Getting Canada's Energy Future Right

A consumer lens on energy in Canada

By Michael Cleland with Rafael Aguirre

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Letter from the Advisory Council

For many years, Canadians have been able to take our energy security for granted. We are blessed with world class quantities of every kind of energy — from oil and gas to hydropower, nuclear, wind and solar — and are well positioned on emerging energy technologies. This has been the source of much of our prosperity and has insulated us from geopolitical instability and threats. We are now in a time when we need to look again at energy security in a serious way.

One of us writes as the Mayor of an Ontario community that lives at the intersection of energy and manufacturing. Sarnia, Ontario, is home to a thriving manufacturing, chemistry and petrochemical sector. These industries provide important jobs for our citizens and goods that all Canadians rely upon. We have seen firsthand how industry and jobs can be lost to competitors, such as the United States, because of high operating costs in Canada for little environmental benefit. Moreover, the people and households of my community, not just businesses, need energy to be affordable and reliable. The more household income goes to energy costs, the greater the impact on social well-being and mobility — key aspects of Canada's promise to its people.

The other writes as a farmer and the head of an organization that represents food producers across the country. Canada's agricultural potential depends on our approach to energy domestically. Today, our farms rely on diesel to run tractors, natural gas to dry grain and keep animals warm and rural electrical systems that have important limitations. Farmers are price takers, when our costs go up, we need to make major adjustments to avoid losses, including scaling down production. This has an impact on food security, in Canada and globally.

For both of us therefore, the intersection of Canada's domestic energy systems with production of goods and job creation, as well as household costs and social mobility, are critical lenses to inform our domestic discussions around energy system transformation.

Communities, workers, industry and governments of all levels are united in their desire to transition to a lower emission energy system. But to be successful, the approach must be pragmatic. It will not be sustainable if it results in Canada becoming less competitive, and Canadians less prosperous. Indeed, it would be directly counterproductive to our collective aspirations around human development if Canada produced and exported less food, LNG, chemicals, minerals and manufactured products, all of which require significant energy inputs.

There are lessons to be learned from other jurisdictions of what a chaotic energy transition looks like: energy shocks, deindustrialization, and geopolitical instability. Canada can still avoid the worst of these consequences by implementing a strategic and thoughtful transition — one that takes seriously the quality of life for Canada's growing population, sustains our biggest industries, and creates good jobs.

This paper explores many of the important questions on Canada's pathway to resilient, low emission energy domestically. It brings insights from a variety of voices on the practical realities of our energy needs, and the ways in which we can sustainably — both economically and environmentally — deliver the energy to fulfill our potential both locally and globally.

As Council members of Energy for a Secure Future, we are proud to see these insights offered, and hope they contribute in a meaningful way to public policy.

Mike Bradley
Mayor, Sarnia, Ontario

Keith Currie
President, Canadian Federation of Agriculture

Energy for a Secure Future is a non-partisan civil society initiative that brings together Canadian business leaders, Indigenous peoples, organizations, and experts in a new conversation about energy and building a secure future for Canada and our allies around the world

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Executive Summary

This paper looks at Canada's stationary energy economy (end use sectors — residential, commercial/institutional, industrial; and power generation) and how it might evolve between now and 2050 with the stated government goal of net zero emissions in mind.

It begins with empirical data from Statistics Canada and then uses the Canada Energy Regulator's (CER) 2023 Outlook[1] as an anchor for a look to the future. We examine, as far as can be determined, what physical changes would need to occur to meet the government's net zero goal and many of the certainties, uncertainties and risks surrounding those changes. Our objective is to illuminate the challenges faced by Canada on the road to emissions reduction in the context of what we call the 'energy trilemma'. The energy trilemma in our formulation consists of three factors which will contend and often conflict and which must be kept in mind:

- Energy fundamentals (safety, security, reliability, resilience and affordability).
- Social acceptability.
- Net zero emissions as a goal.

In terms of challenges, the following stand out:

The first is the inevitable trade-offs embodied in the energy trilemma.

The users of the energy system demand that it works predictably and that it meets all energy needs. The costs of failure on any of the basic factors are costs that all consumers and all policy makers will (or should) always seek to avoid. Sometimes failures occur (for example, power outages, supply security shocks or resilience failures caused by weather conditions); perfection is not a possibility. But much short of perfection is something that Canadians will not accept. The challenge of meeting the objective of affordability is less black and white; some consumers can afford to pay more and businesses can adapt to changing prices. But that doesn't mean that they like it; consumers will express their displeasure through political reactions and investors may choose to take their money, production and related jobs, out of Canada.

Social acceptability will have a very large impact on the potential to build new energy infrastructure, especially given the massive surge in new construction implied by a dramatic shift to electrification or the emergence of a hydrogen economy. We know from experience that a failure to secure social acceptance can easily delay or kill any project and the threat of it will impinge heavily on investor confidence. This is particularly true today and for the future when communities will insist on being heard and as the rights of Indigenous communities are well established. Securing social acceptability takes time.

Approval systems present another difficulty. Policy makers seem to increasingly realize this and efforts at reform will proceed. But there are limits to reforms dictated by social acceptability, costs and political considerations. One way or another, approval processes will add costs, time and risks.

Cost is the elephant in the room. No matter what the eventual cost consequences of transforming Canada's energy systems might be, the immediate implications for capital costs are immense. This is not by any means only to build new energy infrastructure but, just as important, the costs of adapting end use systems such as shifting from natural gas to electricity (where feasible, and it often is not) or shifting to hydrogen. Large numbers are regularly bandied about but far too little attention has been given to what it actually means and who will pay. We know that individual consumers will resist fiercely. We know that energy intensive consumers such as industry could face overwhelming competitiveness impacts if they have to bear much of the burden. We also know that all governments in Canada have less and less fiscal headroom in the face of accumulated debt and growing demands for other services. The numbers simply do not add up and so far, the Canadian discourse has largely ignored the implications.

Cost is the elephant in the room. No matter what the eventual cost consequences of transforming Canada's energy systems might be, the immediate implications for capital costs are immense.

Some of those costs will eventually pay off in terms of higher energy efficiency. But most that involve fuel switching (efficiency aside) will simply substitute one form of energy for another, doing nothing to improve the quality of the energy service and adding nothing to the productivity (and, therefore, the per capita income) of the economy.

Technology may prove to be our friend. At least in principle, technologies such as lower cost renewable sources, carbon capture and sequestration, utility scale storage, more sophisticated IT systems, small modular reactors or hydrogen-based combustion systems may come into widespread use but all are subject to many risks. For the CER outlook, offset technologies such as direct air capture are an essential part of net zero, and those are highly speculative. The one thing we do know is that we don't know; only time and experience will provide the answers.

At present the capability of governments and their agencies falls well short of the massive organizational requirements of the proposed transition and it is not at all evident that they are adapting at a pace consistent with their net zero goal. Communities, most notably, Indigenous communities, will need to secure widespread social acceptance, to become successful investors and to adjust their end use energy systems. The biggest constraint may prove to be skills and supply chains. Important sectors such as construction are already constrained and will become more so in the drive to effectively rebuild the entire energy economy, something that we have barely begun and will need to be done in around 25 years if we are to meet the 2050 goal.

All in all, the above factors will be almost entirely negative in their effects in the drive to net zero. This should give us pause. It should induce much more serious consideration of what systemic changes will be needed. And it should dictate prudence, which means a preference for maintaining flexibility in the face of changing circumstances, preferring incremental change rather than revolution and always being mindful of the basics: an energy system that meets all our needs.

Section One: Introduction and Methodology

This paper was commissioned by Energy for a Secure Future with the aim of exploring the conditions necessary for Canada to have a sustainable energy system for decades to come. By this we mean a system that delivers on energy fundamentals as we grow our population, grow our economy, and maintain an affordable cost of living, all while pursuing national and subnational greenhouse gas emissions reduction goals. In other words, we are looking toward a process that is truly sustainable: environmentally, economically, socially and politically.

We have taken a customer side perspective. The great majority of the energy debate in Canada and elsewhere tends to focus on questions of supply and upstream energy, whether electric power, oil or natural gas. A customer side perspective looks at the variety of energy services that need to be delivered, the variety of needs associated with those services and — looking upstream — at the delivery infrastructure (a.k.a. utilities) that delivers the services.

We have also taken a stationary energy perspective, in other words, the various sectors that are connected to the power and natural gas infrastructure which includes the residential, commercial/ institutional, and industrial (including resource) sectors. For the most part, this means electricity and natural gas but in smaller shares, other fuels such as diesel, heating oil or biofuels.

We also look briefly at power generation, mainly with an eye to how that system may evolve to become less carbon intensive while serving ever more of our total energy end use.

We do not look at transportation and its various sub-sectors which have their own distinctive needs, challenges, possibilities and delivery infrastructure (although with time as transport becomes more electrified, transport will become more integrated with stationary energy infrastructure at the same time placing significant new pressure on electric power systems). Readers should be aware of this point when they consider implications for the overall system and look at the energy source shares laid out in Sections 3 and 4.

Finally, we have complemented our analysis with insights from practitioners from different areas of Canadian society and economy. We've embedded many of their insights, which bring a practical, real world perspective to what is often a theoretical discussion, throughout this paper.

Methodology

We begin by laying out the scale of the challenge of net zero and the various 'energy realities' that impinge on that challenge. Energy realities may be best thought of as matters that should be regarded by policy makers as highly salient to their decisions and which, in any case, will often shape the energy future irrespective of what policy makers wish to achieve. These may involve things like supply and security shocks or consumer or investor reactions to changing circumstances. All of this is captured in Section Two.

If one wants to know where one is going it helps to know where one is starting from. Consequently, in Section Three we draw on energy data from Statistics Canada from 2005 to the latest reported data in 2022 to paint a picture of where we stand today and how the stationary energy system has evolved over almost two decades.

In Section Four we look forward to 2050. We anchor this forward look in the Canadian Energy Regulator's 2023 Outlook, chosen not because it is any more 'right' than any other outlook but because it is authoritative and official. We look, sector by sector, at the changes envisioned by the CER outlook between now and 2050 in terms of total energy use and shares of the various energy sources. We offer a perspective on the implied physical changes in the energy economy. And, then, drawing on several sources, including our own decades of experience; various published sources (cited directly or listed in the Appendix); and several interviews with knowledgeable interlocutors (listed in Appendix B), we explore the potential consequences of those changes and the various knowns, unknowns and risks that may drive or inhibit change.

The last section wraps it up with overall observations and concluding comments posed as questions for decision makers, the answers to which should inform policy.

Section Two: The Challenge and Energy Realities

The scale of the challenge

Governments in Canada have laid out a number of ambitions with implications for our energy systems.

