

MINIMIZING ENVIRONMENTAL AND BIODIVERSITY IMPACTS

Conserving natural resources and the environment for both future generations and the welfare of other species is an essential element of a sustainable low-carbon energy transition. The ecological footprint of human society has nearly doubled over the past 50 years, with consumption exceeding sustainable use. Humans are depleting natural reserves and altering atmospheric composition.[72]

In Canada, more than 500 species are at risk of extinction and have been listed for federal protection.[73] Climate change is a rapidly growing threat; predicted extinction rates rise almost sixfold with a 'business-as-usual' global temperature increment.[74]

Energy infrastructures also raise important concerns for biodiversity.[75] Evaluating total and cumulative environmental costs per kilowatt of energy could allow selection of sustainable energy projects. For example, while run-of-the-river hydropower is often presented as an environmentally-friendly alternative to large, reservoir-based dams, it can have substantial additional environmental costs, for example when roads and power lines must be built to service many small-scale projects.[76] Integrated planning that accounts for cumulative effects is critical for reducing the total environmental impacts as well as infrastructure costs of novel energy sources.[77]

Going further, a no-net-biodiversity-loss commitment to evaluate potential development and energy projects could be assessed according to a risk hierarchy.[78] First, projects avoid placing biodiversity at increased risk. Second, projects reduce risks when avoidance is not possible. Third, any remaining unavoidable risks are repaired or offset.[79] Critically, offsets must be meaningful, satisfying the criterion of additionality[80] and ensuring that losses are more than balanced by gains of equivalent ecosystems (e.g., through reclamation, restoration and expansion of protected areas).

When sustainability is considered, low-carbon energy projects can reduce their footprint and coincide with other developments that limit negative impacts on the environment. Wind turbines that maximize the footprint-efficiency of hydro reservoirs,[81] floating photovoltaic arrays, and rooftop solar, geothermal heating and waste-to-energy biomass conversion in industrialized or urban areas are examples of strategies that contribute to reducing energy infrastructures' impact on natural ecosystems. Finally, energy efficiency and conservation reduce the need for expensive and potentially damaging energy infrastructure.

A commitment to environmental protection could become a field of innovation in itself, incentivizing the development of reduced-impact, low-carbon energy technology. For example, 26 measures have been identified to reduce bird and bat mortality due to wind turbines, and can be employed within a mitigation hierarchy during the permitting process.[82] Eliminating, reducing and offsetting environmental impacts is likely to increase social acceptance of renewable energy projects, avoiding the costly community conflicts that have hampered the transition to low-carbon energy.

How can the protection of environmental integrity and preservation of biodiversity be made integral elements of the low-carbon energy transition?

Current hydro infrastructure can be leveraged to support deployment of renewable energy production, considerably reducing electricity costs while taking advantage of the number of synergistic technological revolutions currently taking place in the electricity/energy sector. Batteries are an energy storage solution in certain small-scale applications. The near-term commercial viability of large-scale batteries to provide storage capacity to the electrical grid is also being demonstrated.[83] The rapidly falling costs and improved performance of renewables—particularly wind and solar—as well as energy storage technologies and development of 'smart grids' facilitate renewables' integration at all, including local, levels.

Demand response or smart grid technology can coordinate flexible energy demand with variable renewable energy supplies (Box 2). For example, the City of Summerside in Prince Edward Island runs its own electrical utility and owns a 12-MW wind farm. Using a smart grid and residential thermal energy storage system, the city can store excess wind power for subsequent home heating, allowing it to supply roughly half of its electricity needs from wind power.[84]

An analysis of the physical availability of renewable energy sources at the provincial level, which examined the match between energy demand and renewable energy potential, suggests that supply exceeds demand.[85]

2

For Discussion:

ENERGY SELF-PRODUCTION: CHALLENGES AND OPPORTUNITIES

Continuing decrease in the costs of localized and distributed energy production, and of storage and demand management technologies, creates new opportunities for citizen and community involvement in the energy system. Rooftop solar, for example, creates potential for household-scale power generation.[86] Coupled with cost-effective batteries or grid connection, these solutions are at the core of a citizen empowerment that could become characteristic of the low-carbon energy transition.[87, 88]

Such a development is already well underway in many countries around the world. Germany's Renewable Energy Act of 2000, for example, has enabled ordinary citizens to become stakeholders in the emerging renewable energy economy. In 2013, 46% of renewable energy capacity was in the hands of German citizens (35% individuals and 11% farmers), while the "big four" power companies controlled just 5%.[89] Combined with the dramatic rise in energy cooperatives (which grew from 66 in 2001 to 888 in 2013[90, 91]), this has transformed Germans into 'energy citizens' who are assuming an active role in the energy transition.

Some utilities already buy electricity produced by consumers. As prices for installing renewable energy production services continue to fall, utilities will have to adjust their business models as more citizens and industries move into self-production.

Without a clear vision and preemptive policies, this transition could however be painful, contributing to rising energy prices and financial costs for private and public utilities—which will affect all Canadians. Such a change could also raise equity issues. Not all Canadians will have access to the space needed to benefit from this opportunity. Additionally, self-production could be seen as a 'privatisation' of what, in many regions, has been a largely public sector activity.

In between citizens and large-scale utilities, energy cooperatives and not-for-profit local or regional entities have been proposed as one way to democratize access to, and control over, decentralized low-carbon energy sources, giving citizens a direct and active role in their energy future.[92]

What role should energy self-production play in future energy systems?

Nuclear is yet another low-carbon option for both heat and power; it currently provides a significant source of low-carbon electricity in Ontario and New Brunswick. Ontario has committed to substantive new investments to refurbish and greatly extend the life of at least one of its existing nuclear facilities.[93]

Despite the ability for nuclear to provide large amount of very low or zero-carbon base power, expanding its role is contentious, given concerns about waste disposal, proliferation risk, public acceptability and long-term economic viability. A year-long series of real-time, online dialogues on used nuclear fuel, which reached 10,000 Canadians,[94] showed that the issue of waste disposal is a concern.[95] Despite consensus around deep depository technology, a disposal site for high-level waste has yet to be selected by the Nuclear Waste Management Organization.

Research efforts are ongoing in Canada and around the world to address these concerns, including work on small modular reactors[96] that could provide combined heat and power. Successful advances in these technologies might improve the competitive positioning of nuclear energy as a low-carbon solution in the future.

KEY FINDING 4:

Given that 80% of Canadian electricity is already considered low-carbon and that many renewable resources remain untapped, Canada has the potential to achieve virtually zero-carbon and much-enhanced electrical production.

2.5.3 LOW-CARBON ALTERNATIVE FUELS

Low-carbon alternative fuels are the third key component of decarbonised energy systems. It seems likely that aviation and heavy freight will continue to require fuels that have high energy density by both volume and weight. It is important that combustion does not lead to a net increase in atmospheric CO_2 concentration. Fuels created from sustainably harvested biomass, electrochemical reduction of atmospheric CO_2 or electrolysis to produce hydrogen all hold promise but, to date, no pathways are economically viable or feasible at the scale needed to address the challenge.[97]

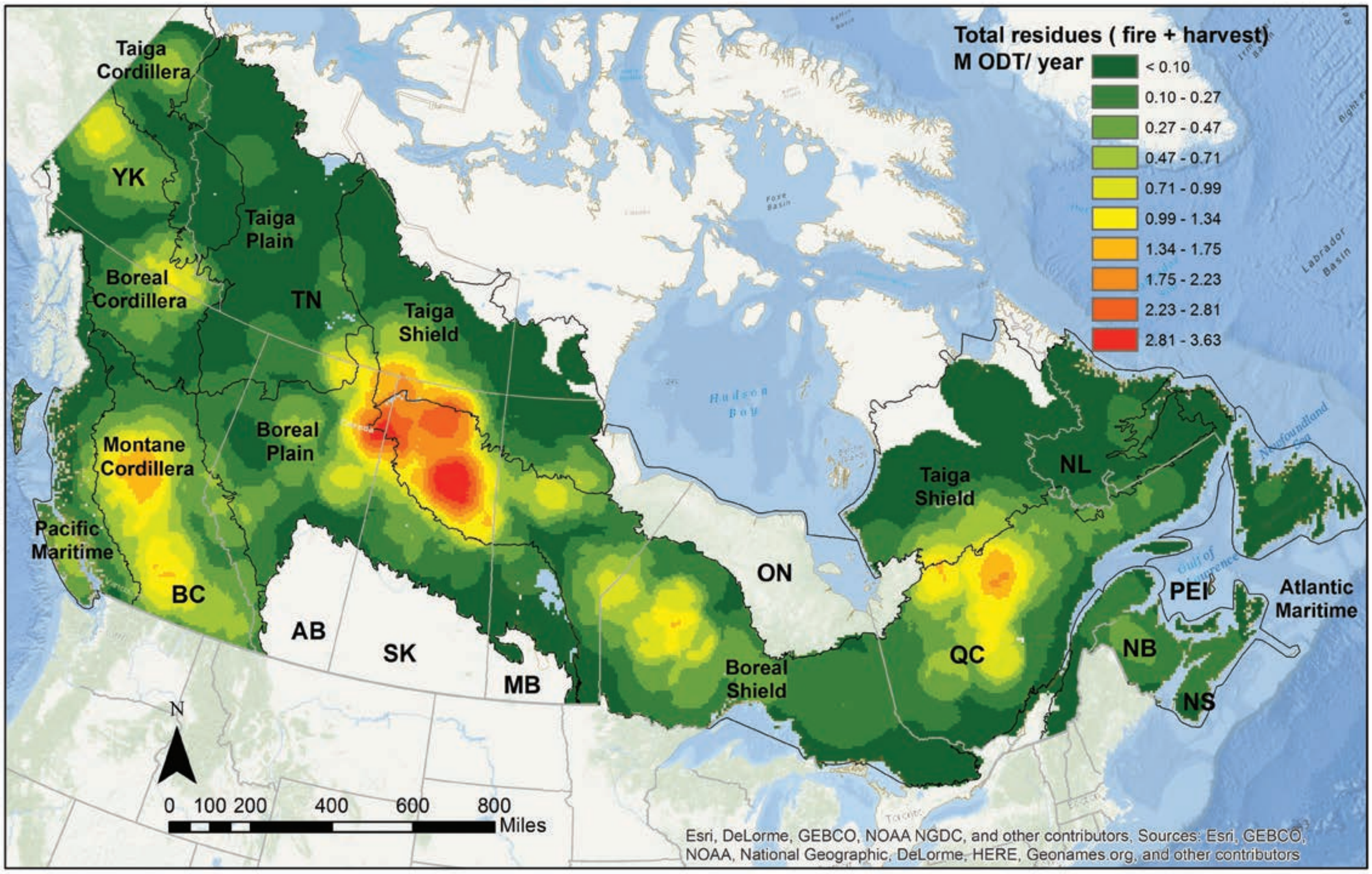
Biofuels are renewable if produced from sustainably sourced feedstocks, and can be blended at increasing ratios with fossil fuels, allowing existing infrastructure to be used during a shift to a greener economy. Growth of traditional biofuels—corn- or wheat-based ethanol and vegetable-oil-based biodiesel—may be limited by concerns that diverting food crops into fuel production will ultimately drive up food prices[98] and significantly expand agricultural operations at local, regional or global scales.[99]

Advanced ('second-generation') biofuels may be produced from non-food ligno-cellulosic (e.g., wood, straw and algae) feedstocks through a biorefining approach. These pathways may also generate co-products such as heat and electricity. Advanced biofuels are now being demonstrated at commercial scale in both the USA and Europe, with one major plant in operation in Edmonton. Such advanced biofuel capacity may be realized by leveraging existing infrastructure and building on established supply chains in agricultural and forest sectors.[100, 101]

The forest sector, in particular, may benefit from a biorefinery strategy,[102] through access to underutilized forest residues or opportunistic feedstocks such as insect- or fire-damaged wood (Figure 2.6). Canadian wood harvests for lumber, pulp and paper production are significantly below the sustainable, allowable cut mandated through legislation. One model suggests that residues, underutilized wood and opportunistic feedstocks could provide as much as 50 million dry tonnes/year. This feedstock is found over a widely dispersed geographic range and its quality is highly variable. However, with effective supply chain management, use of these feedstocks could dramatically increase the availability of advanced biofuels, leading to diversification and growth of Canada's bio-based economy. Advanced biofuels may also be produced with dedicated feedstocks such as energy crops (poplar or switchgrass) or algae. These systems would take many years to establish but may lead to further benefits.[103]

Figure 2.6

ZONES WITH HIGH POTENTIAL FOR FOREST BIOMASS FROM HARVEST AND FIRE RESIDUES, IN OVEN-DRY METRIC TONNES PER YEAR.[104] Reproduced with permission. © Canadian Forest Service.



On a life-cycle basis, emission reductions obtained by corn, wheat, canola and soybeans range between 30–80%,[105] but rise to more than 85% if using waste oils.[106] Biofuel emissions may be reduced by using waste as feedstock, which eliminate emissions associated with waste disposal and create a viable fuel output without the need to harvest additional feedstocks. Further emission reductions can be achieved by eliminating fossil fuel inputs; if these inputs are substituted by waste-based biofuels, the system may shift to one of net carbon sequestration.[107]

Per unit of thermal energy produced on combustion, natural gas generates less CO_2 than oil or coal (51 vs. 73 or 92 kg of CO_2 per GJ, respectively);[108] natural gas has thus been proposed as a bridge fuel for both electricity production, replacing coal, or transportation, replacing diesel or gasoline. However, natural gas is not a low-carbon source of energy, particularly when methane emissions from leaks are considered[109, 110, 111] since methane is a much more potent GHG than CO_2.

As a transportation fuel, natural gas has the benefit of producing lower particulate emissions/air pollution than gasoline or diesel, but unless the industries responsible for extracting, upgrading and transporting natural gas move quickly to dramatically reduce their fugitive emissions, there will be no credibility in claiming that natural gas can be a bridge fuel to a more sustainable energy future.

There is increasing interest in using bio-derived natural gas (renewable natural gas) to achieve reductions in overall emissions. When derived from waste biomass sources, including municipal solid waste, and generated via anaerobic digestion or through pyrolysis or gasification, renewable natural gas is a biofuel[112] that could be mixed into Canada's network of natural gas pipelines and reduce the GHG footprint of this energy source.[113]

Recent work has examined the production of methanol and dimethyl ether from a mixture of hydrogen and CO_2, reporting very advantageous reductions in overall system emissions compared to the fossil fuel reference case.[114] A pilot plant that can convert CO_2 into advanced fuels, such as gasoline or diesel, is currently being tested in Squamish, British Columbia.[115] These technologies are still in their infancy, but could provide a promising pathway towards a greener future economy.

KEY FINDING 5:
Low-carbon alternative fuels are a central part of the energy transition, especially to complement and eventually displace fossil-based diesel and jet fuel in heavy transport and airplanes.

3. INTERNATIONAL ECONOMIC COMPETITIVENESS

Energy has long been a central component of the Canadian economy, contributing substantially to its trade balance, with the strength of the Canadian dollar driven closely by the world market for oil and gas.[116] The future of this industry, in the context of a transition to a low-carbon energy society, is therefore a serious concern for many Canadians who depend—directly or indirectly—on jobs and revenues generated by the oil and gas sector. Canada's oil and gas production is mostly exported. Evolution of the sector is therefore largely determined by global prices and demand.