- To sustain substantial population growth based largely on immigration.
- To add new industries like critical minerals production and processing and battery development.
- To decarbonize all stationary economic sectors.
- To electrify light-duty transportation and otherwise decarbonize heavy duty and long-distance transportation.
- To have a zero emitting electricity system.
- To ensure an affordable cost of living, including housing, food and energy costs.

These goals will require a great deal of energy (although as we will see, the Canada Energy Regulator 2050 net zero outlook projects an overall decline in energy end use), new infrastructure to be built quickly and new technologies to be developed, tested and deployed in a relatively short period of time, all of it involving very large upfront capital costs. The last goal, related to affordability, is particularly important to social mobility and quality of life, in addition to talent and investment attraction in Canada.

Added to these ambitious societal goals, is a goal which is endorsed by most governments in Canada: to achieve carbon neutrality on a net basis by 2050, just over 25 years from now. This would imply largely eliminating fossil fuels and, instead, fueling the economy and society primarily with electricity, hydrogen or gaseous or liquid fuels that can be deemed carbon neutral because they are renewable or because the carbon is captured.

For perspective, today in Canada just under 22 percent of all our stationary energy needs are met by electricity and almost none by hydrogen. This means, the other 78 percent of Canada's stationary energy system, which is fossil-fuel based, would have to be replaced or their emissions somehow mitigated. This is before integration of new demand from transportation. The physical challenge implied by such a change in the proposed time frame is daunting, to put it mildly.

Various estimates suggest that with the changes to the stationary system examined here as well as proposed changes to the transport system, the capacity of the electric power system would need to at least double or even triple along with the transmission and storage infrastructure needed to ensure system viability. This is on top of the challenge of eliminating the use of, or emissions from, hydrocarbon energy sources (coal, oil or natural gas) in the existing electricity system and all end uses.

The existing natural gas delivery system would have to be repurposed to supply low or zero emitting fuels, like hydrogen. Alternatively, it might be phased out, raising questions of compensation for the owners of stranded assets or, just as troubling, the problem of stranded customers, mainly industrial users with high temperature processes, who will still rely on a natural gas system which would have become inherently less viable. Will these customers continue to produce and employ in Canada?

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Most end use systems would need to be fundamentally changed either to use electricity rather than combustion or to employ carbon neutral fuels and simultaneously to ensure much higher efficiency of energy use.

Numerous economic modeling exercises have attempted to estimate the costs involved in such a fundamental transformation. The numbers are hard to make sense of but a few factors are particularly germane.

First, the scale of investment involves numbers in the trillions of dollars for Canada as a whole, numbers which for most of us seem like abstractions that few people can relate to their day-to-day lives.

Second, exactly how big the cost will be depends on numerous factors, from the eventual configuration of the new systems to the way technology evolves, to the inevitable realities of construction times and costs, supply chain questions and availability of skills. Most analytical approaches pay limited heed to these issues, but they are large and they will grow.

Third, there is no consensus on how the eventual cost should be measured. On a full-cycle basis (capital investment and operating costs over the life of the assets) the system may eventually prove to be more economical mainly due to enhanced efficiency. But "eventually" might be too far off for anyone who has to cover the initial capital costs which no one disputes will be enormous.

Finally, as virtually all analysts point out, we know very little about the risks and uncertainties entailed in changes to our relative economic competitiveness in the short, medium and long terms, to the uncertainties of consumer behaviour, as well as questions of social acceptance of new infrastructure. This last set of factors is inherently impossible to quantify or model, and therefore, relies on assumptions based on virtually no real-world experience. We have never before attempted such a radical transformation.

We can say some things with certainty. The capital costs will be very large, in orders of magnitude, comparable to or larger than any of the other big public policy challenges in front of us in the next two decades. The costs will need to be covered by some combination of consumers or taxpayers, both of whom will almost certainly be reluctant to pay those costs, whether it is individual households or business consumers who must compete in the marketplace. Governments will be constrained by already challenging deficits and debt loads. And those human behavioural questions will constantly surprise us, often in ways that will force us to rethink the pace and nature of progress toward net zero.

Meeting the challenge with energy realities in mind

"You have to build on the three pillars of affordability, reliability and sustainability (including emissions). If any of those pillars fails the whole plan comes crashing down."

– Vince Brescia, CEO, Ontario Energy Association

Certain energy realities need to guide us on the path forward.

First, start with what some observers call the "energy trilemma." Different people define this differently but we believe that the following formulation captures it best.

The first aspect of the trilemma is that energy systems need to conform to what we call "*energy fundamentals*." By this we mean: safety, security, reliability, resilience and affordability.

Safety is something that consumers take for granted in our energy systems but underlying that are significant investments in equipment and operating practices which we cannot afford to treat casually. Safety may reemerge as a concern in some quarters along with new technologies such as hydrogen or the return to older technologies such as nuclear. Policy makers need to prepare for those possibilities.

Security used to dominate the energy debate going back to the 1970s. It faded for many years, but it has reemerged as a consequence of the Russian invasion of Ukraine, with all sorts of perverse consequences notably in Europe. For some, the net zero vision creates a world of greater security due to less reliance on imported energy but that remains to be seen, especially as questions of cyber security and availability of strategic materials become more important. We know that today over 80 percent of the supply chain for wind and solar components, batteries and critical minerals is controlled by China. The security implications of this are uncertain but very real. In the face of climate change our hydro systems — existing and new — may find their security compromised as weather patterns change.

Reliability, which concerns the day-to-day functioning of the systems, particularly power systems, is something we are rarely aware of until there is a system glitch of one sort or another. The new systems will have to continue to meet at least current standards of reliability.

A question related to reliability is resilience, which we define as the ability to withstand shocks such as wind storms, wildfires, floods or cyber-attacks and the ability to recover from such shocks quickly. In a time of climate uncertainty and heightened geo-political tension, resilience will grow in importance along with its demands on both capital investment and operating systems.

Finally, energy must be affordable for reasons of business competitiveness, fairness to lower income consumers, and for political viability. The present intense focus on this question may diminish as inflation recedes but it will never go away, and no government can ever operate without affordability firmly in sight.

The second part of the trilemma concerns the fact that all societal infrastructure needs to be built with *social acceptance* — what we used to call social license — firmly in mind. There will be a lot of new infrastructure built on the path to significantly reduced emissions. The impacts that matter most to people will not be the largely abstract contribution to preventing climate change but local and tangible impacts on social, cultural and environmental values and interests. Concerns raised may or may not be well founded but politically they will be no less real.

Finally, the third part of the trilemma — we need to meet our climate goals. But if we pay inadequate heed to any other part of the energy trilemma, proposed changes will not be sustainable in a social, economic or political sense. Energy fundamentals and social acceptance are the foundations on which successful climate policy must be built. Failure to ensure the soundness of that foundation will lead to failure with respect to Canada's economic, social and environmental ambitions.

Energy fundamentals and social acceptance are the foundations on which successful climate policy must be built. Failure to ensure the soundness of that foundation will lead to failure with respect to Canada's economic, social and environmental ambitions.

Another energy reality is that energy is a long game in several respects. Individual elements of energy infrastructure can require a decade or (much) more from conception to being in service. Energy production and delivery assets inevitably have very long lives and long payback periods. Finally, an aspect which is often overlooked is the long life of energy using assets such as buildings, machinery and equipment as prosaic as heating systems. It takes time to change all of that and accelerated turnover, if required, entails costs.

Indigenous rights are another reality which must be taken into consideration in this context. Indigenous communities have become major players in Canadian resource development, in part because of the just recognition of their rights over the past twenty years. This has created opportunities for those communities to benefit from those abundant natural resources. Benefits have taken the form of expanding revenues, employment, training and business opportunities in every phase of resource extraction, and increased participation in regulatory oversight. One particularly important gain has been the enhancement of energy security for Indigenous communities through expanded local distribution and natural gas use[2]. More on that in Section Four.

Finally, Canada's federal system of government will bear heavily on how much can be achieved and how fast.

The goal of net zero reflects a national commitment made in international forums, and to that extent is a federal government concern. But the vast majority of the required actions to achieve the goal rest in the hands of provincial governments and without painstakingly constructed federal provincial cooperation, meaningful progress will be slow and painful. These questions are constitutional and political, but they are also local, habitual, and cultural. Energy is close to people's lives, to the well-being of communities and to provincial political interests and even identities.

With all of this in mind the next two sections look at Canada's actual situation based on the most recent data followed by an examination of possible outlooks out to 2050, what needs to change and the unanswered questions and risks involved in that change.

Section Three: Our Starting Point

If one wants to know where one is going it helps to know where one is starting from.

This section lays out in summary form where Canada stands today and how things have evolved over the past two decades. Our focus, as noted, is on stationary energy use with an emphasis on end-use sectors and some attention to power generation but note in the following box, transport will be a big factor.

Transportation represents almost a fourth of the total end-use of energy.

For 2022, refined petroleum products (RPP) represent 93 percent of the 2,577 PetaJoules demanded in the transportation sector.[3]

This is the equivalent of 716 TWh of electricity consumption — equivalent to the electric generation of roughly 17 Bruce Power Stations or of 140 Site C Dams.

We look first at shares of energy sources by end use sector for Canada as a whole as of the latest reported statistics. From there we go on to examine how things have evolved since 2005 respecting energy growth, changes in energy intensity and shares of different energy sources. We then look at regional breakdowns: energy source by end use sector, and evolution since 2005. Finally, we look at energy sources for power generation in all provinces as of 2022 and over time.

Today, over two-thirds (67%) of Canada's total stationary energy end use is in the industrial sector.

The whole picture – Canada in 2022

Today, over two-thirds (67 percent) of Canada's total stationary energy end use is in the industrial sector. This is something distinctive about the Canadian context and is one of the reasons Canada is a large generator of greenhouse gas emissions (GHGs) relative to our economy and — implicitly — why getting GHG emissions on a downward trajectory has proved so difficult. Simply put, Canada is an inherently energy intensive economy due to the fact that it is a large resource producer and processor from oil and gas to minerals and metals to forestry and agricultural products. As we advance strategies for critical minerals, domestic manufacturing or growth in agricultural production and export, the share of end use attributed to industry will remain dominant.

One big source stands out — natural gas at 48 percent. The next biggest share is electricity at 22 percent but close behind is refined petroleum products (RPP) at 21 percent, which we typically associate with the transport sector but are still extensively used in heat generation, diesel power and local power production. Biofuels have a substantial share (7 percent) which reflects the importance of our large forest industries.

The changing picture – Canada from 2005 to 2022

Total stationary energy end use has increased steadily, mostly reflecting growth in oil and gas industries (mainly oil sands). The share of electricity has stayed steady at around 22 percent while natural gas has gone from around 40 percent to 48 percent, largely mirrored by the decline in RPPs (from 26 percent in 2005 to 21 percent in 2022). Notably, hydrogen remains a future fuel, with no application until 2021. Its use is expected to grow but still from a very small base.

Table 3.1 Canada Stationary End-Use (PJ) 2022				
	Industrial	Commercial/Institutional	Residential	Total
Biofuels & Emerging Energy	493	2	157	652
Electricity	866	555	653	2,074
Hydrogen	0	-	0	0
Natural Gas	3,021	755	655	4,431
Other	140	-	-	140
RPP	1,725	180	54	1,960
Total End-Use	6,245	1,492	1,519	9,257

Regional Breakdowns

Canada's energy use is highly diverse regionally for several reasons, including: weather and its effect on heating and cooling; industrial structure; and the differing availability of low-price power and natural gas. Detailed data region by region or province by province[4] are to be found in Appendix A but here we confine ourselves to interpretation and commentary.

British Columbia's sectoral breakdown (Table A3.1) reflects both its distinct industrial structure and the relatively benign weather enjoyed by its major population centers. Strikingly, biofuels comprise around 30 percent of industrial use, not far behind natural gas. Perhaps equally striking for what we tend to think of as a "hydro" province, electricity comprises under 25 percent of total stationary end use compared to natural gas at over 40 percent. The last figure includes both industrial use and the significant use of natural gas in residential and commercial heating.

Over time the picture has changed very little (Table 3.2). Total energy use has slightly declined as has energy intensity, defined as the amount of energy used per unit of gross domestic product (GDP). Interestingly, the shares of the different energy sources have hardly budged over twenty years despite the B.C. government's strong commitments and policies designed to address climate change.

For ease of presentation, we have grouped the **three prairie provinces** whose energy picture is very much dominated by the Province of Alberta.

Most strikingly, total stationary energy (Table 3.3) use relative to the size of the economy (energy intensity) is much larger than its neighbours. The prairies, again dominated by Alberta, have much higher energy

Striking for what we tend to think of as a "hydro" province (British Columbia), electricity comprises under 25 percent of total stationary end use compared to natural gas at over 40 percent.

intensity than the rest of Canada, most of that reflected in dominance of the industrial (i.e. oil and gas and petrochemical) sector. Note that industrial use comprises around 80 percent of total stationary energy use in the prairies vs. 67 percent in B.C.

In terms of energy source shares the picture in the prairies is very different from B.C. or Ontario (Table A3.3). Electricity is only around 10 percent of total energy use whereas natural gas is at almost 65 percent and RPPs are over 23. It should be emphasized again that Alberta and its industrial activity dominates this picture. Manitoba would reflect energy intensity and energy source shares much more like British Columbia, with Saskatchewan between the two but closer to Alberta.

The picture over time (2005 to 2022) is very much dominated by the growth in the oil and gas sector (Table A3.4). Total energy use has grown from 2005 to 2022 by over 40 percent and energy intensity has grown by 9 percent in Alberta. Saskatchewan and Manitoba experience decreases of intensity of 8 and 18 percent respectively. Shares have changed in notable ways with natural gas going from 55 to 65 percent, electricity declining very slightly and RPPs declining from 28 percent to 23.

Ontario's total stationary end use (Table A3.5) places it lower than the Canadian average in 2022 in terms of energy intensity. Again, total energy use is dominated by industrial use at around 50 percent with roughly equal shares for commercial/institutional and residential, presumably reflecting the larger service economy in Ontario compared to the other provinces. In terms of shares, natural gas still dominates at over 40 percent with electricity at 25 percent.

Over time total stationary energy use in Ontario (Table A3.6) has declined slightly since 2005, much like B.C. but in contrast to the prairies. Shares have changed very little. The share of natural gas has not changed at all. Electricity is up notably from 21 percent in 2005 to today's 25 percent.

Quebec's total stationary energy use (Table A3.7) places it fifth lowest in terms of energy intensity (tied with British Columbia) with industrial use dominant at over half (55 percent) of the total. But in contrast to Ontario, commercial/institutional use is only 22 percent and residential at 27 percent. And, as might be expected in Canada's signature "hydro" province, electricity accounts for over half (54 percent) of total end use whereas natural gas is at only around 18 percent, in second place but only slightly ahead of biofuels and RPPs.

Over time (Table A3.8) Quebec has seen declining energy use and energy intensity, consistent with regions other than Alberta. Electricity's share has grown from around 48 percent in 2005 but so has the share of natural gas (from around 14 to 18 percent) as RPPs have steeply declined (from 24 to 14 percent).

The picture in **Atlantic Canada** (Table A3.9) has some similarities with the rest of the country and some significant differences. Again, industrial use dominates at 57 percent of stationary energy. The share of electricity — much higher than B.C. but much lower than Quebec at 35 percent in 2022 — and the share of RPPs at 33 percent primarily reflect what was until recently the comparative unavailability of natural gas in the region, whose share stands at only 16 percent.

From 2005 to 2022 (Table A3.10), as with all regions other than the prairies, energy use has declined along with energy intensity. Shares have changed significantly. Electricity's share has grown substantially from 28 percent in 2005 to 35 percent in 2022. Against that, natural gas has doubled its share, reflecting the relatively new availability of natural gas due to Scotia Shelf resources becoming available and, in contrast, RPPs have dropped from almost half (47 percent in 2005) to 33 percent in 2022.

Table 3.2 Canada Stationary Use (PJ) 2005-2022						
	2005	**2010**	**2015**	**2020**	**2022**	**Share (2022)**
Biofuels & Emerging Energy	712	589	615	595	652	7%
Electricity	1,871	1,836	1,926	1,987	2,074	22%
Hydrogen	0	0	0	0	0	0%
Natural Gas	3,282	3,425	4,114	4,160	4,431	48%
Other	191	172	144	128	140	2%
RPP	2,130	2,131	2,166	1,959	1,960	21%
Total End-Use	8,185	8,153	8,965	8,829	9,257	100%

Table 3.3. Energy Intensity (MJ/2017 dollar GDP) Provincial Breakdown[5]						
	2005	**2010**	**2015**	**2020**	**2022**	**Change 2005-2022**
Canada	6.6	6.3	6.1	5.6	5.5	-17%
British Columbia	6.6	5.5	4.8	4.4	4.3	-35%
Alberta	11.6	12.1	11.8	12.9	12.6	9%
Saskatchewan	9.5	9.7	9.7	8.9	8.7	-8%
Manitoba	5.8	4.8	5.0	4.7	4.7	-18%
Ontario	4.8	4.5	4.3	3.6	3.5	-28%
Quebec	6.0	5.3	5.0	4.4	4.3	-27%
New Brunswick	8.6	8.7	7.5	6.5	6.4	-25%
Newfoundland and Labrador	6.3	5.7	5.7	5.0	5.5	-12%
Nova Scotia	6.5	5.8	4.8	4.0	3.9	-41%
Prince Edward Island	5.2	5.1	4.4	4.0	3.7	-29%

Overall, the picture that emerges for Canada is as follows:

- A country whose stationary energy end use is heavily dominated by industrial use in all regions but notably in the prairies.
- A country whose overall stationary energy use has grown and whose overall energy intensity has decreased, driven by higher energy efficiency and the economic weight of the commercial and institutional sector in the GDP, relative to the industrial sector.[6]
- An end use picture heavily dominated by natural gas in most regions — particularly for residential and commercial heat, as well as industrial applications and, at 47 percent in 2022, having grown significantly from 2005. The exceptions to this trend are Quebec and Atlantic Canada.

- An end use picture where electricity varies widely from only 10 percent in the prairies to around 54 percent in Quebec but has stayed at 22 percent overall for Canada from 2005 to 2022.
- An end use picture still showing significant but steadily declining use of RPPs (from 26 percent in 2005 to 21 percent in 2022) and biofuels declining from around 9 percent in 2005 to around 7 percent in 2022 probably reflecting the declining relative importance of the forestry sector.
- Distinctive end use pictures varying by region mainly reflecting different industrial (and economic) structures, the availability of low-price electricity (in Quebec) and the unavailability of natural gas (Atlantic Canada).
- All in all, a slow process of change in terms of energy mix, with a decline in RPPs replaced by natural gas, the decline in biofuels, and an unchanging share of electricity end-use.

Power generation

Central to this energy picture and the policy conversation more broadly, is power generation. The evolution of power generation over the past few decades and expectations for the role of electricity in the future are key questions. Notably, many organizations with responsibilities related to electricity generation have published their own assessments of feasible paths to drive emissions toward net zero while preserving energy fundamentals. Much of this is reflected in Section Four. In this section, as noted, we are looking either back to 2005 or at the present (2022) and we focus on the provincial (as opposed to regional) breakdown of power systems.

To note again, this section looks back and at the present; the following section looks forward to how the system might change to meet our climate aspirations and all that that might entail.

Table 3.4 Power Generation (GWh) 2005-2022

	Canada					Share	Growth
	2005	2010	2015	2020	2022	2022	05-22
Hydro / Wave / Tidal	358,381	347,938	378,498	381,169	376,175	58%	5%
Wind	1,453	8,354	26,693	37,454	50,063	8%	3,345%
Biomass / Geothermal	6,997	8,267	8,462	9,141	11,048	2%	58%
Solar	-	123	1,426	5,920	11,441	2%	9,201%
Nuclear	86,669	85,527	96,046	92,646	87,342	13%	1%
Coal & Coke	97,362	71,259	57,142	41,914	27,695	4%	-72%
Natural Gas	40,016	54,093	65,744	68,038	84,841	13%	112%
Oil	8,194	5,188	5,267	2,058	1,494	0%	-82%
Total	599,072	580,747	639,278	638,340	650,099	100%	9%

We looked at growth in power generation from 2005 to 2022 keeping in mind the fact that over the coming 25 years, depending on the extent of electrification and the potential emergence of "green" hydrogen, power generation will need to increase by 110 percent by 2050, according to the Canadian Energy Regulator. It is notable that various system operators across the country, aside from putting out forecasts, have also noted that current capacity is starting to become 'tight.' Some key themes are shown in the text box below:

Theme	Jurisdiction
1. Electric utilities are capacity constrained; more generation is needed.	BC, AB, ON, QC
2. Natural gas is needed to ensure stable power supply, including for aggressive net zero pathways.	All, according to Electricity Canada (2023)[7]
3. Leveraging the gas system and infrastructure can generate a more efficient low-emission pathway.	QC, ON, MB
4. Renewables integration is proceeding apace but remains dependent on responsive generation (such as natural gas) and utility scale storage	AB, ON, MB

In this section, we focus, in particular, on the changing shares of electricity sources other than hydro or nuclear, which have been largely stable for the past two decades. In other words, our focus is the emergence of all non-hydro renewables (wind, biomass, geothermal, solar) and, where relevant, the shift from coal to gas.