In the past five years, for example, sectors of activity related to oil and gas have contracted, following a fall in global prices, while other sectors have expanded, such as service-producing industries, including real estate and finance and insurance, as well as construction.[117] According to the International Energy Agency, a low oil price is responsible for curbing the growth of oil sands development, causing project delays and cancellation (e.g., Shell's Pierre River oil sands mine project) and reducing drilling activities since July 2014.[118] The International Energy Agency report states that the long-term outlook for oil sands development will depend on the duration of low prices, expecting "lower production growth post-2015" and noting that the Canadian Association of Petroleum Producers recently revised its forecast of growth downward but still expects growth of the industry until 2030.

Given Canada's commitment to reduce its GHG emissions and position itself as a leader in climate change mitigation, and worldwide uncertainty vis-à-vis the oil and gas industry, ensuring future competitiveness is paramount.

3.1 THE ENERGY TRANSITION'S EFFECT ON COMPETITIVENESS

Costs, prices, the capacity of firms to use innovative technologies and the quality and performance of products or services are critical factors that help determine a company's competitiveness.[119] Before adopting new policies to stimulate the low-carbon energy transition, it is important to examine how they could affect competitiveness of Canadian firms. Emissions Intensive and Trade Exposed economic sectors include manufacturing steel, pulp and paper, aluminum, industrial chemicals, fertilizers and other primary goods, as well as petroleum refineries and some extractive sectors—such as bitumen extraction and upgrading. They make up 5% of gross domestic product. In most provinces, they represent 1–4% of the overall economy. However, in Alberta and Saskatchewan these sectors represent roughly 20%.[120]

Economists have historically proposed various tools to help Emissions Intensive and Trade Exposed sectors respond to the low-carbon transition:

- **Exemptions**. Exempt a sector of concern from the policy to avoid impacts on its competitiveness.[121, 122]
- **Rebates.** Offer compensation to those sectors to offset any loss in profit or asset value due to the low-carbon energy transition.
- **Output-based recycling.** Rebates conditional on plant output are sometimes known as output-based rebates.[123]

It is important, however, to look beyond each firm when assessing global competitiveness. Economic activities that have adverse side effects on the environment and societies, such as pollution and health impacts, can influence the future competitiveness of a country.[124] These factors must be considered when discussing transitions to low-carbon energy; international competition must be balanced with Canadians' increasing expectations of the social and environmental responsibilities of businesses.[125] Considerable evidence is emerging that the implementation of environmental measures will, in the long run, increase profitability through cost reductions and revenue generation.[127] These transformations can be monetized through 'green branding', which has been identified as one dimension of competitiveness in a world where consumers—and employees—are increasingly conscious of environmental degradation.[128]

Businesses differ in their responses to environmental pressures. Reactive companies tend to resist change in part because of policy uncertainty,[129] limiting growth in the capabilities needed to compete in a low-carbon energy world. Others, taking a long-term view, integrate a broad range of approaches, including investments in alternative energies, multi-stakeholder dialogue and energy efficiency to favour long-term competitiveness.[130] For example, recognizing that the reputation of the oil sands industry was declining, along with access to markets (e.g., pipelines), 12 oil sands companies launched Canada's Oil Sands Innovation Alliance (COSIA) in 2013 with the goal of accelerating the industry's environmental performance through collaborative action.[131]

KEY FINDING 6:

The ability of companies to be proactive when facing environmental challenges has been shown to influence their future competitiveness.[132, 133] Canadian firms could anticipate change and prepare for the low-carbon energy transition.

3.2 NURTURING INNOVATION

Despite a strong record in academic research, business innovationin Canada is comparatively weak by international standards.[134] Canadian businesses have often acquired innovations from the USA, and have been satisfied with exporting to the large US market. Canadian businesses have nevertheless thrived, providing little motivation for change. Enhanced innovation could be beneficial in view of environmental challenges and volatile oil prices.

Innovation policy provides a critical lens through which to view the low-carbon energy transition. Innovation is highly prized in dynamic modern economies, being understood asa gateway to competitiveness, jobs, markets and continuing prosperity. The innovation policy literature establishes aset of general policy conditions for an innovative economy, including macro-economic stability and appropriate intellectual property regimes, as well as defining more targeted measures that can provide financial support at different steps in the innovation chain.[135, 136]

In relation to the low-carbon transition, three important caveats are in order: First, low-carbon innovation requires specific policy support.[137] Second, low-carbon innovation should not be reduced to technical innovation; it also involves business practices, social approaches and financing mechanisms.[138] Third, social innovations that are not necessarily commercially marketable may also contribute to decarbonisation and improve quality of life.

To date, energy research, development and deployment (RD&D) expenditure largely targets the fossil fuel sector. Between 2011 and 2015, federal and provincial investments in RD&D totalled $2,261 million for the fossil fuel industry, including carbon capture and storage, and $1,394 million for renewable energy.[139] The *Pan-Canadian Framework*, however, includes an important place for clean technology, innovation and jobs, exploring ways to build early stage innovation, accelerate commercialization and growth, foster adoption and strengthen collaboration and metrics of success.

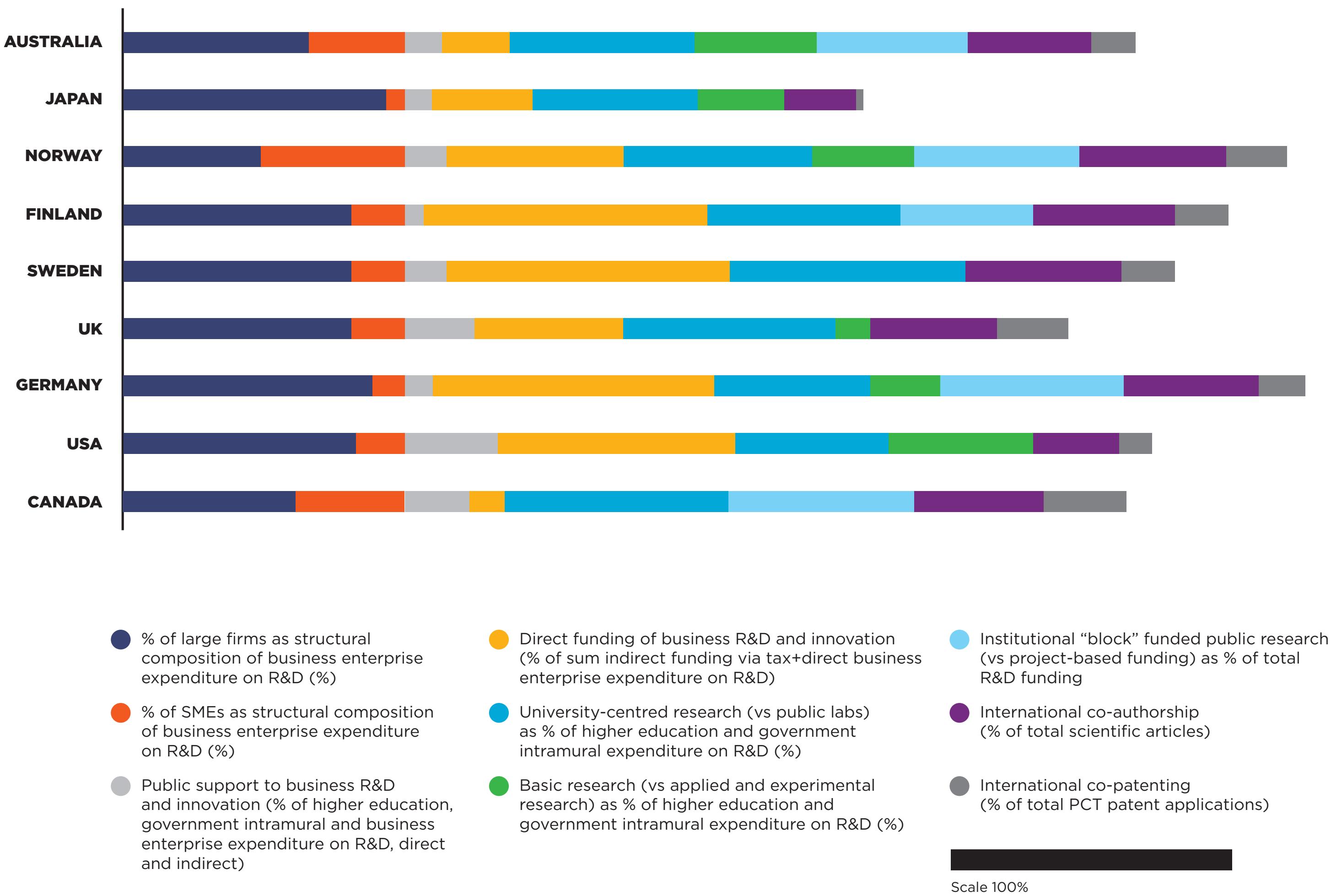
In recent years, considerable efforts have been dedicated to understanding how to become a global innovation leader.[140] An expert panel report commissioned by the Government of Canada proposed six recommendations to stimulate innovation,[141] including simplification of the Scientific Research and Experimental Development Program, using procurement to sustain innovation and helping innovative firms access the necessary risk capital. Another study identified access to finance and engagement with regulators as the most pressing barriers to clean tech industry scale-up.[142]

Recent scholarship suggests that the low-carbon energy transition demands a new model of relationships between energy users, energy producers, technology and government[143] with, for example, enhanced direct access to government for emerging innovators. It is also likely that multiple technologies will have to be deployed rather than a single breakthrough technology, and government will be called to play a variety of roles as buyer,[144] manager and market creator. Many of today's dominant technologies have benefited from direct government support (e.g., smart phones, the internet, biotechnology and pharmaceuticals), suggesting that direct government funding is important.[145]

Canada fares well in comparison to other members of the Organization for Economic Co-operation and Development with respect to investment in RD&D (Figure 3.1). However, Canada has relatively limited direct funding, suggesting that reconsideration of investment strategies and programs could be important. Budget 2017 proposes to establish Innovation Canada, "to simplify support to innovators" and initiate a review of business innovation programs[146] that could be informed by innovation research.

Figure 3.1

DISTRIBUTION OF INVESTMENT IN RESEARCH, DEVELOPMENT AND DEPLOYMENT (RD&D) IN 2012 ACROSS DIFFERENT CATEGORIES.[147]



Innovation goes well beyond direct funding, however. For example, an important challenge of sustaining innovation in the face of a complex problem like climate change is the inherent inability to plan and manage conventionally due to an unforeseeable future.148 Setting an appropriate context for innovation demands that government identify a direction for change broad enough to allow bottom-up exploration, discovery and learning. Following this approach, Denmark has adopted a low-tech bricolage strategy to develop wind energy, enabling learning and experimentation that eventually led it to be a world leader in wind.[149]

KEY FINDING 7:

While investments are necessary to nurture innovation in energy systems, equally essential are the willingness of businesses to take risks and the capacities of governments to provide long-term direction and support.

3.2.1 SECTORS WHERE CANADA COULD LEAD

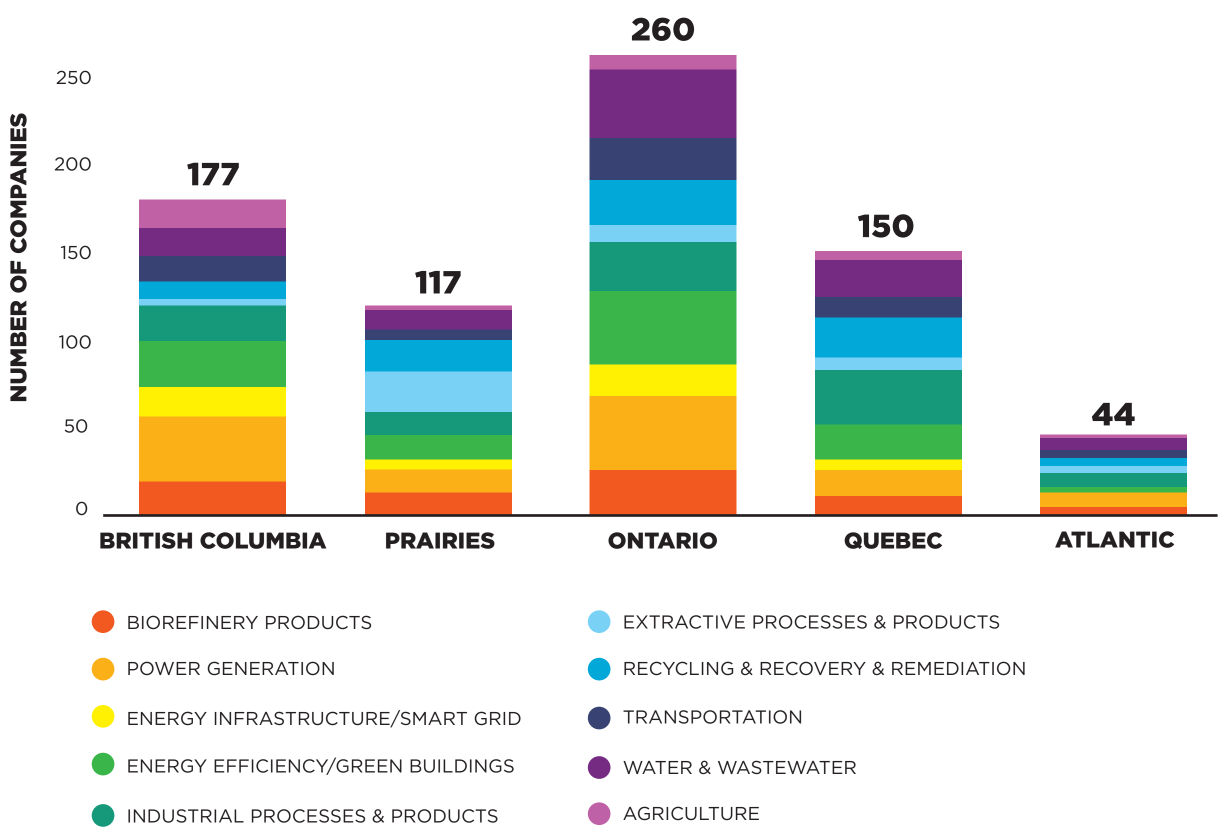
Canada's economy is small compared to that of the USA (9%) and the largest world economies, yet it can find its place in specific niches.[150] Canadian Solar, for example, has business subsidiaries in 24 countries and over 8,900 employees worldwide.[151] Opportunities for developing innovative low-carbon products and services are significant, diverse and often region-specific, for example: marine renewable energy in the Atlantic region, transportation manufacturing in Quebec, vehicle manufacturing in Ontario and carbon capture and storage in Western Canada.[152]

An analysis commissioned by Natural Resources Canada identified electric and hybrid vehicle components together with charging infrastructures and batteries as areas for leadership.[153] It pointed to opportunities in energy efficiency for building and industrial processes and noted global competitiveness in unconventional hydro, bioenergy, waste to energy, solar, off-grid project development, carbon capture and storage, fuel cell systems, biorefineries and biofuels.