British Columbia has seen growth in power generation of approximately 6 percent from 2005 to 2022. (Table A3.11) Almost all of this is accounted for by the growth of non-hydro renewables from just over 4 percent in 2005 to over 11 percent in 2022. Natural gas has dropped from just over 4 percent to just over 2 percent, offset by the growth in non-hydro renewables. Similar to Quebec, British Columbia has been able to use its hydro system to address storage needs as more non-hydro renewables are brought into the system. That said, British Columbia has been facing supply shortfalls due to low-water levels in its hydro system and will need backup systems for power and load management.[8] At the time of writing, British Columbia has launched a call to bring on 3,000 GWh/year of new electricity generation. Among other things, the government has indicated that there is inadequate electricity supply for new planned industries in the province, including new liquefied natural gas and mining projects[9].

Alberta has seen total growth in power generation of 25 percent, (Table A3.12) largely reflecting the load growth associated with oil sands. Non-hydro renewables have grown substantially, from 3.6 percent in 2005 to over 17 percent in 2022. Natural gas, in the meantime has seen its share increase dramatically from 28 percent to almost 65 percent, reflecting the steady phase out of coal from just over 63 percent in 2005 to 16.5 percent in 2022.

At the time of writing, a province-wide moratorium on new wind and solar projects was being lifted (with new land-use conditions) and the construction of 2.7 GW of new natural gas fired power production to shore up their base load was announced.[10]

Saskatchewan has witnessed total generation growth (Table A3.13) in the same range as Alberta at 23 percent from 2005 to 2022. Non-hydro renewables have gone from effectively nothing in 2005 to 4.5 percent in 2022. Somewhat mirroring experience in Alberta, natural gas has moved from a share of just under 10 percent in 2005 to almost 33 percent in 2022 offset by the decline in coal from over 66 percent in 2005 to just under 33 percent in 2022.

Manitoba has seen its total power generation (Table A3.14) drop by 17 percent, mainly reflected in a decline in hydro. Non-hydro renewables have barely changed, from nothing in 2005 to well under 1 percent in 2022. Neither natural gas nor coal are of particular relevance in Manitoba power generation.

Ontario power generation (Table A3.15) has seen virtually no growth overall from 2005 to 2022 while shares of different sources have changed significantly. Non-hydro renewables went from effectively nothing in 2005 to over 17 percent in 2022 while coal declined from 18 percent in 2005 to nothing in 2022. Natural gas, meanwhile, held its share over the period at just over 8 percent.

Quebec has witnessed total generation growth (Table A3.16) of 19 percent over the period, mostly reflecting significant growth in hydro generation. Non-hydro renewables, much as in the rest of the country, were effectively nothing in 2005 but had grown to over 7 percent in 2022. Neither coal nor natural gas are relevant in Quebec power generation.

New Brunswick has witnessed a significant decline in power generation (Table A3.17) — 27 percent — over 2005 to 2022, mostly reflecting lower hydro generation. Non-hydro renewables have grown from nothing in 2005 to over 10 percent in 2022. As with Alberta, Saskatchewan and Nova Scotia, coal has steadily lost share, from around 17 percent in 2005 to just over 12 percent in 2022, offset by gas which has gone from around 11 percent to over 16 percent over the period.

Nova Scotia has also witnessed significant declines in total generation (Table A3.19) of around 27 percent over 2005 to 2022. Non-hydro renewables have grown from essentially nothing in 2005 to a bit over 4 percent in 2022. Meanwhile, following the pattern in Alberta, Saskatchewan and New Brunswick, coal has declined from a 71 percent share in 2005 to just over 45 percent in 2022 with natural gas offsetting much of that, growing from essentially nothing to almost a 14 percent share.

Prince Edward Island, which imports much of its power from New Brunswick has seen extraordinary growth in total generation of well over 2,000 percent. All of that is accounted for by wind.[11] Neither coal nor natural gas are of relevance in Prince Edward Island (Table A3.20).

Newfoundland and Labrador, like Prince Edward Island, is an outlier but for different reasons. Total growth (Table A3.18) over 2005 to 2022 was 6 percent, roughly in line with Canada overall and effectively all of it attributable to growth in hydro which accounts for virtually 100 percent of total generation. Non-hydro renewables (again, wind in this case) has grown from nothing to under a 1 percent share over the period.

Overall, the power generation picture that has emerged is as follows:

- For Canada overall, total power generation has grown by 9 percent from 2005 to 2022, a strikingly low number in the face of the generation growth implied in all available scenarios aimed at net zero in 2050.
- Hydro across the country (with the exception of Quebec, which has grown by 13 percent) has either declined or stayed steady.
- Nuclear has grown substantially in New Brunswick and grown slightly in Ontario.
- The first big story concerns non-hydro renewables, mainly wind which, for Canada overall, accounted for virtually no generation in 2005 but grew to around 11 percent in 2022.
- The second big story concerns coal and natural gas. For Canada overall, coal declined from around 16 percent to 4 percent over the period whereas natural gas more or less doubled its share, rising from 6.6 percent in 2005 to around 13 percent in 2022.
- There has been a notable decline in emissions intensity owing to the growth of non-hydro renewables and the replacement of coal by natural gas.
- Not reflected in these numbers, however, and a vital starting point for future aspirations or expectations has been the growing discussion around adequate electricity supply for current needs and for economic

growth. At the time of writing this paper, the Provinces of Ontario,[12] Quebec,[13] British Columbia[14] and Alberta[15] launched processes to address deficits in electricity generation capacity. With provincial governments highlighting inadequate supply as a driver of higher energy costs for consumers and a barrier to new industries and investment coming to their province. This is true even in the primarily hydroelectric provinces of Quebec and British Columbia.

Section Four: Looking to the Future

This section is anchored in the Canadian Energy Regulator's (CER) 2023 outlook. There are numerous modeling estimates to be found in Canada, all of them with significant differences in total energy use, source shares, and assumptions about technologies such as nuclear (small modular reactors), carbon capture or direct air capture. The CER outlook was chosen because it is an authoritative official analysis, not because it is more or less likely to be 'right.'

To start off, the CER lays out the purpose and limitations of its 2023 outlook, which are important to understand. The outlook is intended to present an option for what a net zero Canada *could* look like; it is not predictive. All outlooks are, inevitably, speculative for several reasons, including the maturity and cost of various technologies, the practicalities of installing new capital, constraints on skills and supply chains, consumer behaviour, and the policy environment (carbon pricing, regulations, subsidies, power market rules). This means that all outlooks are based on numerous assumptions which are made in good faith but are necessarily uncertain.

We do not look at the total picture but rather at the stationary energy uses that are the focus of this paper. We look at each separately, comparing the energy use picture based on 2022 actuals and then 2050 based on 'current measures', and finally at 2050 assuming the achievement of net zero. The CER has another scenario which is entitled Global Net Zero which accounts for things like the pace of technological change in the case where the whole world achieves net zero. For ease of reader understanding we have not included this scenario because the differences are for the most part not material.

Table 4.1 Canada Total End-Use (PJ)[16]

	Current Measures			Canada Net Zero	
	2022	2050	Change 05-22	2050	Change 2022-2050
Total End-Use	11,834	12,631	7%	10,024	-15%
Electricity	2,080	3,212	54%	3,919	88%
Natural Gas	4,435	4,017	-9%	2,172	-51%
RPP	4,367	4,294	-2%	1,606	-63%
Biofuels & Emerging Energy	812	975	20%	1,179	45%
Hydrogen	0	72	N.A.	1,133	N.A.
Other	140	60	-57%	14	-90%

We look at each of the stationary uses (residential, commercial/institutional, industrial and power generation) independently in order to facilitate focus. We examine the percent change from present day actuals through the two 2050 scenarios. Most importantly, we explore what has to change physically in the different energy systems in order for each scenario to come about. This is derived for the most part from the CER outlook. But we draw from both the CER analysis and numerous other sources to try to discern where assumptions may be questionable, where questions of various sorts remain unanswered or where various risks are apparent. In other words, our object is by no means to debunk the scenarios but to try to crystallize the uncertainties which we know to exist. By so doing we raise possibilities of why various scenarios need to be taken into account, why constant learning will inevitably lead us down paths we had not considered and why pace of change may prove to be a critical variable.

Sectoral Breakdowns

Residential Energy Use

The table following captures the main changes under the CER scenarios (as described above) in summary form. The most important large-scale variables are total energy use and energy source shares and how they change under each scenario. By far the biggest factor for residential energy is space heating. Water heating, cooking and other appliances are in many cases still fossil fuel fired although the majority are electric.

Under the net zero scenario total energy use needs to decline by almost 25 percent, in contrast to the current measures scenario which sees growth around 2 percent. This reflects two countervailing factors. Canada's relatively fast population growth produces a significant increase in total housing stock over the next 25 years offset by a significant increase in building energy efficiency. Building energy efficiency has been increasing steadily year by year as building technology improves and as mandated efficiency standards evolve. That, in turn, means changes in building envelope efficiency including increasing density (from single family dwellings to multi-unit dwellings and mixed-use complexes that include residential and commercial/institutional). The current measures and net zero scenarios provide a useful comparison, with current measures giving a good approximation of plausibly expected change supplemented by the estimated effects of policies already in place compared to the requirements of net zero. It should be emphasized that the effects of announced measures are, indeed, "estimated" and should be treated with some caution.

> *"The one thing I will say is there is no silver bullet to a net zero world. Decarbonization is going to require all of us thinking about how we use energy. Conservation should probably be first and foremost in everyone's mind."*
>
> *– Nancy Southern, CEO, ATCO*

New building stock can likely achieve change of that magnitude. To achieve the outcome in the scenario, policy makers will need to impose ever higher standards, encouraging higher density and mixed use where feasible and requiring much more efficient building envelopes (and equipment) of all types. The latter will have inevitable capital cost implications and although the running cost benefits of higher efficiency are well understood, the capital cost issues cannot be downplayed in an era when housing affordability has become such a dominant economic and political factor.

Table 4.2 Canada Residential Use Outlook (PJ)[17]					
	Current Measures			Canada Net Zero	
	2022	2050	Change 2022-2050	2050	Change 2022-2050
Total End-Use	1,519	1,551	2%	1,143	-25%
Electricity	653	878	34%	869	33%
Natural Gas	655	524	-20%	175	-73%
RPP	54	29	-47%	9	-83%
Biofuels & Emerging Energy	157	120	-23%	64	-59%
Hydrogen	0	0	N.A.	25	N.A.

One of the unavoidable constraints is that a great deal of the housing stock that we will have in 2050 is already built and, from that, major retrofits will be required for all but the most recently built housing. Such retrofits may pay off due to lower energy costs, but they face several barriers. Initial cost is the most obvious and something that could be offset by government assistance, although the scale and complexity (who gets assistance, under what conditions, etc.) of such assistance will be daunting. Another barrier is the problem of disruption. Retrofits involve significant rebuilding sometimes from the inside out, installing new insulation and reducing energy leakage from old, inherently leaky houses; they take time, and they are hard to do without considerable, costly and time-consuming disruption.

An unknown barrier, and one that is coming into focus as we contemplate the scale of new builds to accommodate a growing population concerns skills and management ability. The residential construction sector is already capacity constrained and will be so for some years to come. A cautionary tale can be found in the rush to improve building energy efficiency following the 1970's oil crisis when many building owners found themselves saddled with substandard work whose results were ineffective or, worse, created unanticipated problems. This time around, policy makers will need to be able to assure consumers that skilled contractors are available and properly certified.

The most striking projections in Table 4.2 are the very large growth in the share of electricity mirrored by proportionate declines in natural gas and RPPs, obviously driven by the penetration of heat pumps. Heat pumps also contribute to the overall decline in total energy use in the net zero scenario due to the efficiency gains that they afford. However, the economic case for heat pumps still rests on several limitations and assumptions about the relative costs of natural gas and electricity.

How plausible these changes are remains to be seen. Heat pump technology is mature and heat pumps can be an effective alternative except in the case of cold temperatures, a not uncommon occurrence throughout most of Canada. As temperatures reach the minus 10's,

The residential construction sector is already capacity constrained and will be so for some years to come.

conventional heat pumps lose energy efficiency and supplemental energy is required, whether from electric resistance or fuels such as natural gas. Cold climate ducted heat pumps — i.e. not conventional — can handle colder temperatures better,[18] but they also carry a higher price tag.

As with many low or zero GHG technologies, heat pumps face a barrier based on initial cost. This can be offset in the short term by subsidies and over the medium term by lower energy source costs due to their high efficiency and provided that electricity costs remain relatively low, at best a questionable assumption. Heat pumps have an additional advantage, in that they can work in reverse, cooling homes which lack air conditioning.

“Even with energy efficiency gains, an all-electric buildings sector is not practical. Capital cost for consumers is a big barrier. It makes more sense to go to hybrid heating.”

– Vince Brescia, CEO, Ontario Energy Association

A bigger barrier may prove to be the necessity of ensuring that the building envelope is highly efficient and that duct work within the building is efficient. For new buildings these conditions are relatively easily met[19]. But for a lot of old housing stock that is by no means the case, so that considerable retrofit will be unavoidable along with the sorts of barriers described above. An additional barrier at least for some time to come may be the capabilities of HVAC (Heating, Ventilation and Air Conditioning) installers. Heat pumps may not require new skills, but the scale of change will certainly require that there are more HVAC installers and ones with higher capacities and, like building trades, there will be inevitable constraints.

“The house (or building) is a system. You can’t just do things piecemeal. And every situation, every house, is different and will need different upgrades to be heat pump ready.”

– Building Industry and Land Development Association (BILD)

Indigenous Energy Security – an emerging issue

Indigenous energy security is an issue that is not often discussed but should be a part of our conversation on the future of energy. Communities themselves are by no means homogeneous. The possibilities for those in close proximity to resource development, urban areas and power and natural gas grids largely mirror those in the rest of the residential and commercial/institutional sectors.

Other communities have unique challenges by virtue of not being proximate to networks – either natural gas or electric. Some may be an hour’s drive from a major centre and have access to the electric system and not the natural gas system. Typically, the energy picture in remote communities is also dominated by various factors: poorly insulated, leaky and ill ventilated building stock; in building heat sources based on petroleum or wood which are inherently dangerous in terms of indoor air quality; local power systems dominated by relatively polluting (and expensive) diesel. Some may benefit from local renewables such as small hydro or wind but the limitations of those options are inescapable.

Natural gas remains the most affordable source of residential heat. Communities which lack access to the natural gas distribution system can pay up to four times more for their heat. As Ownership and Beyond explains, “Despite natural gas being cleaner and more affordable, only about 40 percent of people living on-reserve in B.C. have access to it to heat their homes – compared to 95 percent of other B.C. residents.” This is a problem for Indigenous communities in other provinces as well.

story continues on next page…

The recent federal government commitment to cover the full cost of heat pumps to replace heating oil may well be a useful case study of how this will all work out. The (subsidized) heat pump itself may well be affordable to the consumer, but building retrofit costs, disruption and the capabilities of HVAC installers will remain real constraints, especially in Atlantic Canada where the volume of new installations will be large relative to existing capabilities — and possibly — relative to the capacity of power distribution systems. Structural conditions (ownership of dwelling) and bureaucratic hurdles accessing support programs can add to the mix of policy challenges.[20]

Other technologies play very little role in any of the changes projected by the CER.

District heating systems (thermal grids) may well continue to play an important role in high density building environments (office centers, institutions such as universities and hospitals) but probably limited in the residential sector.

The gradual introduction of renewable natural gas (and possibly hydrogen) into natural gas streams may prove to be a more economical alternative due to the fact that they make effective use of existing infrastructure (including in-building infrastructure) even if they do not produce zero GHG emissions. In short, the existing natural gas infrastructure opens several options to enhance the reliability, resilience, and affordability of the system. At this stage the most practical and prudent conclusion is that a wide range of carriers and technological options must stay on the table.

A critical factor in all of this will be the relative cost to the consumer of electricity and natural gas. Future electricity costs will only remain in their current range if virtually all capital costs are covered by government subsidy. Gas prices vary greatly depending on market conditions combined with the effect of escalating carbon prices. But as we are seeing today, consumer level carbon pricing is under great political pressure and not only with heating oil.

continued…

In many provinces, including British Columbia, Alberta, Saskatchewan and Ontario, work has been done to expand access to the natural gas network to increase access to more affordable energy. As an example, phase 2 of Ontario's Natural Gas Expansion Program allocated more than $234 million to support approximately 8,750 connections in 43 rural, northern and Indigenous communities.[37]

Commenting on natural gas expansion in Ontario, Tyendinaga Mohawk Council Chief R. Donald Maracle said, "the expansion project will provide reliable and affordable heating to many residents and will support economic development across the community."

Commercial/Institutional Energy Use

As Tables 4.2 and 4.3 indicate, total energy use in the commercial/institutional sector is at present roughly comparable to that in the residential sector. Total energy use in the commercial/institutional sector increases substantially by 2050 under current measures but sees a significant (approximately 10 percent) decline in the net zero scenario, likely driven by the combination of more efficient building envelopes and the inherently higher efficiency of electric applications such as heat pumps.

Table 4.3 Canada Commercial/Institutional End Use Outlook (PJ)[21]					
	Current Measures			Canada Net Zero	
	2022	2050	Change 2022-2050	2050	Change 2022-2050
Total End-Use	1,492	1,730	16%	1,337	-10%
Electricity	555	818	47%	879	58%
Natural Gas	755	651	-14%	199	-74%
RPP	180	247	37%	199	10%
Biofuels & Emerging Energy	2	14	521%	26	1,034%
Hydrogen	0	0	N.A.	33	N.A.

In terms of energy source shares the two dominant sources — electric and gas — move, as one would expect, in opposite directions. In 2022 electricity accounted for around 37 percent of total use and natural gas 50 percent. By 2050 under the net zero scenario electricity is up to 65 percent and natural gas has radically declined to around 14 percent. In the meantime, RPPs have increased their share from around 12 to 14 percent.

Interestingly, in some situations, energy users may encounter the need to continue to use combustion-based heat sources but will find themselves stranded if natural gas systems become non-viable. In that case they may turn to propane or diesel, actually increasing their GHG emissions.

“We have to think of how our gas system serves multiple uses. If you compromise its viability by banning it in some places you make it harder to achieve gains where gas is the viable near medium term option.”

– Vince Brescia, CEO, Ontario Energy Association

A problem with many analyses is the use of ‘buildings’ as an analytical category. Buildings are far from homogenous and a far more useful way of looking at things in the search for low carbon solutions is to consider what goes on *inside* buildings. A separate look at residential and commercial structures, as we do here, is essential because of the distinctive energy use characteristics of the two sectors. But almost as important is that commercial use is far from homogenous and low carbon solutions vary widely. To illustrate the point, consider the following:

> Office use depends heavily on electricity for lighting, equipment and air conditioning. Space heating is derived from natural gas, or in many dense commercial or mixed-use districts such as downtown areas, thermal grids (district energy), which are more efficient and for the most part fired by natural gas but may also be hybrid, involving biomass, solid waste, geothermal and solar and may involve combined heat and power systems.
>
> In contrast, the hospitality sector, essentially hotels, bars and restaurants, has around double the energy intensity of the commercial sector overall and depends on natural gas (or in some cases propane) for the great majority of its needs due to what amounts to process heat — cooking and hot water.
>
> Considerable parts of the institutional sector, notably universities and large hospitals are relatively energy intensive and most often rely on their own energy systems for heat and sometimes electric power, again largely based on natural gas.

Many of the solutions are common in principle but different in practice. Heat pumps can be practical options for many commercial/institutional applications, like producing hot water. But replacing long lived district systems (such as standalone systems in institutional buildings or regulated utilities in office applications) is a potentially difficult option for several reasons, among them the stranded costs for district utilities, the need to install new heating equipment when none had been necessary in individual buildings or the need to convert natural gas boilers to biofuels or hybrid systems using biofuels and gas supplemented by local renewables. Cooking can be done using electrical appliances but at a cost in responsiveness, a not inconsiderable factor in restaurants.

The point of this is simply that one size does not fit all. Offices, institutions, hospitality, warehouses, laundry and dry cleaning, repair shops (and the list goes on) all face distinctive opportunities and challenges, and policy needs to account for that.

But the possibilities to improve building envelope efficiency and to install electricity-based heat systems are in sight, as with residential and in contrast to industrial, as the next section makes clear. And as with all sectors, the problem is not so much whether change is technically feasible, but with other factors.

It is critical in the first instance to distinguish new builds from retrofits. As in the residential sector, a net zero emission new build is likely to be relatively practical. But, again like residential, a great deal of the building stock in 2050 is already here. And though energy systems have shorter lifespans than buildings and most will eventually be replaced one way or another, it remains the case that retrofitting is often disruptive and expensive.

One critical factor is the relatively high upfront costs of zero emissions systems. For large users such as office and institutional, the financial depth and sophistication of their owners may reduce this hurdle and even multi-year paybacks may be feasible. That is much less true for smaller enterprises. Canada has over 480,000 commercial and institutional buildings (in contrast to residential of which there are 15 million) and, of these, a significant proportion are small with occupants and proprietors who are inevitably cash constrained, face relatively high financing costs and have other priorities for capital expenditure. Governments will need to help such facilities over the first cost hurdle.