The clean tech industry's current profile in Canada provides further indications on future competitiveness. In 2014, this sector had 774 firms generating $11.63 billion in revenue.[154] The breadth of the sector's focus is large—power generation, energy efficiency and industrial processes lead in terms of company numbers. According to Analytica Advisors, Ontario's strength in energy infrastructure or small scale grids, and energy efficient or green buildings is explained by provincial investments in renewable resources and intermittent energy management.[155] Biorefineries are a subsector of activity with great potential in the Prairies, where innovation has been targeting extractive processes and recycling, recovery and remediation (Figure 3.2). Solar potential in the Prairies and wind potential in the Atlantic suggest that power generation of the clean tech sector could improve greatly with the right incentives.

Figure 3.2

NUMBER OF CANADIAN CLEAN TECH COMPANIES BY SECTOR IN 2014. © Analytica Advisors 2016.[156]



Potentially competitive areas also include those for which innovation, investment and industrial foundations already exist and modernization can be achieved with limited efforts. For example, investors could take advantage of the oil and gas industry's expertise in designing and operating large engineering projects, including offshore installations, to run renewable energy projects like geothermal, offshore wind, wave and tidal.[157]

Transformative technologies in the oil and gas sector, using biological systems in petroleum reservoirs, nanotechnology or *in situ* hydrogen generation to turn petroleum reservoirs into either large-scale electrical power resources or hydrogen,[158] might also enable the industry to evolve with renewable energy developments. It could also be possible to develop geothermal from existing or abandoned oil wells.[159] Innovation also concerns energy consumption. Canada's large renewable energy potential coupled with its cold climate suggests that it could be competitive in novel, energy-intensive industries like data storage.[160]

3.3. FINANCING THE LOW-CARBON ENERGY TRANSITION

Historically, one of the major obstacles to widespread adoption of low-carbon energy has been the cost difference between producing electricity from renewables and non- renewables. Venture capitalists, individuals or companies that invest in start-up companies make their decisions on a predicted risk and return basis, typically investing for a 5–10-year period. They prefer to invest in projects with low capital intensity and high technology, such as energy efficiency, lighting, power storage and wind and solar projects. Projects with high capital intensity and high technology risk—like carbon capture and storage, advanced biofuels, unproven solar cell technology and wave technology—have difficulty finding funding and often require governmental support to bridge the 'valley of death'.[161] Government policy plays a key role in several domains, such as in creating feed-in tariffs, acting as a first adopter or large-scale procurer of low-carbon technologies, providing financial support or subsidy programs for research and development, reducing fossil fuel subsidies, pricing carbon, setting renewable investment portfolio standards and creating public-private partnerships.

New global investment in renewable energy has experienced a compound average annual growth rate of 18% from 2004 to 2015. Asset financing is the largest component of total financial investment. Wind and solar receive by far the most funding. In 2016, China (US$78.3 billion), Europe (US$59.8 billion) and the USA (US$46.4 billion) made the largest investments in renewable energy.[162] Companies may not want to take on the added risk of investing in new industries, businesses or technologies without a clear mandate from the federal government.

According to the Organization for Economic Co-operation and Development,[163] subnational subsidies to the oil and gas industry in Canada in 2014 totalled $3.1 billion. Subsidies were mostly from Alberta ($1.9 billion), British Columbia ($532 million), Quebec and Ontario (about $270 million each). Almost all provincial subsidies went to either the extraction or mining stage (34%) or to "other end uses of fossil fuels", for example in agriculture and forestry (65%). At the national level, subsidies totaled $123 million. Redirecting these subsidies to finance the low-carbon energy transition would create a stable source of financing that could be leveraged to attract private investors. By comparison, the sum of the pledges made by the federal government in the *Pan-Canadian Framework* to support climate action amounted to $321 million per year.[164]

Direct public ownership of low-carbon generation facilities provides another financing option to add to private investments. Hydro-Québec, Manitoba Hydro and BC Hydro have been able to provide affordable electricity due to the long-term benefits of public investments in addition to attracting an active cluster of private industries. Crown corporations could play a significant role in expanding low-carbon energy portfolios, especially where the private sector is reluctant to invest but where there are significant benefits to society—such as economic development opportunities and improvements to health and quality of life.[165]

Worldwide support for green technologies and GHG reductions has directly contributed to the emergence of numerous low-carbon initiatives from the private sector investment community that have the potential to help accelerate the low-carbon energy transition. Investors can green their investment portfolios by buying green bonds[166] and swapping fossil fuel companies for renewable energy companies. As of 2015, US$100 billion worth of green bonds has been issued globally.[167] In January 2016, Ontario issued its second round of green bonds worth $750 million,[168] and Quebec is following its neighbour.[169]

Fiduciary duties might lead public pension fund trustees to divest away from fossil industries, particularly as the risks of a warming climate become clearer.[170] The Carbon Disclosure Project, for example, measures and monitors company CO_2 emissions.[171] One source pegged the total loss to fossil fuel industries due to divestments at US$5 trillion as of December 2016.[172] Controls on carbon emissions could negatively impact companies through stranded assets, but climate change itself will also impact stranded assets.[173] The authors estimate that, for the present market value of global financial assets, this risk (or cost) of business-as-usual represents US$2.5 trillion. Investors, however, may expect that technology fixes will maintain the predominance of the oil and gas sectors, remaining sceptical of the world's ability to transition to cleaner energy sources.

Finally, given that energy, transport and building infrastructure lasts several decades and locks in development along specific pathways,[174] investments made at the time of renewing infrastructure are among the most efficient, as they entail little additional investment and financial flows.[175] To a significant degree, the low-carbon energy transition's pace will be determined by the replacement of aging infrastructure across the country and the need to address climate change impacts.

A broad perspective on the cost of the low-carbon energy transition could account for climate change's negative impacts on economic sectors. Under business-as-usual economic activities, costs of climate change are estimated to range from $21–$43 billion per year by 2050 ($2008 value).[176] Delay in domestic GHG policy action from 2012 to 2020 could cost an additional $86 billion from 2020 to 2050 in terms of firm investment.[177]

KEY FINDING 8:

A number of options exist to finance the low-carbon energy transition, calling for collaboration between the public and private sector.

3.4 ADDRESSING EMPLOYMENT

Transformations in the energy sector will reshape related job markets. The recent fall in global energy prices, for example, has had a major impact on employment in the oil sector. Estimates range from 47,225 jobs lost since 2014, primarily in Alberta,[178] to 75,000 direct oil and gas jobs lost, with direct and indirect impacts totalling 185,000 jobs.[179]

These losses are exacerbated by advances in labour-saving technologies that increase productivity and reduce employment in resource-producing sectors.[180] For example, the coal mining industry—which employed 8,790 workers in 2013 and 6,220 in 2015—is facing significant declines in employment,[181] probably due to continuing technological advances in addition to low international prices and, more recently, government climate change policies. The transition to a low-carbon economy will therefore be only one component of the transformation of the future job market, especially in export-dominated sectors. Yet, it is important to recognize that it can have significant negative or positive impacts on specific industries.

A *Workers' Climate Plan*[182] produced by Iron and Earth, a group of skilled tradespeople and oil sands workers, argues that by upskilling existing energy sector workers for related jobs in the renewable sector, building upon existing manufacturing capacity and actively integrating renewable energy into existing non-renewable energy infrastructure, Canada could position itself to ensure a just transition that benefits all provinces. In Germany, for example, renewable energy supported more than 350,000 jobs by 2015.[183]

Across the country, the potential for job creation in the buildings sector is large, given the number of buildings that need retrofitting and the small investment per job required.[184, 185, 186] Green building sector growth generates compound job creation effects through additional local design, planning and policy, and infrastructure and engineering jobs. Low-carbon construction also has high skill requirements, providing opportunities for the development of jobs with good remuneration and promising career paths.

Fossil-fuel-rich provinces can also count on their specific strengths to transition their economies as the international demand for oil and gas falters. Alberta and Saskatchewan both highlight agriculture, forestry, life sciences and manufacturing as key provincial economic sectors.[187] Minerals and biotechnology are other important sectors in Saskatchewan. Financial services, tourism and advanced technology industries, including information technology, clean technology and nanotechnology, are also key sectors contributing to the Albertan economy.[188, 189] In Newfoundland and Labrador, important current and future economic sectors include the fishery and aquaculture,[190] travel and tourism,[191] and advanced technology industries, including the ocean technology sector.[192]

KEY FINDING 9:

In the context of fluctuating prices and product demand, oil and gas companies will continue to face pressure. Specific actions should be taken to retrain oil and gas workers.

4. GOVERNING THE LOW-CARBON ENERGY TRANSITION

Transitioning to low-carbon energy entails a shifting constellation of private and public actors, through formal and informal mechanisms that can work to spur innovation across the country.

Energy system governance has traditionally been highly fragmented, with a variety of ministries and regulatory bodies responsible for different dimensions of the energy landscape.[193] Yet, as the International Energy Agency argued in 2015,[194] 'integration'—such as district energy or electrical interconnections—is critical for cost-effective decarbonisation strategies. This suggests that enhancing policy coordination and cooperation among governments at all levels is a critical issue for managing the low-carbon transition.[195]

4.1 TAKING STOCK OF THE CURRENT LOW-CARBON POLICY LANDSCAPE

Climate change mitigation targets often take the form of a pledged reduction in emissions with respect to a baseline. Canada's current target is a 30% reduction in economy-wide emissions from the 2005 level by 2030. This entails reducing emissions from 747 MtCO_2-eq to 523 MtCO_2-eq.[196]

Provinces and territories likewise have targets (Figure 4.1); the aggregate emissions resulting from these targets were calculated (Table A.1). For 2030, aggregate emissions amount to 535 MtCO_2-eq, roughly consistent with the national target.

The two main current federal policy measures to date include a 40–45% reduction by 2030 of methane from 'fugitive emissions' (emissions unintentionally released to the atmosphere by leakages during oil and gas production). Although information released in April 2017**[b]** suggests that the federal government now plans to postpone this measure, if it were to follow the schedule set in the agreement signed in March 2016, the measure would contribute reductions of 23.2 to 26.1 MtCO_2-eq. The second measure is the phase-out of coal-generated electricity, which as announced would result in a reduction of about 5 MtCO_2-eq.[197] These two 'key' measures together would only bring emissions from the energy sector down by 28.2–31.1 MtCO_2-eq, leaving a balance of 193–196 MtCO_2-eq to be found to reach the 523 MtCO_2-eq target.

The numbers are clear: Current policy measures are not sufficient to deliver on the main short-term Canadian GHG objective. The results of a review of existing energy modelling studies likewise suggested that the current policies are not sufficient to drive the low-carbon transition.[198]

For the long-term, the *Mid-Century Strategy* explores an economy-wide national reduction of GHG emissions of 80% below 2005 levels by 2050,[199] which would result in total national emissions of about 149 MtCO_2-eq (Table A.1). The present provincial/territorial pledges would result in 316 MtCO_2-eq, double the level represented by a possible 80% economy-wide emission reduction (Figure 4.2).

[b] http://www.ledevoir.com/environnement/actualites-sur-l-environnement/497582/trudeau-recule-sur-le-methane-et-sur-le-climat

Figure 4.1

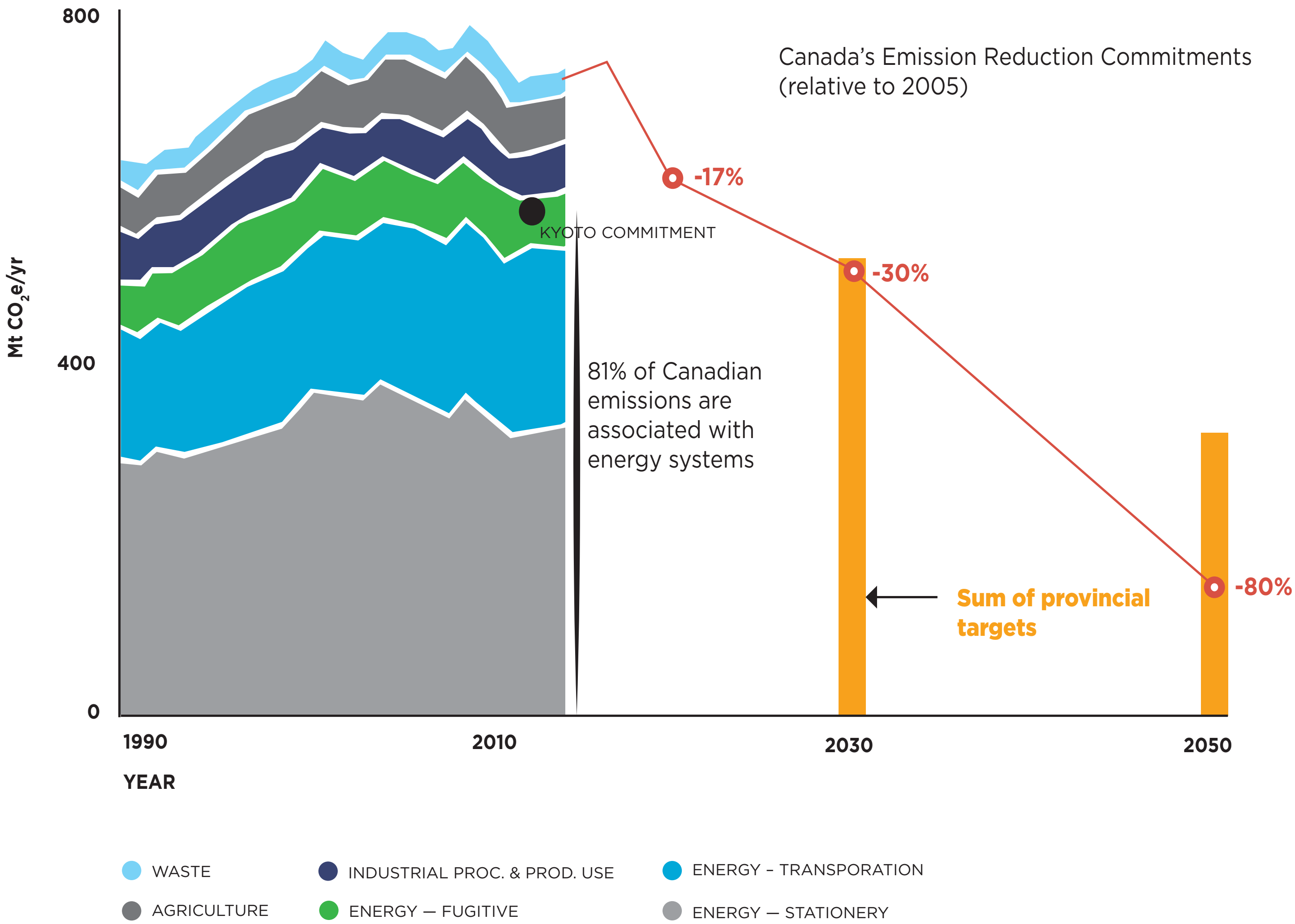
PROVINCIAL/TERRITORIAL LONG-TERM GHG EMISSION REDUCTION TARGETS

Targets taken from the *Pan-Canadian Framework*[200] unless otherwise specified. Canada's long-term target is that explored in the *Mid-Century Strategy*.

Figure 4.2

CANADA'S GREENHOUSE GAS (GHG) EMISSIONS (1990 TO 2014 DATA)[209] PAST, CURRENT AND TENTATIVE NATIONAL TARGETS (shown in red)

The yellow bars depict the sum of estimated emissions from provincial and territorial targets for 2030 and 2050 (See Annex I for explanation of calculations).