The potential pace of change is dictated by two factors: the rate of expansion in the sector, and the dynamics of capital stock turnover in existing facilities. As a general rule, retrofit aimed at modernizing and improving functionality combined with improved building envelope efficiency and energy system replacement may produce reasonable paybacks. But standalone energy retrofits are bound to be more difficult, even with government subsidies. This is not to say that retrofit can't be done, but the pace will vary greatly. The key will be to seize opportunities when they arise (such as when commercial buildings are adapted to residential use), driven by a combination of relative energy costs as between electricity and (carbon price burdened) natural gas, along with ever stricter regulatory standards, mainly to do with efficiency rather than emissions per se.

Underlying all of this (as with residential buildings) is the question of reliability in the face of disruptive events such as weather. For most large buildings (apartments, offices) and those that rely on energy for crucial processes (such as hospitals) even a brief loss of energy is not an acceptable option. In most cases these facilities rely on combustion-based backup systems, fueled by natural gas, propane or diesel.

Looking at residential and commercial together, the striking projection is the drop in the share of natural gas from 43 percent in residential and 50 percent in commercial/institutional to around 15 percent in both cases. Would the respective residential and commercial needs currently met by natural gas still be adequately met with alternatives? So far at least — policy makers have largely skipped over this question.

One possibility concerns the degree to which natural gas systems can become the conveyors of low or zero emission options such as renewable natural gas or hydrogen. At present some of these options exist but they would account for at best a fraction of the total energy delivered, and emission reductions would be limited. Offsetting this is the relative economy of utilizing existing (gas) systems combined with the reliability advantages of below ground systems.

Industrial Energy Use

The following table sums up the CER outlook for changes in industrial energy (resource production including agriculture, resource processing and manufacturing) implied by net zero. (Note that in the following text we refer at times to "industrial" use and at others only to manufacturing.)

A few things stand out.

Total energy use grows slightly under the current measures scenario but declines substantially under net zero, presumably mostly reflecting efficiency improvements, either standalone or associated with electrification. Interestingly, electricity's share increases dramatically in the current measures scenario most likely reflecting several factors such as carbon pricing and the broader pressures on industrial users to decarbonize. Correspondingly, natural gas' share declines in both current measures (slightly) and then substantially in net zero. By 2050 under net zero, natural gas declines from around half of industrial use in 2022 to the point where natural gas and electricity each account for close to one-third by 2050.

But strikingly, neither natural gas nor RPPs disappear, probably attributable to the continuing need for high temperature processes in many industries, although by 2050, under CER assumptions a good share of that is likely abated by carbon capture, utilization, and storage (CCUS). Biofuels and emerging energy make substantial gains as does hydrogen (a dramatic increase from a very small base) although the share of hydrogen remains small at just over 6 percent of total energy use.

Table 4.4 Canada Industrial Use Outlook (PJ)[22]

	Current Measures			Canada Net Zero	
	2022	**2050**	**Change 2022-2050**	**2050**	**Change 2022-2050**
Total End-Use	6,245	6,646	6%	5,502	-12%
Electricity	866	1,309	51%	1,358	57%
Natural Gas	3,021	2,838	-6%	1,792	-41%
RPP	1,725	1,750	1%	1,172	-32%
Biofuels & Emerging Energy	493	618	25%	809	64%
Hydrogen	0	72	N.A.	357	N.A.
Other	140	60	-57%	14	-90%

Several aspects of industrial energy use warrant highlighting. The first, as noted in Section Three is that industrial use in 2022 accounted for around two-thirds of total stationary end use in Canada. Canadian industry is very energy and GHG intensive, reflecting the dominance of resource development and processing, notably agriculture, energy, minerals (especially steel and aluminum), chemistry and cement as compared to other manufacturing which is both lower energy intensity and more likely to rely heavily on electricity. How the decline in industrial energy identified in the CER scenario maps onto growth in Canada is not clear but is an important consideration given the starting point of our economy.

“The chemistry industry has a complex relationship with the climate challenge. The industry is a large emitter from both energy use and inherent process emissions; it is simultaneously the base from which we can make all the products that provide the solutions that enable other sectors to move towards a net zero economy.”

– Bob Masterson, CEO, Chemistry Industry Association of Canada

Something not captured in these data is the importance of inherent process emissions which can only be abated by fundamentally redesigned processes[23]. This can take many forms such as steel production based on direct reduced iron-electric arc furnaces, advanced catalysts (and lower temperatures) in chemical production or a growing share of recycled materials for plastics. All these sorts of changes are coming or under serious examination today, but many will require some years to become the norm. This fact, combined with the intrinsic need for very high temperatures (and, therefore, combustion-based energy) emphasizes the centrality of CCUS to a low carbon future.

It is vital to consider the importance of industrial activities to the Canadian economy. Not only do they account for a very large share of energy use but also an enormous share of export revenue. In 2019, the Canadian energy sector contributed almost 10 percent of the GDP ($187 billion. For that same year, exports of energy products amounted to $124 billion, or more than 20 percent of exports of merchandise.[24] These are also very high labour productivity sectors, especially oil and gas, in a country where we’ve been seeing very slow growth in labour productivity in recent years, with all that that implies for Canada’s overall economic well being.[25] In addition, industrial activities are important in virtually every region, thereby distributing well-being beyond urban centers and, as we are beginning to see,[26] creating new development opportunities for Indigenous people in Canada.

“The challenge is not only one of environmental policy but, rather, of investment policy; how do we attract the significant investment necessary to deliver deep decarbonization?”

– Bob Masterson, CEO, Chemistry Industry Association of Canada

The challenge faced by Canadian industry is much deeper than the need to decarbonize. With rapid technological change worldwide and given the export orientation of most industries, Canada faces a pressing need to increase investment in industry. But according to the Canadian Manufacturers and Exporters (CME), investment in Canadian industry compared to — for example — our Canada, U.S., Mexico Agreement partners, is anemic — equivalent to only 1.2 percent of global manufacturing investment between 2015 and 2020. By comparison the U.S. attracted 23 times Canada’s amount and Mexico 10 times.[27] In this context Canadian industry has faced more stringent carbon policies than either the U.S. or Mexico, with some effect on our competitiveness in attracting investment. This is the foundation upon which decarbonization investment must be built and the resulting dilemma is daunting:

- Canada must significantly increase investment in industry simply to remain competitive.

- Cost increases that don't contribute to productivity advances (labour or total factor productivity) reduce our competitiveness and although increased energy efficiency and some process changes will enhance productivity, many decarbonization measures will not.
- At the same time, investors and customers are increasingly looking not only to cost competitiveness but to carbon competitiveness throughout their supply chains and Canadian industry is under steady pressure to adapt.
- The question is how all of this can be taken on board, making Canada an attractive destination for new investment while steadily decarbonizing.

How that question gets answered will mean a great deal to Canada's economic position in coming years and policy makers face some steep challenges, whether directly contributing to new investment with direct or tax incentives, developing systems of border adjustment or considering pathways to decarbonization that allow diverse, practical — and perhaps more gradual — solutions.

Even more than with residential and commercial/institutional use, regional variation will remain a very large factor in the possibilities to decarbonize industrial energy use in Canada.

"Quebec's advantage is its heritage power; new power coming on such as wind is at marginal costs several times higher than the average cost. Major power users can switch production all over the world. In some industries electricity is as much as 70 percent of their costs of production; Quebec industry competes not on labour costs or closeness to markets or an efficient regulatory environment but on competitively priced electricity."

– JB Allard, President, Québec Association of Industrial Consumers of Electricity

There are several critical factors. One is the widely varying availability of competitively priced zero-emission electric power, substantial (but as noted in the next section, becoming capacity constrained) in B.C., Manitoba, Ontario and Quebec, much less so in the prairies and Atlantic Canada. But even in the 'hydro' provinces low-cost power may be more in the past than in the future. Most plausible estimates for the cost of new hydro place it well above the cost of 'legacy' power.

Another is the practicality of carbon sequestration, a function of geology as well as social acceptance, as discussed below. Yet another may be the geographical concentration of industrial uses which will likely be a critical factor in the feasibility of hydrogen hubs and CCUS hubs. North-central Alberta and (possibly) southwest Ontario will be winners in this game; other regions may struggle.

Finally, a notable aspect of Canadian manufacturing is that the great majority (96 percent) of companies are small or medium sized (less than 100 employees).[28] Such companies face even steeper challenges than larger ones. They do not have the management depth or ready access to new technologies enjoyed by large and multinational corporations. They face the same challenges to ready their workforces to deal with new processes and technologies but lack the depth to facilitate training or to recruit new skills.[29]

"Overcoming skills shortages and developing the workforce of the future will be a major challenge. While old systems can be managed with existing skills and expertise, the transition to new, clean energy systems demands a fresh set of competencies."

Dennis Darby, CEO, Canadian Manufacturers and Exporters

The following is a very high-level overview of the kinds of changes that are implied by the drive toward net zero.

- Process changes. As noted earlier, aside from energy use or energy source, many industries will need to introduce radical process changes. Many are technologically feasible (and described briefly above) but most are not yet economic. Large efforts are needed to support technological innovation across the board.

- Efficiency. Changes to enhance energy efficiency will play an important role given the numerous possibilities to be found every time a process is updated or energy systems are changed out. And increased efficiency pays a double dividend: reduced emissions and lower energy costs.
- Electrification. Electrification could prove feasible and cost effective in numerous applications but likely not for the big emitting sectors (and it should be recalled that Canada aspires to be a big producer of critical minerals, the production and processing of which may not be feasible based entirely on electricity). As the CER outlook shows, despite the significantly growing share of electricity, it still accounts for only around one-third of total industrial energy use by 2050.
- A critical factor will prove to be significantly increasing electricity production to displace currently used fuels in Canada's economy, implying electrical generation and infrastructure that is multiples of Canada's existing electricity system. The additional challenge of ensuring this electricity is low emission and competitively priced will also be critical. With demand set to grow in many competing applications, notably electric vehicles and building heat at the same time (as noted above), low-cost power will likely become a distant memory. This fact may prove especially onerous in Quebec whose processing industries are largely electricity based and whose competitiveness has been dependent to date on low-cost legacy power.
- Natural gas. Despite a big drop in natural gas' share, it still accounts for around one-third of total energy use in 2050. Over time, the emergence of hydrogen (still only 6 percent in 2050) could provide an alternative source of high temperature heat, but much of that remains to be proven and implemented. In any event, there is little doubt that a robust gas delivery network will remain a critical factor supporting Canadian industry and that will turn, in part, on well informed policy concerning the functioning of gas in the Canadian economy overall and the continued economic viability of natural gas delivery systems.
- Refined petroleum Products. RPPs remain a substantial part of industrial energy use (about 20 percent) in the 2050 net zero scenario despite a big drop from 2022.
- CCUS. Given the combination of process emissions and the continuing need for combustion fuels CCUS is likely to be a vital part of the puzzle. CCUS remains a nascent technology, and there are still many skeptics. But it is gradually proving itself in western Canada in power generation and in oil and gas production, so it may be nascent but hardly speculative. Apart from the technical feasibility and economics of carbon capture, there remains the question of socially acceptable and reliable sequestration. The prairies are well positioned in terms of their geology, but with the possible exception of southwestern Ontario opportunities for sequestration will remain limited in the rest of Canada.
- Hydrogen. Hydrogen remains a big question mark. Again, as noted above, despite dramatic growth in the net zero scenario, hydrogen still accounts for a minor share of industrial energy use in 2050. Hydrogen faces many challenges, not least the cost of producing it. Steam methane reforming is a ready possibility but, by comparison, hydrogen from electrolysis is much more costly and, even if economically feasible, will place significant load on power systems which will, as noted earlier, be stretched to perform multiple tasks in the net zero economy.
    - There is a convincing case to be made that the priority with hydrogen should be to ensure growing end use applications, a robust hydrogen market and a robust delivery system. Especially in combination with CCUS, hydrogen derived from natural gas can be an important contributor to the gradual transformation of industrial energy use and emissions. With a pragmatic approach (and counting on the development of technology in Canada and beyond Canada), over time, hydrogen can evolve from grey to blue to green. It is arguable that the

debate over the colour of hydrogen may, perversely, inhibit its application.[30]