The ability to accelerate the low-carbon energy transition to meet emission reduction targets depends on the choice of appropriate policy measures. Because the energy sector represents about 80% of emissions (Figure 4.2), energy policies are critical to the low-carbon transition.

According to the International Energy Agency global database for renewable energy[210] and energy efficiency,[211] there are currently 13 regulatory policies in force in Canada to stimulate the use of renewable energy and 41 regulatory policies targeting energy efficiency. Several renewable energy policies focus on bioenergy (13/31 policies in force).

The *Pan-Canadian Framework* positions the energy transition at the core of Canada's response to climate change while maintaining a strong economy. Its policies can be analysed using the framework proposed by Hughes and Urpelainen,[212] distinguishing between policy approaches that target specific industries and those that apply across economic sectors (Table 4.1). Except for carbon pricing, the new measures proposed in Annex II of the *Pan-Canadian Framework* are regulatory in nature and targeted in scope.

Table 4.1

POLICY OPTIONS PROPOSED BY THE *PAN-CANADIAN FRAMEWORK*

Policies were classified using mechanisms most widely deployed internationally, including carbon pricing, subsidies, regulations, procurement and information provision.[213] The sectors targeted by the policy followed Hughes and Urpelainen.[214] The jurisdictions that could most likely implement the different policy options were determined.

POLICY CATEGORY	POLICY OPTIONS	TARGET EFFECT	JURISDICTION	ANNEX I: *PAN-CANADIAN FRAMEWORK*	EXAMPLES
CARBON PRICING	Cap-and-trade/ Tax	Environment	Federal and Provincial	Carbon pricing by 2018	
SUBSIDIES	Renewable energy certificates	Industry	Federal and Provincial		
	Users' subsidies	Industry	Federal and Provincial		• Tax credit for low-carbon vehicles • Retrofit incentives
	Feed-in tariffs	Environment and Industry	1st Provincial		
REGULATIONS	Portfolio standards	Industry			
	Pollution control	Industry	Federal and Provincial	Reduce methane emissions from oil and gas	
	Ban		1st Provincial	Phase-out of traditional coal-fired electricity by 2030	
	Performance standards	Industry	Federal and Provincial	• For natural-gas-fired electricity • Develop a clean fuel standard • Existing renewable fuel regulations • Reduce HFC consumption standards	• LCFS • Building codes • Zero-emission vehicle standards
GOVERNMENT INVESTMENTS	Training programs	Environment	Federal and Provincial		
	Public procurement	Industry	Federal and Provincial		
INFORMATION	Corporate carbon disclosure	Environment	1st Provincial		
	Certification	Environment	1st Provincial		Passivhaus
	Labelling	Environment	Federal and Provincial		Energy Star

Table 4.1 also shows that, while some policy measures such as feed-in tariffs, bans or certifications are mostly under provincial jurisdiction, the federal government has many options to facilitate the low-carbon energy transition. Spending power is key to the federal government's ability to stimulate this transition. The creation of the Infrastructure Bank, with a pledge of $35 billion, and a $2 billion Low-Carbon Economy Fund—as well as numerous other budget items announced in Budget 2017—is an encouraging development that shows that the federal government is keen on acting by financing.[215]

KEY FINDING 10:

The sum of the provincial targets is still insufficient to allow Canada to deliver emission reductions consistent with 80% below 2005 by 2050.

4.2 CHARACTERISTICS OF LOW-CARBON ENERGY GOVERNANCE

The scale of the change needed to tackle climate change is clearly beyond any one sector and level of government to solve and implement.[216] Mobilization of all sectors of society is needed. In this context, new governance approaches need to factor in the contribution that individuals and groups in communities make to place-based decision-making at the lowest appropriate governance level.[217, 218]

To implement its renewable energy and climate protection strategy, Germany's federal government, for example, empowers and resources states and municipalities, while bottom-up citizen leadership has emerged in municipalities. As of 2013, through federal government support, 136 regional governments, cities and rural communities with 21.2 million citizens (26% of the population) were certified with 100% renewable energy.[219] While citizens have provided leadership in climate protection and the *Energiewende* (energy transition), the federal government strategically enables and supports these initiatives through research institutes, ministries and strong targets embedded in federal legislation, eliminating barriers and sharing in the operational costs of municipal leadership.

In the Canadian context, key governance features include:

- **Establishing a permanent framework** for the provinces, territories and federal government to continue to work together at transforming energy systems;
- **Integrating the energy transition** within the work of relevant ministries and agencies and ensuring horizontal coordination across departments;
- **Re-examining the finances** and powers of municipal governments to ensure they have the authority and financial resources to play their part in the low-carbon energy transition;
- **Considering Reconciliation** as a fundamental building block while developing clean energy partnerships with Indigenous peoples;
- **Adjusting the mandates of energy regulatory bodies** at all levels to ensure they are empowered to pursue a low-carbon transition while enforcing social, health and environmental safeguards;
- **Creating frequent, iterative opportunities** to learn and change course in light of emerging technologies, market dynamics and social practices, based on robust monitoring.

Notions of multi-level governance and collaborative process design are not new and can serve to inform governance of the low-carbon energy transition.[220, 221] A congruent suite of federal, provincial and local government policy tools that are predictable, flexible and buttressed by a supportive regulatory framework could accelerate the transition.[222, 223] Congruence does not mean uniformity, but rather reflects the notion that policies that are pursued by different levels of government avoid unnecessary duplication and tensions and maximize synergies in their objectives and measures. As early as 2004, the Energy Dialogue Group representing 17 industry associations—including some of the largest energy producers and distributors—called on all levels of government to come up with clear, coherent policies on energy.[224] The Ecofiscal Commission recently pointed to a number of inefficiencies caused by lack of interprovincial and inter-territorial coordination.[225]

The diversity of regional energy systems offers an opportunity to experiment with, and learn from, the most effective and cost-efficient measures to transition to a low-carbon future. Policymakers could draw on the experience of different jurisdictions to ascertain the most effective policy for achieving a particular objective.[226] No single community or level of government has all the answers; given the diversity of Canadian geography, aspirations and governance systems, promoting and evaluating different solutions across the country is more likely to deliver socially desirable outcomes (Box 3). What will work well in Alberta will not necessarily do so in Quebec.

Adopting an experimental approach could be especially valuable to the extent that it would enable various governments and relevant stakeholders to agree on a shared framework of objectives, measures for assessing their achievement and regular processes for monitoring and deliberation, while providing flexibility in the specific means that are adopted for reducing carbon emissions from the energy sector.[227]

3

For Discussion:

DEFINING APPROPRIATE ROLES IN MULTI-LEVEL ENERGY GOVERNANCE

There is ongoing debate on the respective roles of the federal, Indigenous, provincial, territorial and municipal governments in the low-carbon transition, given that many provinces have adopted energy transition targets that are more ambitious than those of the federal government, whereas others oppose target-setting.

In 1992, the Supreme Court concluded that the provinces have primary responsibility where the environment is concerned.[228] They hold the power to regulate pollution and exploitation of most natural resources within their boundaries. As for the Federal Parliament, its powers are mostly subject-specific, relating to fisheries, navigation, offshore waters, the nuclear industry and interprovincial undertakings such as pipelines, trains, transmission lines and interprovincial and international commerce. Nevertheless, because of its power over taxation, the federal government can play a central role in energy and natural resource management, via policies enacted through fiscal incentives and spending to support greater sustainability.

Since different provinces will be affected very differently by the energy transition, a national perspective could ensure that all provinces are treated fairly, in terms of both contributing to the energy transition and receiving the funding necessary to transform their economies. Furthermore, important elements of the transition—such as efficiency regulations in many sectors, interprovincial energy transport and international commerce—are within federal jurisdiction. Since the federal level is responsible for Canada's international commitments, only a federal program would be able to ensure that these commitments are met.

Previous experience, such as the National Energy Program established in 1980, which lasted only five years, suggests that a top-down approach imposed by the federal government is unlikely to deliver the expected results. Real dialogue and collaboration between provinces and the federal government is therefore essential.

Other levels of government also matter. Municipalities, for example, are directly and indirectly associated with a significant proportion of energy use.[229] In the words of the Supreme Court: "Law-making and implementation are often best achieved at a level of government that is not only effective, but also closest to the citizens affected and thus most responsive to their needs, to local distinctiveness, and to population diversity".[230] This principle highlights the fact that local initiatives, especially at the municipal level, are as important as—and sometimes imbued with greater legitimacy than—actions targeting the whole country, even though municipalities do not have a protected constitutional role.

Given Canada's complex federated structure, what are the best ways for provinces, federal institutions and municipalities to collaborate?

In addition, responses to sustainability issues call for breakdown of the silos of traditional government departments.[231] Besides having **flexible and collaborative** governance arrangements, energy governance requires that decision- and policy-making processes be **transparent**.[232]

Social acceptability, a factor that may enhance the possibilities for a low-carbon energy transition, has been depicted as a triangle connecting policymakers, key stakeholders, local authorities, consumers and investors.[233] This model distinguishes between socio-political, market and community acceptance, where each of the abovementioned actors plays his/her part. The top-down tendency to 'consult' the public to obtain social acceptance, rather than working collaboratively to co-produce desirable outcomes, fails to recognize the unequal distribution of power within policymaking processes.[234] The absence of visible opposition is deemed tantamount to consent, when in fact it may mean an inability to access political institutions, ineffective or mistrusted processes or public disengagement.

As demonstrated in several countries where low-carbon energy practices or technologies have been linked to perceived gains in quality of life, status, resilience and/or cost savings, such practices and technologies may spread across neighbourhoods without intense promotion by government.[235, 236, 237] A new low-carbon energy governance can contribute to individual Canadians 'seeing' themselves as implicated in energy governance.

There is evidence that innovative participatory energy planning and visioning processes—both virtual and place-based, and led or hosted by local government or energy experts—can achieve citizen learning and promote changes in attitudes.[238] Grassroots and third-party mobilization on energy can lead to significant reductions in energy usage in relatively short timescales in neighbourhood or multi-family housing settings.[239] Successes have been associated with a range of factors, including close spatial proximity and local identity, pressure and cooperation or competition among neighbours,[240] and supportive partnerships with other actors like city staff, non-governmental organizations or other third-party intervenors.[241] For example, Gitga'at First Nation installed a smart metering program following community energy planning with the help of Pembina Institute.[242]

A just transition to a low-carbon future requires a vision of sustainability that is **inclusive, equitable, adaptable and holistic**, and that recognizes the importance of racial and gender[243] issues as well as the reality of poverty. The way that future communities look and function will depend on the distribution of low-carbon energy resources, economic development, citizens' cultural preferences and pre-existing infrastructure or urban form. Procedural inequalities and unequal access to institutions often limit the participation of lower income and Indigenous people and racial minorities in policymaking.[244, 245] Participatory models of governance can allow the emergence of solutions that simultaneously deliver multiple social and environmental benefits.

Consideration of those Canadians whose livelihoods might be threatened by transition is paramount.[246] The resource industries are particularly susceptible to cycles of boom-and-bust akin to the rise and fall of international oil prices in Alberta, resource collapse—such as that of the Atlantic cod fishery—and loss of competitiveness, as seen with forest products in the 1990s. If appropriate policy frameworks are adopted, it may be possible to reduce the risks of such sudden shocks during the decades-long low-carbon transition.

KEY FINDING 11:

The breadth of the energy transition affects all levels of government and a wide variety of stakeholders. To be successful, it will require ongoing collaboration, transparency and flexible mechanisms that allow for course correction.

4.3 POLICY FRAMEWORKS

The *Stern Review on the Economics of Climate Change* identifies climate change as "the greatest market failure ever seen".[247] Economic theory suggests that carbon pricing provides the most efficient way to spur economy-wide change, sending a clear price signal to businesses and households while allowing them to make their own decisions about when and how to adopt lower carbon alternatives.[248]

Yet, carbon pricing poses many political difficulties.[249] There is also clear evidence that, to address a problem as complex as climate change, measures like regulations, innovation policy and behavioural incentives are necessary.[250, 251] Furthermore, in some circumstances, regulatory policies are more politically acceptable.[249] The most substantial GHG reductions in recent years have been achieved by regulatory initiatives—in particular Ontario's coal phase-out.

With the adoption of the *Pan-Canadian Framework*, the country is moving towards a national carbon price involving distinct mechanisms in different provinces, and coordinating numerous complementary measures. To succeed in the energy transition, it will be necessary to move beyond the general objectives of the *Framework* and adopt appropriate, specific policy tools and regulatory measures based on evidence and best practices.

Transition pathways entail a combination of policy mechanisms that should constantly be evaluated according to their (1) economic efficiency, (2) environmental effectiveness, (3) political acceptability, (4) administrative feasibility,[253] (5) equity and (6) alignment with other social, economic and political goals. Over the past two decades, the international community has gained considerable experience with policies intended to secure GHG emission reductions and encourage the uptake of low-carbon energy alternatives.[254, 255] Existing literature discusses advantages and drawbacks of particular policy instruments and examines diverse national experiences.[256]

At the core of an effective policy effort, there is usually one or more mandatory initiative involving compulsory compliance. Voluntary and subsidy-based programs alone do not typically induce economy-wide changes at the desired scale and timeframe.

No single policy instrument can meet policy objectives across the range of economic sectors and spatial and administrative scales. California, for example, has various policy instruments covering all aspects of energy systems, including a carbon cap-and-trade program, stringent energy efficiency standards for appliances and buildings, an initiative to promote methane reduction on farms and encompassing policies for the transport sector.[257] While policy stability is broadly desirable to encourage investment, a successful policy mix necessarily evolves over time, calling for flexibility and a willingness to adjust policies rapidly when problems surface.[258]

A broad dilemma faced by governments is how to encourage the rapid uptake of low-carbon alternatives while simultaneously avoiding lock-in to solutions that are eventually proven suboptimal.[259] Substantial state support for a favoured technology can allow it to secure early market dominance while other, ultimately more beneficial but less mature, technologies are locked out. Such concerns have been expressed with respect to first generation biofuels vis-à-vis cellulosic alternatives, for example.

Partly to address this risk, it is sometimes argued that governments should *always* aim for ‘technology-neutral’ policy designs[260] that avoid ‘picking winners’, and leave it to producers and consumers to sort out which approaches will ultimately triumph, focusing the policies on objectives instead of technologies. However, such an approach is not always possible, particularly in the case of large-scale technologies with long-lived infrastructure or substantial environmental risk, or when a policy can serve as supporting the emergence of a world-class leader.[261] Moreover, uncertainties about which technology will ultimately succeed can impede deployment, as all parties hold back to see where things are headed. There is no simple or universal solution to this dilemma.

Public acceptance of renewable energy systems is not black-and-white; there are sometimes divisions within the community around tangible issues like local aesthetic impacts of energy infrastructure.[262] Evidence suggests that renewable energy projects “fare better when the public is engaged in the process and feels empowered about its results,”[263] through careful and equitable approaches to siting, design, viewscape management and revenue-sharing with affected people.

Beyond unfamiliar energy technologies, public acceptability of sustainable social practices and lifestyle changes related to energy may create barriers to a low-carbon energy transition. For example, higher density housing and high-rises, new transit lines and higher energy costs may be unacceptable to local citizens.[264] Social acceptance, in contrast, has been used to explain the fast spread of solar panels in Californian communities.[265] Such evidence suggests that social interaction and peer effects can be utilized within intelligent governance and engagement processes to increase the uptake of low-carbon living. A low-carbon energy transition will be facilitated by options that combine reduction in energy demand with improvements in comfort and lifestyle for citizens.[266]

Finally, transition policies must not only be designed, but also implemented and periodically revised to remain relevant, calling for appropriate institutional and organizational innovations.[267] The design of institutions is crucial to enhance the viability of energy-related projects.[268]

5. ACCELERATING THE LOW-CARBON ENERGY TRANSITION

To illustrate how the transition to a low-carbon energy system could proceed, we consider four 'fields of action'. These identify politically important arenas in which governments, citizens, communities and businesses can work together to use the low-carbon transition to build a better future for Canadians. While energy systems are often seen from the supply side, their magnitude and nature are largely determined by service demand.[269] The fields of action examine how changes in energy supply and demand can offer citizens and companies a range of attractive low-carbon options.

The first field of action focuses on transport, which today remains almost entirely dependent on fossil fuels. The second emphasizes cities, where most Canadians live and the energy transition can be made most tangible to citizens. The third relates to Indigenous communities, many of which remain disadvantaged and are often disproportionately dependent on fossil fuels. The final field of action highlights heavy industry, including the oil and gas sector, which poses considerable challenges in terms of the nature of its energy requirements.

5.1 FIRST FIELD OF ACTION: RE-IMAGINING THE MOVEMENT OF PEOPLE AND GOODS

Any realistic vision for a future sustainable society requires developing low-carbon means to transport people and goods over long and short distances. The transport system has been identified as the most promising demand-side sector for decarbonisation.[270] Options to gradually eliminate fossil fuels include improving vehicle efficiency, low-carbon fuels, increasing occupancy, developing alternative vehicle technologies, changing transport modes and reducing the need for transportation.

Freight transportation is an important component of the low-carbon energy challenge. Local delivery trucks are well-suited to electrification.[271] They tend to repeat the same limited-distance routes during daytime and can thus be charged overnight at a fixed terminal. A case in point: Purolator will be testing an electrified version of its familiar courier step van developed and assembled by TM4, Cummins and McGill.

Heavy Class 7 and 8 vehicles are more difficult to electrify because of their high energy requirements. These vehicles often haul heavy freight over long distances on hilly terrain. Nonetheless, bus makers have been able to tackle a similar challenge and vehicle manufacturers such as Tesla and Daimler have announced their intention to develop battery electric tractor-trailer trucks featuring long-range, fast-charging and autonomous-driving capabilities. Other companies such as Nikola Motors and WrightSpeed have adopted efficient reduced-emission hybrid-electric architectures for their tractor powertrain designs.

Beyond powertrain technologies, re-engineering delivery systems to improve the filling rates of trucks—while making sure they do not experience congestion when transporting goods—could improve energy efficiency. Options include reserved truck lanes, more flexible delivery hours, consolidation of deliveries and moving towards efficient urban logistics using right-sized vehicles.

Discussion of freight transport warrants examining the role of trains and water-based transport options for moving goods across the country. Taking a life-cycle perspective, trains have been shown to be more energy-efficient than both heavy trucks and medium heavy trucks by 77% and 86%, respectively.[272] In North America, freight train deployment has been growing and faces a capacity constraint.[273] Since interprovincial railways are under federal jurisdiction, they are one aspect of decarbonisation in which the federal government could advance by building on existing expertise in train engineering from Canadian companies.

Despite the potential energy efficiency gains from rail, the federal government has largely failed to drive transformation of the railway by ensuring access in cities willing to develop regional and suburban rail-based public transportation, efficient and reliable intercity passenger transportation and regional freight. Canadian railways specialize in hauling natural resources and other bulk commodities, and have sized and equipped their infrastructure accordingly, creating incompatibilities with the movement of higher speed passenger trains for local, regional or intercity passenger travel. Changing this would require proactive action from the federal regulator that favours public and private investments to increase the speed and capacity of train movement, as well as to electrify the rail corridor. A 2016 study on decarbonisation of freight transport in Europe identified key elements that determine transportation mode choice, including: transit time, door-to-door cost, service availability, safety and security, and environmental friendliness.[274] Considering these two last characteristics, the authors concluded that rail could have an advantage over other transport modes.

VIA Rail, AMT and GO Transit (MetroLinx) already own about one-third of the track needed to develop a high-speed electric train corridor between Montreal, Ottawa and Toronto. A second promising corridor in which the federal government could support infrastructure investment is between Calgary and Edmonton.

In regions of the country where rail is not a viable option for long-distance travel, passenger connections could be ensured by improved bus transit to stimulate emission reductions and efficiency. Recent adoption of the hybrid-electric transit bus was quickly followed by technology improvements towards complete electrification of the powertrain. Full-size battery-electric transit and intercity buses are now entering the market, with overhead fast-charging capabilities and optional large batteries offering ranges up to 500km on a single charge.[275] Given the recent purchase of several electric buses by large cities like Edmonton and Seattle and rapid growth of the electric bus market in China, investments have increased sharply to accelerate their deployment. The global electric bus market is expected to grow by 20–25% annually to reach US$85 billion by 2025,[276] and by then may dominate the market over conventional combustion engine propulsion in North America and China.

Electrification applied to road vehicles can increase efficiency fourfold.[277] The number of electric vehicles worldwide is growing by approximately 50% annually[278] and electric vehicles have the potential to displace fossil fuels at least in part.[279] Recent technological advances in lithium ion batteries are now available on the market.[280]

A revolution in transportation could be triggered by combining proven technologies like electric trains and emerging options like electric buses and autonomous electric cars with energy efficiency measures and low-carbon electricity.[281] The advent of autonomous cars[282, 283] is an important innovation in the industry.[284] These technologies may favour multi-mode mobility: Drivers and passengers will not be bound to their own cars, but rather able to call cars for the first or last kilometer of their journey, allowing greater integration with intercity trains and buses.[285]

Jaccard et al. (2016)[286] used a hybrid energy-economy model to compare outcomes from business-as-usual, emissions pricing and flexible regulation scenarios. The flexible regulation scenarios hinged on the transport sector, including: a partial-zero-emission vehicle standard mandating vehicle manufacturers to sell a minimum aggregate number of zero-emission vehicles; a low-carbon fuel standard requiring fuel distributors to sell increasingly low-carbon fuels; a truck emissions standard with greater stringency than current standards, as well as a low-carbon fuel standard for trucks; and phase-out of diesel and other fossil fuels for public transit buses, intercity buses and passenger and freight trains by 2030–2035. In addition, the model eliminated coal without carbon capture and storage from electricity production by 2030 and applied performance standards to industry. The magnitude of emission reductions driven by implementing the proposed suite of flexible regulations is similar to that obtained through economy-wide carbon pricing at ~$200 t$CO_2$-eq by 2030, and would reduce emissions by 45–55% below 2005 by 2050.

POLICY PERSPECTIVES: TRANSPORT

Transportation has the potential to become a focus for economic growth and development with a zero-emission vehicles mandate at its heart.[287] According to the McKinsey report,[288] electric vehicles and plug-in hybrids are sectors in which Canada can be globally competitive and that could benefit Ontario's auto and Quebec's public transport industries.

Technological development could be stimulated by immediate adoption of flexible regulations on partial-zero-emission vehicles and low-carbon fuel standards,[289] coupled with thoughtful regulation and planning regarding public and active transportation[290] and clear leadership from the federal government regarding rail and waterway transportation.

It has been suggested that a shift from privately-owned to shared-use vehicles could decrease energy emissions. However, a high level of automation could also lead to increased travel and related energy consumption, emphasizing the need to rapidly develop policy and measures to ensure that the deployment of autonomous vehicles will serve decarbonisation.[291]

5.2 SECOND FIELD OF ACTION: CITIES AS SUSTAINABILITY LABORATORIES

With almost 25 million people living in Canadian urban areas[292] and populations expected to grow considerably, cities are demonstrating leadership and pioneering new tools and programs on low-carbon transitions.[293] The proximity between municipal governments and their constituents[294] provides many practical opportunities for government to interact with businesses, community groups and citizens to mobilize energy conservation through lifestyle choices and behaviour change.[295]

Planning and managing urban growth have a central role in the low-carbon energy transition, affecting energy use with respect to both the built environment and mobility.[296] The transition requires a thoughtful shift towards compact, more complete forms of new and existing communities.[297] This shift has begun: Between 2011 and 2016, population density grew in all but two metropolitan areas.[298]

The city 'toolbox' includes smart density, mixed-use neighbourhoods, public transportation, walkable local environments, reduced space allocated to cars, revitalized urban centres and brownfield sites, whole neighbourhood retrofits and protection and expansion of urban forest canopy and green infrastructure.[299] Sustainable cities require more shared walls, higher building standards and, often, district energy systems that efficiently generate and distribute heat, reuse waste heat and provide cooling energy.[300]

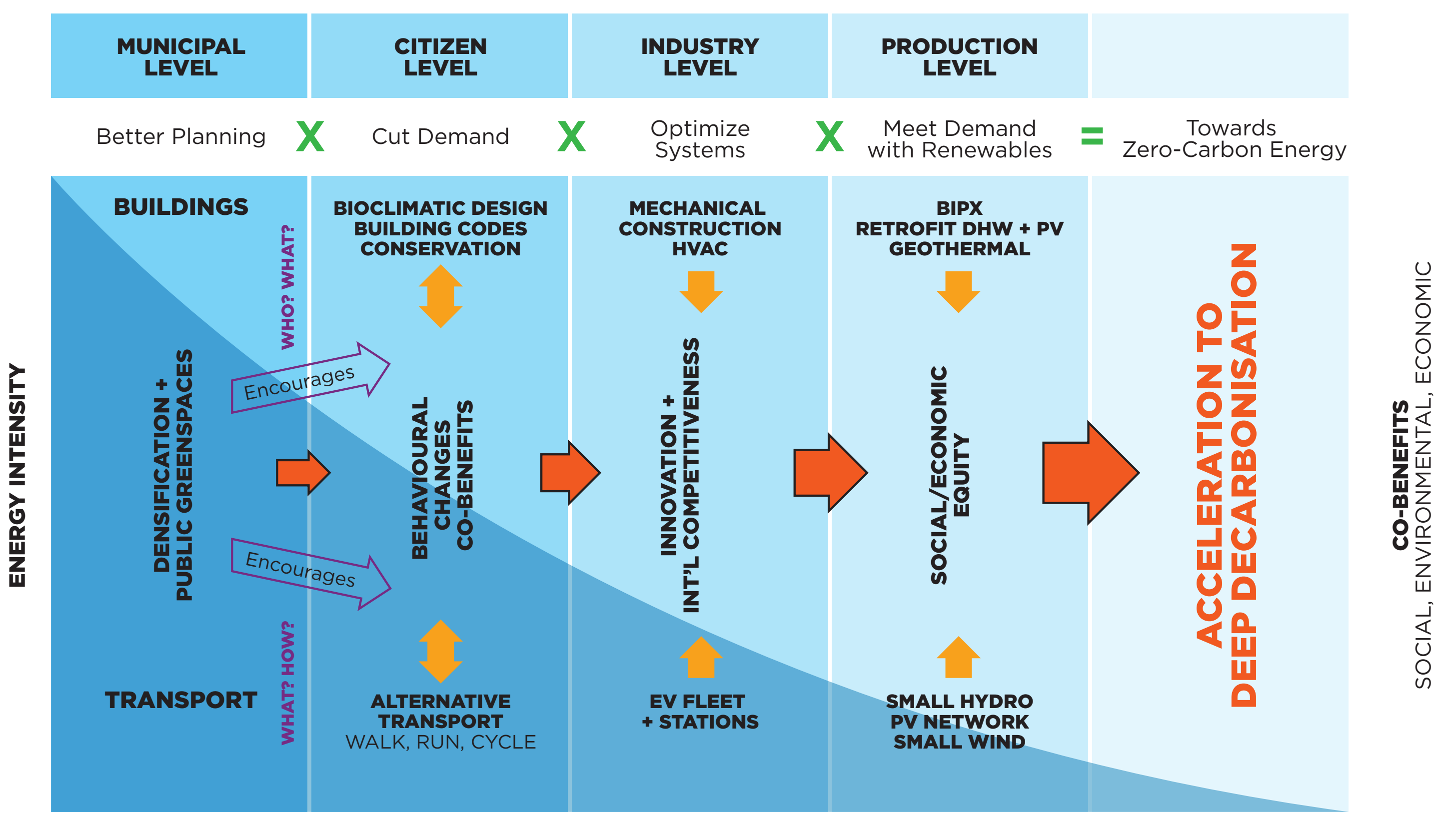
Novel, energy-efficient city planning could strengthen synergies between the individual household- and city-scale to accelerate the low-carbon energy transition and improve liveability. A framework to guide decision-making in the low-carbon energy transition (Figure 5.1) could include:

1. Reducing the demand for energy services through energy-efficient planning, infrastructure investments, appropriate urban densities, integrated greenspaces, diversity of public and active transportation options, stringent construction and retrofit standards (insulation and airtightness) and bioclimatic strategies such as daylighting, passive heating and cooling;
2. Promoting energy conservation through behavioural change of householders and commuters via education campaigns, social movements and shifting social norms;
3. Increasing the energy efficiency of installed utility systems and equipment that meet this reduced demand, by efficient heating, cooling, lighting, control systems and appliances; and
4. Increasing access to low-carbon energy supply for buildings and transportation.

Figure 5.1

THE MULTIPLIER EFFECT FOR ZERO-CARBON ENERGY/NET-POSITIVE CITIES

Concept development: A. Potvin, Université Laval.



Synergistic planning can provide considerable benefits. In addition to aesthetic, health and air quality benefits, urban forest canopy and green infrastructure contribute to offset the 'urban heat island effect'[301] and associated increases in energy demand.[302] TD Economics estimated trees in Toronto to be worth about $80 million annually.[303] Infill development on parking lots, houses above shopping centres, better transit, green networks to encourage active transportation and mixed land uses are other examples of neighbourhood changes that both save energy and increase residents' quality of life (Figure 5.2).

The pledge by the global organization Architecture 2030 to transform the built environment by modifying building codes so that existing buildings are 50% more efficient[304] and new buildings carbon-neutral by 2030, with buildings constructed under standards akin to PassivHaus (<15kWh/m^2) by 2050,[305] speaks to the level of ambition that could be taken up in the construction sector. This ambition is demonstrated, for example, by the award-winning Varennes Library building in Quebec.[306]

Figure 5.2

VISUALIZATION OF POSSIBLE RETROFITTING OF A HIGH-CARBON NEIGHBOURHOOD IN BURNABY, BRITISH COLUMBIA, TO REDUCE PER CAPITA ENERGY DEMAND WHILE SWITCHING TO RENEWABLES AND INCREASING POPULATION. Photograph by Stephen Sheppard and visualization by David Flanders and Peyvand Forouzandeh, Collaborative for Advanced Landscape Planning (CALP).