- Looking towards 2030 and 2050, the CER outlook considers reductions in the cost of electrolyzers of 62 and 70 percent (See Current Measures scenarios in Table 4.5) and 74 to 82 percent (See Net Zero scenarios in Table 4.5).[31] As mentioned, low cost electricity and overall contribution to emissions abatement are a requisite. Today, electrolysis is outperformed by natural gas-based hydrogen (with abatement of CO_2 emissions) and into 2050, in all the net zero scenarios anticipated by the International Energy Agency.[32]
- It is important to note that developing hydrogen across the energy system requires making other decisions in which governments must show resolve and technical capacity. At this moment, the availability of new applications and associated infrastructure and markets creating more demand is as important as the availability of hydrogen. Industrialized nations are competing to gain advantage in the hard-to-abate segments that hydrogen is called to occupy, notably in heavy duty and maritime transportation, aviation and some industrial applications, like steel. As the CER assumptions implicitly recognize, the success of these applications depends on a global technological race, to which Canada can contribute but that Canada cannot define.

Power Generation

> *"The most economical and reliable way to relieve the uncertain nature of wind blowing or the sun shining is through natural gas fired generation."*
>
> *– Nancy Southern, CEO, ATCO*

As the following table shows the CER net zero scenario produces an increase in power generation in Canada overall from 650,000 GWh in 2022 to around 1, 360,000 GWh in 2050 (28 years), a 110 percent increase. For reference, this compares to a historical increase totalling 9 percent from 2005 to 2022 (17 years. See Section 3). In capacity terms this translates to an increase from 152 GW to around 350 GW, around a 130 percent increase which places the CER estimate in the mid-range of the capacity growth estimated by other analysts.

Table 4.5 Power Generation (TWh CER 2023)[33]

Canada						
	Current Measures			Canada Net Zero		
	2022	2050	Change	2022	2050	Change
Hydro / Wave / Tidal	376,175	439,732	17%	375,440	474,316	26%
Wind	50,063	247,580	395%	50,024	425,064	750%
Biomass / Geothermal	11,048	31,214	183%	11,188	71,889	543%
Solar	11,441	62,977	450%	10,465	74,699	614%
Uranium	87,342	87,524	0%	87,113	249,972	187%
Coal & Coke	27,695	656	-98%	27,613	0	-100%
Natural Gas	84,841	102,350	21%	82,039	62,772	-23%
Oil	1,494	449	-70%	1,535	1,004	-35%

In terms of energy sources, hydro grows substantially but wind, biomass/geothermal, solar and nuclear (the base data refers to the fuel — uranium — but we refer hereafter to *nuclear*, which is a more widely understood term) grow by very large increments. Natural gas declines almost 25 percent, RPPs a bit more and coal disappears entirely.

As with the historical data there is a great variation by province. British Columbia sees its growth (in absolute terms) strongly dominated by wind (solar grows more in percentage terms but from a very small base) and, interestingly, nuclear shows up for the first time. The prairies show substantial absolute increases in hydro and wind and a substantial increment of nuclear, all of that slightly offset by a drop in natural gas. Of course, there is wide variation with Manitoba accounting for most of the hydro, Saskatchewan dominated by nuclear and Alberta accounting for the biggest increment of wind. Ontario's biggest absolute increments are wind and nuclear along with a substantial increase in natural gas. Quebec stands out from other provinces showing its largest absolute increase in hydro and modest amounts in wind and nuclear. The Atlantic region, consistent with most other regions or provinces shows by far the largest absolute increment in the form of wind.

Parenthetically, the CER outlook (and others such as the Manitoba Hydro Integrated Resource Plan) pay some attention to distributed generation and to the potential for demand response (basically shedding load to reduce peaks) but neither play a very big role overall and we have left that out of our analysis.

All of the above makes sense, at least in principle, given the resource endowments of the various provinces. But at least two of the hydro endowed provinces (B.C. and Quebec) are already reporting emerging capacity constraints as industry in particular looks to shift to zero GHG power so significant growth may be unavoidable under current conditions, leaving net zero aside. What is less clear is what it might mean in practice. Several key factors will come into play.

The very large increment of wind, province by province, appears consistent with resource availability with the biggest challenge likely being how to integrate such large increments of intermittent power balanced by substantial base load increases (in theory hydro and nuclear) and substantial utility scale storage which is only beginning to emerge. Social acceptance may be a bigger question than has been considered to this point. We have witnessed local resistance to wind turbines over the years, and one cannot discount such resistance emerging in future. And of course, in recent months we have seen Alberta pressed by mainly rural populations to take a harder look at wind (and solar) and its purported impacts on agriculture. Some of these concerns may be unjustified, but they exist and thus are 'real' in social acceptance and political terms.

Hydro will present an interesting case. With the exception of Site C in B.C., Muskrat Falls in Labrador and la Romaine in Quebec, there has been very little large hydro development in recent years and large hydro faces a number of challenges. The biggest may be social acceptance driven in large measure by the significant environmental impacts of stored hydro. As with virtually all development of all sorts, in every province much will turn on the degree to which Indigenous communities are brought on board, a process that has seen growing success in recent years, but which inevitably involves taking the needed time.

But another question concerns what may be involved in construction and the consequent cost. Site C and Muskrat Falls may or may not be harbingers for the new hydro era; in contrast, the four units of the La Romaine complex (which is larger than either Site C or Muskrat Falls) began construction in 2009 with commissioning in 2014 through 2022, a relatively short time span. In any event, the possibilities may be demonstrated one way or the other reasonably soon as Quebec embarks on hydro expansion at several yet to be identified sites. Time to approve and build may prove a challenge given the relatively short time (in hydro building terms) between now and 2050. Note that Site C, and Muskrat Falls — a total increment of around 2,000 MW between them (less than 2 percent of what may need to be built by 2050) — have each passed 20 years since inception and neither is yet in service. Total investment costs including new transmission will be significant and it is just possible that the era of 'cheap' hydro may be history, with all that that implies in jurisdictions that have used low-cost power as a major competitive advantage for industry.

Nuclear may prove to be an even more interesting case. Over the course of several decades nuclear power went from a purported "too cheap to meter" to being a pariah due to perceived safety concerns and a still unresolved puzzle with respect to nuclear waste disposal. But nuclear has begun to make a comeback as a zero emissions base load source and in the form of small modular reactors (SMRs) which may prove less costly than conventional reactors. Social acceptance may prove to be manageable in jurisdictions with some familiarity with nuclear and brownfield sites. Capital Power in Alberta is in discussions with Ontario Power generation to examine the feasibility of SMRs in Alberta. Saskatchewan, a large nuclear producer but with no experience to date with nuclear power will be interesting to watch.

An important factor may prove to be the time asymmetry between load growth and capacity growth. Large scale new sources, as noted above, involve very long investment horizons anticipating load profiles well over a decade into the future. The question is whether load growth will move in lockstep. Governments are attempting to mandate electrification in light duty vehicles and possibly in residential and commercial space heat, and industry is ever on the lookout for opportunities to reduce their emission profiles. But as noted in other sections, the speed at which such transformations take place, or whether they occur at all is a matter of conjecture. Power producers, transmission and distribution utilities, electric system operators and economic regulators will be cast into the role of something closer to crystal ball gazers than to forecasters and factors such as natural risk aversion (or painful debates about who will bear the risk) will affect the pace and scale of change.

Finally, a very big factor which is only beginning to attract attention is the matter of capability: materials, equipment, supply chains, management capability and skills. This is a factor that will bear on all sectors, as noted earlier but it may loom largest for power generation which will have very high requirements across the board if we are to more than double Canada's electric power capacity in about 25 years.

Section Five: Overall Observations

Many factors will influence the pace and scale of change as governments try to achieve net zero. One big one that receives far less attention than it should is the modeling of an energy future which is utterly different from the past and cannot rely on many established statistical relationships. With any net zero energy outlook modelling rests mainly on assumptions. As an example, the CER Outlook usefully outlines several "what ifs" that will affect the results[34]:

- What if the technologies to enable wide-scale adoption of hydrogen are more or less costly?
- What if small modular reactor (SMR) technology matures less quickly and is more costly?
- What if direct air capture (DAC) technology matures more quickly and is less costly?
- What if carbon capture, utilization, and storage (CCUS) technology does not mature as quickly and is more costly?
- What if electricity vehicle charging patterns result in higher peak electricity demand?

All of these are highly plausible risks but there are several others.

One of these — and a potentially big one — is social acceptance along with regulatory approval processes. To again quote the CER Outlook:

> Given our assumptions, the model might suggest that building a wind farm, for example, is the optimal outcome. However, the process to build such a facility would also depend on additional factors like the results of regulatory decision-making and societal viewpoints towards the project. We look at these factors in a general sense to assess if our projections are reasonable, but these factors are not easily accounted for within our energy models or study design, and largely fall outside the scope of EF2023.

The above paragraph neatly captures two of the most vexing problems with any energy outlook, both of which raise questions across the board from end use to power generation.

The first part of it is individual people and their behaviour as explored briefly in the residential and commercial/institutional sections. Behavioural factors of various sorts could loom large, and their effect will almost always be to slow change rather than accelerate it.

Approval processes — as explored in some depth in Cleland and Gattinger[35] will inevitably be a drag on change. Approval processes involve resource regulators, environmental impact agencies, economic regulators, power system operators and numerous permitting authorities. They are complex and multi-dimensional, especially in a federal system and one where Indigenous communities will insist, with the law and constitution behind them, on playing a bigger formal role.

As noted in the CER Outlook and as reported almost daily in the press, the availability of critical minerals is a very real risk (and cost) factor. Most of this will affect power storage and electric vehicles (which is outside the scope of this paper), but they will also affect the building (think of copper) and the operation of power systems (think new IT systems) from generators to transmission and distribution to end use technologies.