AFTER

BEFORE

Cities like Vancouver have already brought in strict new building codes.[307] Several residential, commercial and institutional buildings, such as Manitoba Hydro Place in Winnipeg, showcase the innovation of Canadian architects, engineers and the clean tech sector. At the residential level, the AYO Smart Home at University of British Columbia in Vancouver combines Indigenous architectural inspiration with modern technical advancements in energy efficiency to deliver affordable, innovative housing solutions to First Nations communities. The user-friendly construction approach empowers First Nations to participate in meeting the high demand for new housing construction in their own communities.[308]

Choice of building material also affects GHG emissions. Wood is a renewable resource produced in abundance with a considerably lower carbon footprint than concrete or steel, since wooden buildings provide long-term storage of carbon. Tall wood buildings are a growing trend globally, and University of British Columbia's new 18-story wooden residence, one of the world's tallest wood buildings, is a remarkable demonstration of Canadian innovation in wood products and design.[309] By recognizing the environmental and aesthetic advantages of tall wood buildings, building codes could contribute significantly to long-term reductions in GHG emissions.

While it is simpler to achieve high standards in new building and site design, many buildings pre-date current building code standards; 75% of homes were built before 2000.[310] Assuming a 30-year renovation cycle, the current building stock needs or will soon need retrofitting[311] through improved insulation, window glazing and air-leak sealing. Valuable experience on how to carry out massive retrofit projects for high-rises is accumulating[312] and stimulating whole neighbourhood-scale retrofitting through collective behavioural change and incentives via thermal imaging and incentives.[313] MyHEAT, for example, is an Alberta-based high-tech application of thermal imagery systems with the potential to guide energy-saving programs in Alberta and around the world.[314] MyHEAT will visualize, quantify and web-enable heat loss maps for over a million single detached houses in over 20 cities and towns in Canada by 2018. This represents operational HEAT-maps for three-out-of-five Albertans and one-out-of-seven Canadians, with many more in progress.[315]

With some regional exceptions, most homes and commercial buildings use natural gas for heating.[316] Electrification and the provision of lower-grade heating and cooling services could provide low-carbon energy. Successful precedents for replacing natural gas include: biomass in efficient district heat systems; solar hot water; waste heat from industry and sewage; and various kinds of heat exchange, such as geo-exchange, air source heat pumps and ocean exchange. A recent study shows that, for British Columbians, a combination of renewable electrical energy and intensive home retrofitting, along with these local sources of low-carbon community energy, could achieve 54–82% reductions in building energy use.[317]

City and neighbourhood design is also key to reducing the energy footprint of transport. Translink's Transit Oriented Communities guidelines for Metro Vancouver propose 'the 6 Ds' concept to guide development of urban mobility: destinations, distance, design, density, diversity and demand management. Prior to imagining strategies to decrease car use, the need to own a private car must be reduced. In private households, cars are usually parked up to 95% of the time for typical days of travel.[318]

In this context, cities are recognizing the economic opportunities and potential of car-sharing.[319] Provision of car-sharing services contributes to reduction in car ownership[320] and allows individuals and households to access a car when needed without the burden of private-car ownership. Communauto, for example, North America's oldest car-sharing company, chose to integrate itself into the 'transportation ecosystem' and encourage a shift in transport habits to complement rather than replace other forms of active and public transport.[321]

POLICY PERSPECTIVES: CITIES

The *Pan-Canadian Framework* approaches the built environment from the viewpoint of the building. We propose that a systems approach that puts cities and urban planning at the heart of decision-making has the potential to stimulate the low-carbon energy transition in cities while improving quality of life in urban spaces.

A possible basket of policies could include regulatory instruments, such as zoning and urban planning by municipalities, new building codes, emissions standards for vehicles, subsidies for home energy retrofits and electric vehicles, investment in public transit and development of informational tools to guide decisions.

Cities' potential in accelerating low-carbon solutions can be enhanced by revisiting how municipalities are funded. With income derived mostly from property taxation, municipalities are locked in a development pathway that favours urban sprawl, and have limited resources to pursue ambitious transitions.[322]

5.3 THIRD FIELD OF ACTION: SUPPORTING ENERGY INNOVATION IN INDIGENOUS COMMUNITIES

Indigenous peoples have historically borne, and still bear, a heavy burden from resource development on their land, be it oil and gas extraction, dam building or mineral exploitation. Over the years, the Supreme Court has recognized the importance of Indigenous peoples' rights. Canadian constitutional law, buttressed by the United Nations Declaration on the Rights of Indigenous Peoples recognizes that the rights enshrined in treaties and other agreements cannot be ignored. Indigenous peoples are partners in Canadian federation—through treaties and other agreements—with rights recognized in the Constitution. The rights recognized by United Nations Declaration on the Rights of Indigenous Peoples include those related to conservation, protection, ownership, use and development of the land, self-determination and self-government.

Energy transition policy offers an opportunity to engage constructively with Indigenous peoples on a basis of equity, seeking partnerships that enable self-governance, building energy security, economic opportunities and sustainable communities. As development and renewable energy projects spread in and around their territory, Ontario's Six Nations, for example, established the Six Nations of the Grand River Development Corporation to secure royalty payments, equity investment opportunities and employment, and ensure a role for community members in negotiations and approvals of such projects.[323]

Out of hundreds of renewable energy projects, ongoing research has identified 79 that are conceived and led or co-led by Indigenous communities in mostly the hydro, solar and wind energy sectors.[324] In many cases, sustainable energy projects contribute to local resilience and employment while also reducing a community's footprint. In a spirit of Reconciliation and in recognition of the nation-to-nation relationship, appropriate consultation, free, prior and informed consent, equity and partnerships must become a new cornerstone of the energy future.[325] Equity here means respecting Indigenous peoples' rights to self-determination and self-government[326] during the low-carbon transition.

Over half of Northern and remote communities require diesel to be transported across long distances for electricity and home heating.[327] Black carbon from diesel fumes can increase melting when landing on snow and ice.[328] In Arctic winters, atmospheric conditions trap diesel particles near the ground surface,[329] worsening the related health impacts. Transitioning to renewable energy could resolve the diesel dependency of remote communities while simultaneously addressing a myriad of other challenges (e.g., health and employment). While solar potential is limited to summer in the North, wind energy is promising for coastal and Arctic Quebec and Nunavut, and parts of the Yukon Territories and British Columbia. Wood is available as biofuel south of the Arctic tree line, and hydro has potential in the western Arctic.[330]

Taku River Tlingit First Nation in British Columbia combined a micro hydro project to help replace diesel-generated electricity,[331] geoexchange space heating and home retrofitting programs in an ongoing effort to shift the entire community away from diesel.[332] Taku River Tlingit is also working to expand its small hydro project to sell power to Yukon and help reduce the territory's GHG emissions. In Quebec, the Mi'gmaq Wind Power Partnership acts as a bridging institution to ensure that locals harness economic benefits from wind projects on Gespe'gewa'gi lands through training and employment.[333, 334] Such projects are good examples of more decentralized energy production systems that can help to undo the legacy of unsatisfactory, top-down approaches that have contributed to the sub-standard conditions that characterize some Indigenous communities.[335]

In the case of Indigenous community-based projects, issues of capacity, governance and revenue generation have been deemed critical to successful implementation.[336] Concepts of balance, respect and reciprocity are some of the principles that maintain cultural identity in the context of adaptation to contemporary social, environmental and economic challenges as well as Reconciliation.

POLICY PERSPECTIVES: INDIGENOUS COMMUNITIES

Indigenous communities are already actively engaged in innovation projects that can inspire other communities and Canada as a whole. However, increased support in the form of equitable participation throughout the low-carbon energy transition is required, including employment generation, technological transfer and full participation in public-private partnerships.

Renewable energy projects have enabled Indigenous partnerships, providing communities with new sources of funding and a transition out of diesel.[337] This transition to low-carbon energy must be led by Indigenous peoples themselves and involve the establishment of community-owned and—controlled energy systems that recognize their diversity and respect their traditional laws[338] in keeping with the spirit of Reconciliation.[339]

Elders play a significant role in Indigenous communities. As traditional knowledge-keepers, healers and teachers, Indigenous leaders have always relied on the vision and wisdom of Elders to provide direction for community governance and the associated challenges. The creation and support of a nonpartisan, independent, national Council of Elders would allow meaningful engagement of Elders. The Council of Elders would have an educational and teaching role, an advisory role, a peacemaking role when called upon to assist in communities dealing with confrontation and, importantly, a mentoring role for youth. Modalities for establishing the Council of Elders would rest with Indigenous peoples themselves and be inclusive.

5.4 FOURTH FIELD OF ACTION: ENGAGING WITH INDUSTRY, INCLUDING OIL AND GAS

5.4.1 ADDRESSING ENERGY DEMAND IN HEAVY INDUSTRY

Taking advantage of Canada's vast natural resources, heavy industry sectors contribute significantly to both the economy and GHG emissions. Heavy industries require (1) electricity to move liquids, gases or solids, (2) fuels or electricity to alter the structure of chemicals or materials (e.g., aluminum, iron and fertilizer) and (3) combustible fuels to generate intense heat (e.g., oil sands, cement, melting steel and more).

Addressing the heat demand of heavy industry is challenging from a low-carbon energy perspective. In provinces that are reliant on coal-fired electricity, bringing together power generation and heavy industry using natural gas co-generation can achieve system-level reductions in GHG emissions.[340] However, more is needed to meet emission reduction goals. Using electricity—from low-carbon sources—is possible, but costs can be high.

Capturing and geologically storing the CO_2 product of fossil fuel combustion is a promising technology, but can also be expensive. In recent years, molten carbonate[341] or solid oxide[342] fuel cell technologies have been developed that can use natural gas to provide (1) industrial scale heat, (2) significant amounts of electricity and (3) a stream of almost pure CO_2 that could be geologically sequestered or used in another way that keeps it out of the atmosphere.
Altering fuel sources for heat production is another possibility. Biomass combustion is widely used in the pulp and paper industry in large part because the residual fuel is readily available. Nuclear combined heat and power plants[343] are another option, but issues around the economics and public acceptability of nuclear deployment would need to be addressed (see 2.5.2).

Another way to reduce emissions from heavy industry is to reduce demand for the products.[344] Moving away from 'planned obsolescence' of products and our 'throwaway' society should reduce industrial demand, as would incorporating more wood products into buildings to replace some of the energy-intense steel and cement that currently dominate the building sector.

Ultimately, decarbonisation strategies for the heavy industry sector will vary with the industry itself, the technologies that emerge, where the companies are located and the policies and regulations of those jurisdictions.

5.4.2 TRANSFORMING CANADA'S OIL INDUSTRY

Each year, Canadians consume about 19 barrels of oil per capita,[345] reflecting a strong appetite for refined petroleum products, more than two-thirds of which are used as transportation fuels. While 'downstream' combustion of refined petroleum products generates about 450 (± 50) kg CO_2-eq per barrel, GHG emissions are also associated with recovery and processing of the oil to create the refined petroleum products. Depending on the origin and chemical characteristics of the oil being recovered, these 'upstream' and 'midstream' emissions can range from 70 to about 250 kg CO_2-eq per barrel.[346]

Oil production in Canada is dominated by heavier oils (e.g., oil sands), that tend to have high upstream and midstream emission profiles. Moreover, Canada produces about twice as many barrels of oil than it consumes domestically—and Eastern Canada also imports oil and refined petroleum products from other countries—creating a major export market, but resulting in additional GHG emissions.

Since oil sands production has grown rapidly over the past 10–15 years, the oil and gas sector in Canada has been the fastest growing source of GHG emissions, increasing by 79% between 1990 and 2014, or from 107 to 192 $MtCO_2$-eq.[347] This growth may continue, since Alberta's Climate Action Plan has capped oil sands emissions at 100 $MtCO_2$-eq, 34.4 $MtCO_2$-eq above 2014 emissions.[348]

Canada's oil and gas sector has been a major magnet for investment. Hundreds of billions of dollars have been spent to construct the current infrastructure for extracting, refining and distributing fossil energy supply. In 2015, oil and gas extraction contributed 6.1% of Canada's gross domestic product.[349]

Alberta, Saskatchewan and Newfoundland and Labrador produce 97% of all Canadian oil. Alberta and Saskatchewan receive the majority of direct revenues (Figure 5.3). The other provinces benefit at various levels from subcontracts, indirect employment and equalization payments.

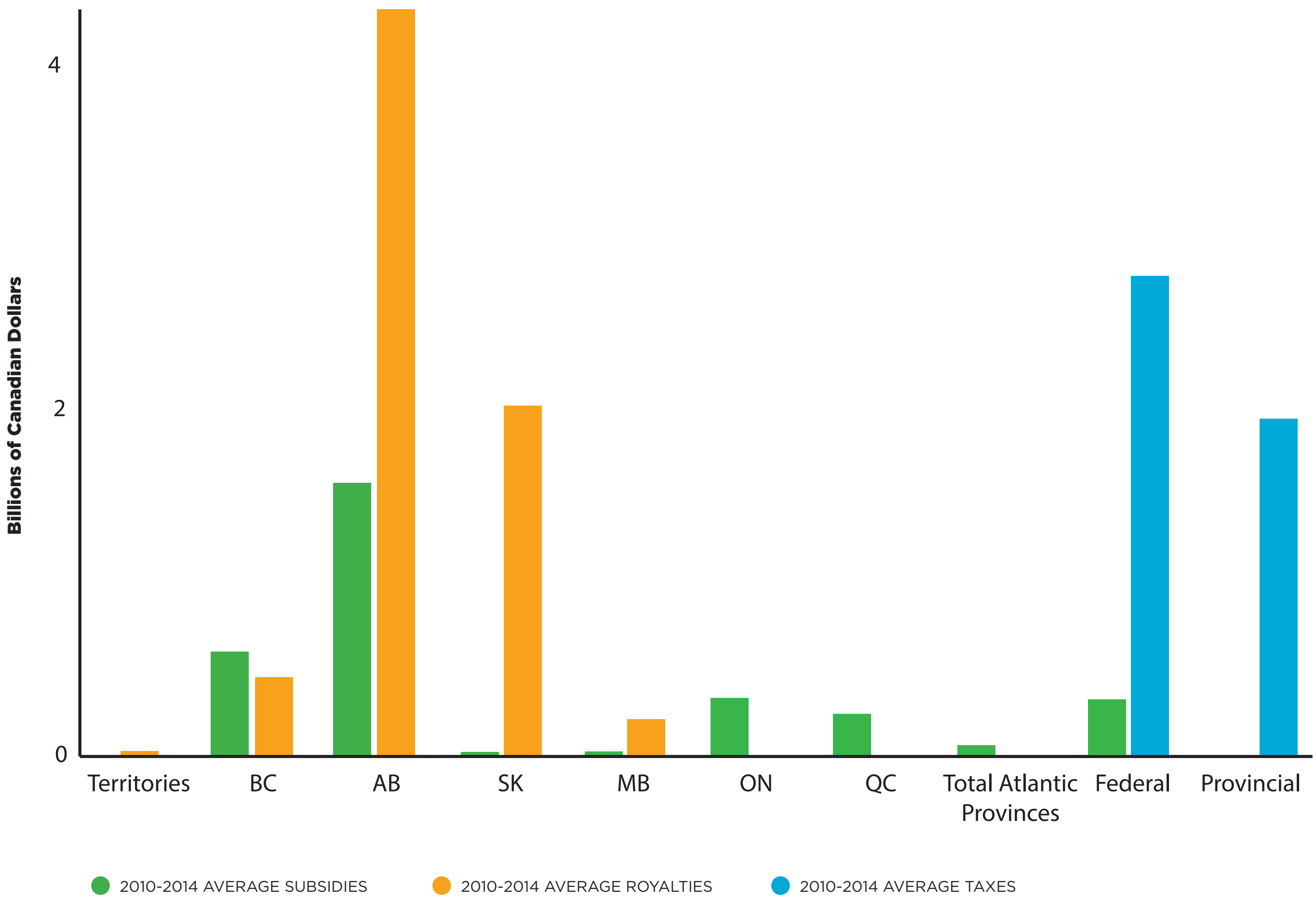
The energy sector, mostly oil and gas, is also a major source of revenue for governments. Between 2010 and 2014, it provided $22.2 billion per year on average in taxes and royalties to all levels of government (Figure 5.3).[350]

The recent drop in oil price has reduced investment in new oil sands operations, although many of those under construction have continued to be developed. Subsequent industry and government[354] forecasts of future oil sands production suggest lower and lower growth prospects for the future but, to date, no official forecast suggests that this sector will decline over the next 20 years in Canada.

Figure 5.3

REVENUES FROM AND SUBSIDIES TO THE OIL AND GAS INDUSTRY (NAICS CATEGORIES 27, 38, 324 AND 412) AVERAGED OVER 2010–2014

Fossil fuel subsidies from federal, provincial and territorial governments[351] (green), industry royalties[352] (yellow) and total federal tax and provincial income taxes[353] (blue). Territories' subsidies are from Yukon only. Total Atlantic Provinces' average royalties includes offshore Newfoundland and Labrador and Nova Scotia. Average royalties for 2009–2013 were used for territories, Quebec and Atlantic Provinces, for which there were no 2014 values.



4

For Discussion:

THE OIL AND GAS INDUSTRY: TENSIONS AND ONGOING DEBATE

Canada is home to about 0.5% of the world's population, but produces 1.6% of the world's CO_2 emissions. The country is also a major exporter of fossil energy, and the emissions associated with the use of these fuels counts in the inventories of importing countries.

Climate models suggest that to remain "well below 2°C", as stated in the Paris Climate Agreement, total future emissions of CO_2 should not exceed 1000 billion tonnes.[355] This notion of a 'carbon budget' can be used to calculate the proportion of existing fossil fuel reserves that could be burned if warming is to be limited to the specified temperature. Accepting the concept of 'unburnable carbon',[356] one scientific paper estimated that approximately three-quarters of Canada's known oil reserves and one-quarter of its gas reserves should not be burned by 2050 to remain below 2°C warming.[357]

In light of climate change, continuing expansion of oil and gas expoitation has become a source of tension, raising debates about the future.

Some Canadians are mobilized against fossil fuels through social movements like fossil fuel divestment campaigns and opposition to both infrastructure projects, like pipelines[358] and liquefied natural gas facilities, and local extraction activities. For example, hydraulic fracturing now faces moratoria or bans in New Brunswick, Quebec, Newfoundland and Labrador and Nova Scotia.

Other Canadians foresee growing oil demand—as China, India and other developing countries adopt cars and other energy-hungry technologies[359]—as a major economic driver for Canadian jobs and global competitiveness. As long as the world wants oil, they argue, companies should participate.[360]

Much uncertainty remains regarding the future of oil (for a review of this topics see[361]). It is increasingly likely that the future of oil and gas production will be limited by demand constraints rather than supply availabilities. For example, rapid uptake of electric vehicles and falling prices for renewable energies like solar and wind could trigger a major shift to a low-carbon energy economy. In many parts of the world, electricity produced from these sources is already cheaper than that from oil, coal and gas. Decreased demand for fossil fuels over the next decade[362] could thus significantly reduce inward investment in the oil and gas sector, making the industry a less attractive and riskier business.[363]

Managing these contradictions will be a long-term challenge for the low-carbon energy transition.

How can Canada reach its long-term climate change goals and contribute meaningfully to global mitigation efforts while continuing to be a major exporter of fossil fuels?

If Canada is to meet its climate change commitments, there will need to be a major reduction in either the magnitude of oil production in Canada or the GHG intensity associated with recovery and processing of each barrel of oil or bitumen. The oil sands recovery technology receiving the most attention is steam-assisted gravity drainage, since it has been the fastest growing and has one of the higher GHG footprints.[364]

A fundamental challenge to low-emission energy recovery from steam-assisted gravity drainage operations is that 80% of the oil sands reservoir's mass is sand, thus high pressure steam is used to heat the sand and reduce the viscosity of the bitumen so it can flow to a recovery well and leave the sand behind. Numerous technologies have been proposed—and some are currently being tested—to make steam without releasing CO_2 to the atmosphere (e.g., nuclear heat and power, or carbon capture and storage), or to lower the temperature needed to reduce the viscosity of the bitumen (e.g., use of solvents with heating using electricity from low-carbon sources).

Carbon capture and storage is perhaps the technology closest to commercial deployment. Canada leads in the development of novel CO_2 capture technologies (including direct CO_2 capture from air), catalytic systems for converting CO_2 back to fuel (carbon-neutral fuels) and industries that will need abundant hydrogen. The technology behind carbon capture and storage has now been tested over relatively long periods. Issues like carbon leakage remain a concern; the injection of CO_2 under pressure can lead to shear failures within rock, causing ground-heaving and potential leaks.[365] Technologies that can detect CO_2 leakage from geological formations are being introduced, and should improve the monitoring and implementation of future carbon capture and storage activities.[366] While cost remains an issue, particularly when paired with existing, relatively inefficient infrastructure,[367] recent work examining the application of these technologies in Ontario suggests that carbon capture and storage can be deployed with modern, high-efficiency systems like natural gas combined cycle turbines at a cost that is competitive with other forms of low-carbon power generation.[368]

Recent work[369] suggests that biomass may be used in various ways to reduce the emissions footprint of oil sands operations, including biofuel heavy machinery and bio-based diluent to transport oil sands bitumen—although significant research and development is still needed to make these products cost-competitive.

Whether any of these alternative technologies eventually become economically viable remains to be seen, and will depend on the future oil price which, in turn, is impacted by demand, carbon price and the effectiveness of other competing technologies for oil recovery. The shift to electric vehicles, for example, could reduce demand sufficiently to keep the oil price below that needed to develop or even maintain oil sands operations, and would reduce upstream, midstream and downstream (vehicle) GHG emissions from oil (see Box 4).[370]

Another alternative for Canada's vast oil sands reserves is to consider how they could be used to produce energy carriers other than traditional transportation fuels.[371] Developing alternate energy systems capable of direct electricity production[372] or hydrogen generation from reservoirs[373] could simultaneously accelerate decarbonisation, promote renewable energy developments in the fuel cell/ redox flow battery and grid technology areas, and develop Canada's substantial hydrogen production industry.[374]

5.4.3 REDUCING FUGITIVE EMISSIONS

As mentioned in Part 4, fugitive emissions have been targeted by the federal government as part of an agreement with the USA in March 2016.[375] Various technologies to reduce fugitive emissions have been known since the early 2000s.[376] Options include, among others, re-injecting or liquefying gas to preserve it for future use in power generation.[377] In the case of oil sands, collection and compression of gas for transport in pipelines offers a way to reduce emissions that should be economically viable.[378]

Canada's foundation in monitoring and remediating contaminated fossil fuel development sites could also be expanded into a global industry, as oil and gas and coal developments are phased out. New technologies and approaches are also needed for environmental cleanup. Canada leads in technologies to produce hydrogen, currently largely used for upgrading low-quality oils, but which will retain a large market sector in the future and grow substantially if carbon-neutral fuel development accelerates.

POLICY PERSPECTIVES: INDUSTRY

If Canada is to meet its international commitments, the industrial sector, including oil and gas, must dramatically reduce its energy-related emissions. A judicious combination of carbon pricing, regulations and technology investments is needed to encourage the necessary changes to how Canada exploits it vast natural resources.

Oil and gas sector development is driven by private investment. Governments should transfer the total environmental cost of production from taxpayers to those investors. Budget 2017, for example, indicates that it will begin to reconsider the tax treatment of oil and gas.

As the world moves to lower-carbon energy, policies to help transition the economies of provinces most affected may include targeted support for alternative sectors, workers' retraining and extended unemployment benefits.

6. THE JOURNEY

Canada's energy transformation can be seen as a journey that is not defined solely by the final destination but also by the road itself, as changing circumstances call for ongoing planning and adjustments along the way. Developing a series of essential governance structures at the outset can help ensure that actions and directions taken are revised, reoriented and rethought as efforts move forward.

We propose a staged approach to this journey (Figure 6.1). Urgent preparations include co-creating a vision of Canada's low-carbon energy future and setting up institutional structures to get there. The coming decade will then be dedicated to early implementation. We envision embedding the low-carbon energy transition in a 'low-carbon development strategy' that focuses on implementation of policies targeting both energy supply and demand, quantifying and verifying emission reductions and nurturing experimentation. By seeing what does and does not work, Canada will be able to advance further on deep decarbonisation. Continuous progress assessments and re-evaluation of policy options and emission reduction targets would be an integral part of this staged approach. In keeping with Canada's international obligations, this journey would be punctuated by regular stock-taking and reporting.

6.1 PREPARING THE JOURNEY

6.1.1 CO-CREATING A VISION

Developing and implementing a country-wide vision for the low-carbon energy future is the challenge of our time.

It entails maintaining and expanding the dialogue with Indigenous peoples, the provinces, the territories, municipalities and all citizens. While it can seem daunting, similar national efforts have succeeded in the past—including the profound transformation of our healthcare system, which recognized the central role of provinces while providing a common vision and set of principles.

An important aspect of such a vision is the pace of change.[379] We propose that national discussion around the vision for the low-carbon energy transition take into consideration the suggestion that high-responsibility and high-capacity countries should act more rapidly than countries with lower per capita emissions.[380] We also favour low-carbon energy pathways that contribute most to promoting sustainability in the spirit of Reconciliation with Indigenous peoples, justice and environmental protection.

The federal government has a role to play in helping co-create a common vision, offering all Canadians opportunities to refine or adjust it as the low-carbon energy transition advances.[381]

6.1.2 ADAPTING INSTITUTIONAL ARRANGEMENTS

To implement the common vision for the low-carbon energy transition, institutional arrangements are a priority. Governance structures will ensure that the actions and directions taken drive a successful low-carbon energy transition. The immediate actions that we propose are:

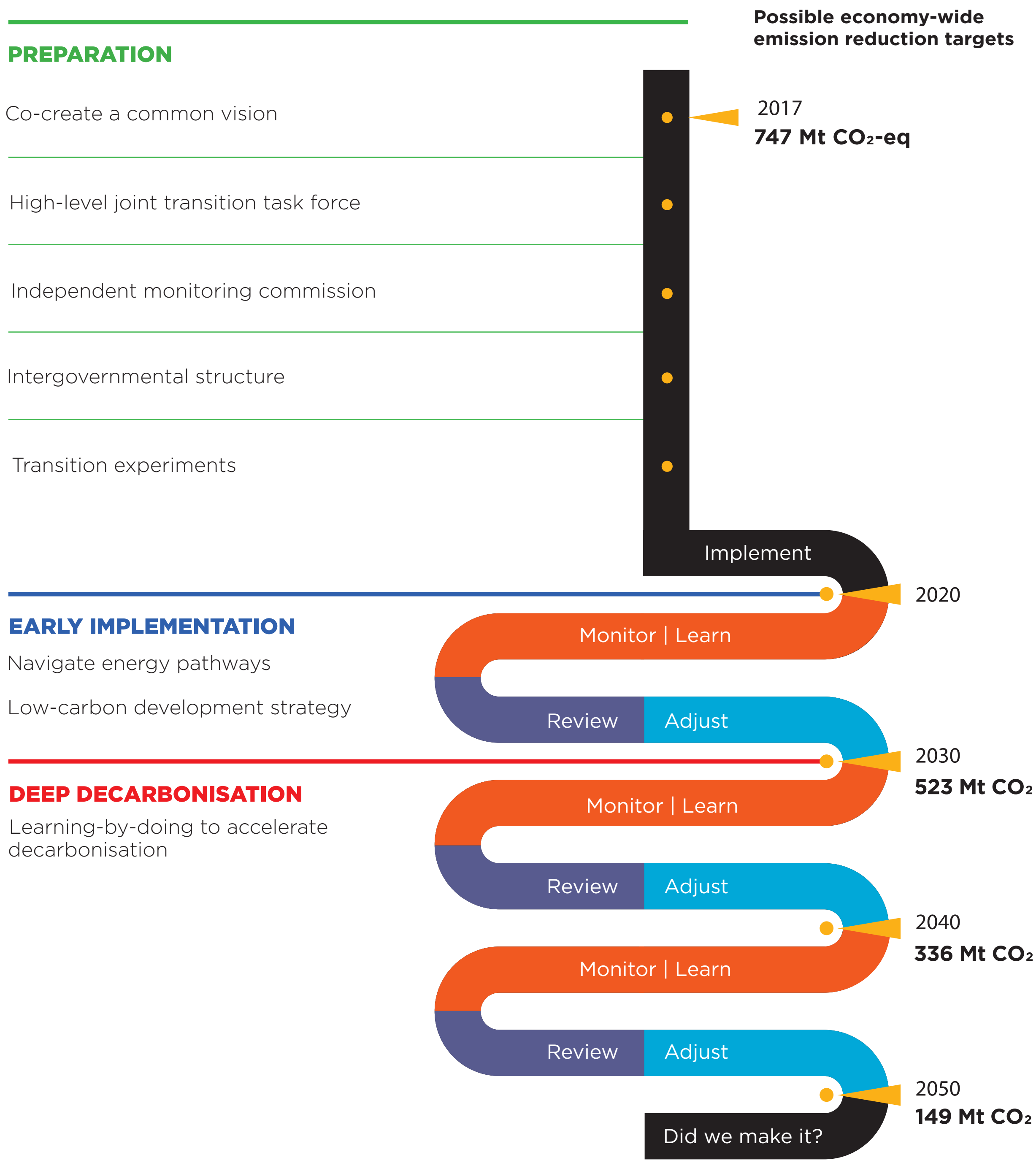
Following the steps of the *Pan-Canadian Framework,* flesh out a long-term national vision led directly by First Ministers with the support of all governmental institutions and based on dialogue with stakeholders. It is important that this vision consider the need to support the provinces and territories that are ready to embrace the low-carbon energy transition as much as those for which it represents a major challenge.

Assign responsibility for *advising* on the energy transition at the federal level to a Joint Task Force that reports directly to the Prime Minister and an associated, high-level cabinet committee. This committee could bring together senior civil servants from energy, environment, economy, technology, transportation and more to implement tactical planning at the federal level, respecting the national and provincial visions. With large investments announced by the federal government to support the low-carbon transition, one of the key responsibilities of the Task Force will be to develop a monitoring, verification and reporting framework for projects to ensure that the investments serve to stimulate the low-carbon energy transition. A second key element of the Task Force's mandate should be to carry out a gap analysis of existing policies, develop additional policies as necessary and assess performance.

Figure 6.1

A STAGED APPROACH TO DECARBONISE ENERGY SYSTEMS

Emission reduction targets are on the right-hand side.



Create an independent commission to evaluate progress with respect to milestones and long-term goals, assess the efficiency of various actions and programs both existing and proposed, provide scenarios based on these and report to First Ministers. If a single independent commission is seen as intrusive, the provinces, territories and Indigenous organizations could set up their own independent commissions to work in concert with their federal counterpart. What is needed is an independent body that can provide a global evaluation of progress and scenarios to support a successful energy transition, and ensure the commitment to reporting adopted by the *Pan-Canadian Framework*. The work of the commission needs to be supported by an enhanced data collection structure that will provide relevant, high quality and timely data as a central element of evidence-based decision-making.

Establish an ongoing dialogue with provinces, possibly with the creation of a formal structure to link and/or integrate the various plans, goals and objectives with the national vision. By establishing structures that facilitate exchanges among provinces, territories, Indigenous peoples and municipalities, the federal government could expand communication and help decrease tensions that remain between regions with respect to energy. Inspiration can come from an organization such as the Canadian Council of Ministers of the Environment that is comprised of environment ministers from the federal, provincial and territorial governments. On the eve of Canada's 150th anniversary, it is important to recall that no constitutional barriers prevent achieving such multi-level collaboration.

Allocate resources to experimentation by providing funding for local experiments to advance the low-carbon transition. These projects would trial practical innovations—technologies, social practices and so on. The focus would be on novel, challenging and risky ideas that: improve businesses and communities; deliver sustainability and low-carbon benefits; have the potential to deliver a significant return—scaling up; offer fundamental rather than just incremental change; and are proposed by stakeholders from at least two societal sectors—business, public bodies and non-governmental organizations. The fund would be administered by an independent body or agency and could be financed with the money already allocated to innovation.

Allocate resources to establish a network of low-carbon research institutes to advance research on technologies and economic, environmental and social dimensions of the long-term transition. Several institutes would be based in different regions of the country and specialize in distinct areas of applied research. This network of institutes would also cover the adaptation dimension, already announced in Budget 2017, but offer much more coherent and complete support for the transition.

6.2 EARLY IMPLEMENTATION

6.2.1 NAVIGATING LOW-CARBON ENERGY PATHWAYS

Both the *Pan-Canadian Framework* and 2017 Federal Budget refer to 'clean energy', but what is clean energy? From the perspective of decarbonisation, clean energy could include hydroelectricity, mature variable renewables such as solar and wind, emergent renewables like wave, tidal, geothermal and biomass, low-carbon fuels, waste reuse, nuclear and carbon capture and storage. In this report, we refer to these sources of energy as low-carbon—in contrast to renewables that would exclude nuclear and carbon capture and storage.

Different technological and social options can be combined to define alternative pathways to a low-carbon future. Such pathways involve varied trade-offs and patterns of social and environmental risks, costs and benefits. Commitments to large-scale technologies—such as big hydro, nuclear, carbon capture and storage or utility-scale photovoltaic arrays and solar thermal plants—each have risks, costs and advantages. Similarly, demand management strategies and new renewables such as wind and solar have their own sets of challenges.

There is continuing debate among experts and, more generally, the Canadian public about which mix of options would bring the best package of societal benefits. There are no simple answers here. All pathways involve costs and hard choices. Such choices are not just technical decisions but involve values, priorities and attitudes towards risk. We need an informed and continuing public debate about alternative pathways that aims to build understanding and consensus.

Still, choices about which avenues to prioritize may differ over time and across provinces and territories. Only by moving forward with building new low-carbon energy systems can we gain experience and clarify the implications of different choices.

6.2.2 THE TRANSITION AS A LOW-CARBON DEVELOPMENT STRATEGY

Policies chosen to support the low-carbon energy transition matter not only through their direct effects but also for their ripple effects through political, economic and social domains.[382] Feed-in tariffs, for example, are typically used to support an increase in both renewable energy production and industrial development.

Recognizing that the low-carbon energy transition needs to be accelerated, we suggest that the federal government follow international examples and integrate its various policies into a broader Low-Carbon Development Strategy.[383] This would provide a unifying context to the increasing number of actions and policies that are emerging, favouring coherence and leveraging between various initiatives. A Low-Carbon Development Strategy would be comprised of policies that are experimental and creative in nature, and would address the concerns of a wide array of actors.[384]

The transition to low-carbon energy can serve to reinvigorate economic activity, modernize and exploit Canadian comparative advantages that matter in a carbon-constrained world, improve the overall quality of life of citizens and enhance justice and equity. Many of the specific measures adopted to encourage widespread deployment of low-carbon technologies and social practices, and accelerate low-carbon innovation, will also contribute to the growth of jobs, investment and export opportunities.

A Low-Carbon Development Strategy would:

- Continuously strengthen *policy frameworks* (including carbon pricing, regulatory and other measures) to stimulate ambitious climate action;
- Focus on *international markets* for Canadian low-carbon technologies and services (finance, insurance, asset management, maintenance and more). Budget 2017's announcement of $15 million over four years starting in 2017–2018 for a clean technology strategy to capitalize on growing markets could stimulate this component of the Low-Carbon Development Strategy;
- Support *emerging high-carbon/low-carbon linkages* that leverage existing technical and institutional strengths by retooling manufacturing processes (for example in drilling, offshore work, hydrogen production and other oil-and-gas-related processes) to expand low-carbon energy production;
- Explore *new resource combinations* where Canada has natural advantages, such as agro-fuels and -chemicals, the bio-economy, forest-based building materials and technologies and so on;[385]
- Stimulate *innovation* in technology development, practices and management, since the transition can begin with existing technologies but innovations will be essential to complete it;
- Develop *regional decarbonisation strategies* that employ the particular resources, industrial and financial assets and skillsets of each region to leverage place-based low-carbon development. Leadership here should rest with the provinces and municipalities, with the federal government providing support;
- Create *information and training programs* to help meet the labour needs of renewable industries and employment needs of workers in the oil and gas industries. Budget 2017's announcement of $1.8 billion over six years starting in 2017–2018 to expand the Labour Market Development Agreements to upgrade workers' skills is relevant here. We propose that information and education must also target the industry itself to allow companies to envision future options linked to retooling.

6.3 TOWARDS DEEP DECARBONISATION: THE IMPORTANCE OF EVALUATION AND ADAPTING BEST PRACTICES

Key to the success of the low-carbon energy transition is a simple fact: Emission reductions need to add up to the target pledged while ensuring a development that is truly sustainable. This demands (1) identifying where and how emissions could be rapidly reduced, (2) shaping policy approaches based on this information, (3) developing a monitoring system to evaluate the effectiveness of policies and measures taken and (4) adapting to novel conditions including climate, technology development, fluctuating energy prices and more.

We propose that adopting a coherent set of evidence-based best practices will determine the success of our efforts. These include:

Carbon pricing. As one of the pillars of the *Pan-Canadian Framework* and most provinces' climate change plans, a price on carbon will increase competitiveness of low-carbon energy alternatives, while providing revenues to finance the transition and sending a strong signal about the costs of climate change to industry and consumers. This price will need to rise steadily if it is to provide a continuous stimulus to change. Indexing this price to inflation would be an important first step.

Education, dialogues and engagement. The energy transition will take place with the support and active participation of citizens. This can only be obtained through strong and sustained education and information-sharing to help Canadians understand the links between fossil fuels, GHG emissions and climate change, energy issues (price, technology and labeling), possible actions (in transportation, renovation and consumption) and more. Dialogues are needed to share concerns and ideas between citizens and decision-makers, leading to active engagement in co-developing energy solutions.[386]

Energy efficiency and conservation, low-carbon electrification and alternative fuels are key components of low-carbon energy systems. A national low-carbon development strategy must focus on opportunities to significantly increase energy efficiency and electrification by supporting energy conservation, increasing the use of renewable energy in industrial processes and heat production, interprovincial interties, decentralized production, feed-in tariffs and much more.

Experimentation and risk-taking. Since the pathways to a successful energy transition are not known, it is important to support experiments in innovative social practices and technologies that will cover the spectrum of diversity found in Canada. As risks of failure increase with the degree of innovation, it is essential that policies be designed to support testing, recognizing that some degree of failure is expected and that knowledge gained from successes and failures is put to good use. We note here Budget 2017's $8.1 million investment for experimentation over five years starting in 2017–2018.

6.4 REGARDING NATURAL RESOURCES CANADA: ALLOCATING SUFFICIENT RESOURCES

With Budget 2017 allocating $13.5 million over five years starting in 2017–2018 to Natural Resources Canada to "provide expertise to other federal departments in the best approaches to implement energy efficiency and clean energy technologies, to retrofit federal buildings, and to reduce or eliminate emissions from vehicle fleets," the transformation to low-carbon energy will have to begin in-house.

Transformative change, such as those alluded to in the *Pan-Canadian Framework* or suggested by budgetary decisions, demands new ways of thinking, new priorities and a transverse approach that cuts through standard ministry orientations. For example, deployment of renewable energy will be central to Canada's future international competitiveness. Yet, in its planning for 2016–2017, Natural Resources Canada assigned seven full-time employees to this sub-program compared to 165 working on geomapping for energy and minerals.

The need for more resources dedicated to the energy transition within Natural Resources Canada is also evidenced by the paucity of information on the potential of variable and alternative renewables. This contrasts with the level of real-time information available in Denmark on energy production from renewables including grid-connections.[387] The recent release of the second edition of the map of clean energy resources and projects[388] is an encouraging step in the right direction.

CONCLUSION: ENERGY FOR A LOW-CARBON FUTURE

Canada is embarking on a remarkable journey towards a low-carbon energy future. Getting there offers many opportunities to build sustainable communities, and demands imaginative and creative approaches to producing them. The diversity of economy and geography is one of our greatest strengths going forward. The country's social and cultural diversity brings creative innovations, and the multitude of ecosystems and natural resources distributed from coast to coast to coast lends itself to a variety of policy instruments and technologies to transform this country's energy systems. Visions for a sustainable future will vary from province to province and place to place, but research and innovation already occurring show that Canadians can take on the challenge of decarbonisation while also creating jobs and building more liveable and equitable communities.

By choosing to act on climate change, Canadians can contribute to global efforts to build a future that protects coming generations. Embracing the low-carbon energy transition could provide a sense of 'mission'—an essential element of the kinds of innovations needed to tackle climate change.[389]

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Discussions with Elder Dave Courchene and the Turtle Lodge team enriched the document, including the suggestion for the creation of an independent national Council of Elders that they wish to host at the Turtle Lodge. A national network of Elders already exists at Turtle Lodge and would be strengthened by official recognition and support.

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ANNEX I: CALCULATION OF AGGREGATE PROVINCIAL/ TERRITORIAL GHG EMISSIONS IN 2030 AND 2050

GHG values were taken from the *National Inventory Report 1990–2014*;[1] 2001 values from *Canada's Greenhouse Gas Inventory 1990–2001*.[2] In the absence of 2030 or 2050 targets, total $MtCO_2$-eq in 2030 and 2050 were extrapolated assuming linear reduction in emissions identical to the period between 2005 (aligning with Canada's baseline) and 2014 for Nunavut and Yukon, between 2005 and the informal target of minus 20% from 2006 by 2020 for Saskatchewan, between 2005 and the 2030 target for Northwest Territories, and between the 2020 and 2050 targets for Alberta and British Columbia. New England Governors and Eastern Canada Premiers regional targets, to which Newfoundland, Nova Scotia and Prince Edward Island contribute, were used to calculate emissions in these provinces in the absence of targets.

Table A.1

PROVINCIAL/TERRITORIAL GHG EMISSIONS IN 2030 AND 2050 IF TARGETS ARE MET

JURISDICTION	2030 EMISSIONS (MT CO_2-EQ)	2050 EMISSIONS (MT CO_2-EQ)
Alberta	240.1	200.4
British Columbia	32.9	12.8
Manitoba	14.1	10.5
New Brunswick	10.4	4.5
Newfoundland & Labrador	5.3–6.2	1.4–2.4
Nova Scotia	11.0–13.0	4.2
Northwest Territories	1.7	0
Nunavut	0.3	0.3
Ontario	114.7	36.4
Prince Edward Island	1.1–1.3	0.3–0.5
Quebec	55.6	4.5–17.8
Saskatchewan	45.5	25.9
Yukon	0	0
Province/Territory Total	532.6–535.0	301.2–315.8
Canada	522.9	149.4

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ANNEX II: PROCESS

In November 2016, Natural Resources Canada commissioned Sustainable Canada Dialogues (SCD) to produce a scholarly consensus on Canada's transition to a low-carbon economy, to contribute to the evidence base that will inform national dialogues on Canada's energy future. The SCD scientific committee contacted 20 or so scholars, in addition to the existing network, with relevant areas of expertise to join SCD from November to December 2016.

Eighteen SCD scholars (five remote) participated in a two-day scoping meeting in Ottawa in December 2016 consisting of:

- A meeting with Natural Resources Canada representatives to clarify mandate and process;
- A meeting with representatives of Natural Resources, Environment and Climate Change, Transport, Infrastructure, Innovation, Science and Economic Development, Global Affairs, Statistics and Indigenous Affairs Canada to ensure SCD's work would be coherent with all federal activities connected to climate change;
- A closed-door brainstorming session among SCD scholars to scope the report, determine its orientation, identify essential board topics and authors, discuss the scope of policy options for Canada and the barriers to action, validate the process proposed and discuss SCD's communication strategy; and
- A meeting with Natural Resources Canada to share these brainstorming results, in particular: the ways in which SCD will address Natural Resources Canada's four tasks, topics included and which scholars will take on initial drafting responsibilities.

The proposed report structure was distributed to all SCD scholars for comments and minor revisions made. As of December 2016, scholars shared key documents and drafts on Basecamp (an online platform for team projects), to which, for transparency, Natural Resources Canada was given access.

Writing began in January 2017 organized around seven themes. A writing team of 4–10 scholars coordinated by two lead authors who were present at the December 2016 meetings in Ottawa was assigned to each theme. Sections were compiled by CP in mid-January to produce a first draft. As of this point, a content committee met frequently over Skype to continually edit the paper's structure. A communications committee edited drafts for clarity, length and language. At each stage, comments nourished the discussion among scholars.

- Mid-January: Draft 1 circulated to all SCD scholars (those not part of the writing teams) for comments and to Natural Resources Canada; reviewed by content and communications committees
- Mid-February: Draft 2 circulated to all SCD scholars and internal SCD reviewers; reviewed by content and communications committees
- Early March: Draft 3 circulated to all SCD scholars, external reviewers and Natural Resources Canada; reviewed by content committee
- Mid-March: Draft 4 circulated to all SCD scholars; reviewed by content and communications committees
- End of March: the final report submitted to Natural Resources Canada

A series of meetings were held to receive input from experts outside of SCD during the drafting process. On March 3rd, 2017, CP presented the draft paper to about 40 participants at University of Toronto's Munk School of Global Affairs' Climate/Energy Policy Workshop. On March 14th, 2017, five scholars met at Natural Resources Canada with an Assistant Deputy Minister and other civil servants to discuss progress so far. The scholars then held a meeting with eight key energy stakeholders from outside academia in Ottawa (see Acknowledgements). CP spoke over the phone and by email with three stakeholders who could not attend the meeting. Their comments served as input to the fourth draft.

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