More generally, capability will almost certainly prove to be a big and growing constraint. Critical minerals are one part of that along with supply chains and management capabilities, but the biggest question will be skills. Energy systems from upstream to end use require numerous very highly sophisticated skills both to build and operate. One very prosaic example is residential construction which is already supply constrained and will be for some time to come. The more sophisticated skill sets involved in things like nuclear construction will be in tight supply, with implications for cost and pace.

Overall, it is worth coming back to the point that the CER outlook — which still envisions considerable natural gas use — points to increased power generation of over 100 percent (and larger capacity increases). For perspective, this means annual growth at a rate vastly greater than Canada has experienced in the past two decades.

To return to the overarching theme of this paper, the primary job of the energy system is to deliver energy services in a way that is safe, secure, reliable, resilient and affordable, and building those systems will rest fundamentally on social acceptance. A prudent approach to the problem would involve all actors in the search for solutions asking themselves several questions as we proceed. These are outlined below.

Section Six: Concluding Comments

As noted, these conclusions are framed as questions to be asked as Canada proceeds toward net zero. Governments especially need to be asking these questions and the evidence to date is that they often fail to do so, at least until things go wrong.

The first, to repeat, is whether policy has adequately taken into account the need to pay careful attention to energy fundamentals. We know how consumers react when things go wrong, whether it be in the form of power outages or cost increases. We also know that an energy intensive Canadian economy will continue to depend on guaranteed availability of energy at competitive prices. All of these have social, economic and political implications, inattention to which will almost certainly cause failure to reach the net zero goal.

Another is whether adequate attention is being paid to questions of social acceptance, the costs and risks of formal approval processes and whether public authorities are doing the work necessary to mitigate them.

“*Let’s actually ask our citizens what they’re prepared to make choices on and understand the benefit and the cost of making (those) choices.*”

– Nancy Southern, CEO, ATCO

The next question — a big one — concerns how much serious and honest attention has been given to costs. A plausible look to the future toward the end of such a transition sees the costs of energy and the risks to security being reduced in the new energy world. Of course, that is subject to many unknowns, especially as dependence grows on critical minerals and vulnerable supply chains.

The short and medium run is inevitably dominated by extremely large capital costs, a problem made worse in recent years as interest rates have climbed. Individual consumers will not easily wear those costs and the potential social equity and political concerns of forcing it will dominate the future. Large (business) energy consumers may bear some of those costs if they can see their way forward to a reasonable risk adjusted return and are able to attract the necessary capital. A big “if.” But for most consumers, be they cash strapped individuals or large businesses who must compete for global capital, that is a stretch. And while it is widely assumed that governments will step in to fill the gap, the fiscal constraints increasingly faced by all governments in Canada make that expectation tenuous. Has serious and honest consideration been given to all of this? The answer is no, and it is past time to turn our collective minds to the problem.

Yet another concerns whether adequate consideration has been given to the relative merits of incremental change consistent with behavioural realities and the myriad technological unknowns. A drive to net zero tends to produce a single minded focus on political commitments to achieve quick emission reductions, but the behavioural, technological and investment uncertainties and the risk of producing stranded assets and possible stranded consumers argues for a more prudent approach.

Have we given appropriate consideration to the potential benefits of doing this incrementally? As we move away from high GHG fuels such as coal and RPPs, how much practical consideration has been given to the merits of moving by stages to natural gas, to GHG mitigated natural gas and eventually to zero emission electricity and hydrogen? Is the hydrogen future more likely to emerge from a steady build out of hydrogen markets and infrastructure, even based on less than green hydrogen or from the hope that green hydrogen will quickly become economic? A more gradual approach reduces the risk of system failures and increases the durability of change. It may not even slow the process of emission reduction, if it facilitates consumer and community buy-in that sticks, and is not overthrown by economic, social or political reaction.

“*We aren’t here to hold things back but to help build the new future based on established infrastructure, skills, expertise and research capabilities. Build on what you’ve got, don’t tear it down.*”

– Mike Bradley, Mayor, City of Sarnia

Have we given adequate attention to the merits of building on existing capabilities, most notably including established infrastructure. Infrastructure you don’t have to build is the most affordable kind, and in the case of the natural gas system, it can be leveraged for both renewable natural gas blending and hydrogen blending. Reducing emissions while keeping costs down. It is worth noting as well that where certain applications cannot be substituted with electricity, the risk of stranding customers becomes a concern, especially where other customers are being pushed off the natural gas system. This leaves other customers on the gas system bearing full system costs. The economic and environmental benefits of this outcome are not obviously a net positive — highlighting the importance of looking at various risks together.

Have we properly considered the time it will take to build capability? We know, for example, that numerous Indigenous communities are looking for both energy security and to participate in building new energy systems, but we also know that those communities will need time to build social acceptance, management capabilities and skills. And, speaking of skills yet again, do we have any idea of the time it takes to develop and deploy them to avoid constraints and the inflationary effects that will be inevitable when such constraints arise?

And, finally, have we reflected on the fact that energy is a long game? Looking at the evolution of the Canadian energy system since 2005, we can see that it has changed generally in the direction of carbon reduction, but that change has happened slowly. GHG mitigation policy appears to have sped this up in recent years, but at nowhere near the pace implied by the net zero scenarios. Achieving such a pace is a truly daunting challenge, and there remains a real danger that when the monumental nature of that task is more widely appreciated, the public will feel betrayed and be inclined to throw out the baby with the bathwater.

Addressing each of these questions is an absolute necessity if we are to attain our most important goal of prudently building out a truly sustainable system which is flexible enough to respond to changing circumstances, is fully capable of supplying Canada's energy needs and enjoys the confidence of citizens, consumers and investors.

Appendix A: Provincial Energy Data Breakdown

Tables for Section 3[36]

Table A3.1 British Columbia Stationary End-Use (PJ) 2022				
	Industrial	Commercial	Residential	Total
Biofuels & Emerging Energy	196	1	12	209
Electricity	94	57	70	221
Hydrogen	0	-	0	0
Natural Gas	229	78	73	381
Other	9	-	-	9
RPP	96	6	1	103
Total End-Use	623	143	157	923

Table A3.2 British Columbia Total Stationary Use (PJ) 2005-2022						
	2005	2010	2015	2020	2022	Share (2022)
Biofuels & Emerging Energy	229	195	200	194	209	23%
Electricity	227	209	199	208	221	24%
Hydrogen	0	0	0	0	0	0%
Natural Gas	366	305	338	362	381	41%
Other	13	11	7	4	9	1%
RPP	106	102	108	103	103	11%
Total End-Use	940	823	852	871	923	100%

Table A3.3 Prairies Stationary End-Use (PJ) 2022				
	Industrial	**Commercial**	**Residential**	**Total**
Biofuels & Emerging Energy	92	0	10	102
Electricity	249	116	84	450
Hydrogen	0	-	0	0
Natural Gas	2,307	332	235	2,874
Other	5	-	-	5
RPP	957	91	2	1,050
Total End-Use	3,611	539	332	4,482

Table A3.4 Prairies Total Stationary Use (PJ) 2005-2022						
	2005	**2010**	**2015**	**2020**	**2022**	**Share (2022)**
Biofuels & Emerging Energy	128	87	99	91	102	2%
Electricity	345	366	425	446	450	10%
Hydrogen	0	0	0	0	0	0%
Natural Gas	1,742	2,047	2,551	2,643	2,874	64%
Other	16	15	4	1	5	0%
RPP	881	921	1,028	1,049	1,050	23%
Total End-Use	3,112	3,435	4,107	4,231	4,482	100%

Table A3.5 Ontario Stationary End-Use (PJ) 2022				
	Industrial	Commercial	Residential	Total
Biofuels & Emerging Energy	77	-	32	109
Electricity	146	198	177	521
Hydrogen	0	-	0	0
Natural Gas	286	261	320	867
Other	100	-	-	100
RPP	411	53	12	477
Total End-Use	1,020	512	541	2,073

Table A3.6 Ontario Total Stationary Use (PJ) 2005-2022						
	2005	2010	2015	2020	2022	Share (2022)
Biofuels & Emerging Energy	116	99	105	95	109	5%
Electricity	468	483	496	497	521	25%
Hydrogen	0	0	0	0	0	0%
Natural Gas	934	792	909	855	867	42%
Other	133	119	109	101	100	5%
RPP	550	593	631	475	477	23%
Total End-Use	2,201	2,086	2,250	2,023	2,073	100%

Table A3.7 Quebec Stationary End-Use (PJ) 2022				
	Industrial	Commercial	Residential	Total
Biofuels & Emerging Energy	90	1	77	168
Electricity	331	144	264	740
Hydrogen	0	-	0	0
Natural Gas	145	71	26	242
Other	21	-	-	21
RPP	159	16	10	186
Total End-Use	746	233	377	1,356

Table A3.8 Québec Total Stationary Use (PJ) 2005-2022						
	2005	2010	2015	2020	2022	Share (2022)
Biofuels & Emerging Energy	165	143	152	159	168	12%
Electricity	693	646	677	705	740	55%
Hydrogen	0	0	0	0	0	0%
Natural Gas	200	226	254	234	242	18%
Other	24	19	19	17	21	2%
RPP	358	275	221	195	186	14%
Total End-Use	1,439	1,309	1,323	1,310	1,356	100%

Table A3.9 Atlantic Stationary End-Use (PJ) 2022				
	Industrial	Commercial	Residential	Total
Biofuels & Emerging Energy	39	-	25	64
Electricity	45	37	57	138
Hydrogen	0	-	-	0
Natural Gas	51	11	1	63
Other	5	-	-	5
RPP	90	12	28	130
Total End-Use	229	61	111	401

Table A3.10 Atlantic Total Stationary Use (PJ) 2005-2022						
	2005	2010	2015	2020	2022	Share (2022)
Biofuels & Emerging Energy	73	65	59	56	64	16%
Electricity	135	130	127	127	138	35%
Hydrogen	0	0	0	0	0	0%
Natural Gas	36	49	58	63	63	16%
Other	5	7	5	5	5	1%
RPP	224	230	164	126	130	33%
Total End-Use	473	481	413	376	401	100%

Table A3.11 Power Generation (GWh) 2005-2022							
British Columbia						Share	Growth
	2005	2010	2015	2020	2022	2022	05-22
Hydro / Wave / Tidal	60,327	53,971	64,999	63,814	59,554	86%	-1%
Wind	-	123	868	3,008	2,008	3%	1,533%
Biomass / Geothermal	2,863	3,811	3,659	3,935	5,521	8%	93%
Solar	-	-	-	27	438	1%	-
Nuclear	-	-	-	-	-	0%	-
Coal & Coke	-	-	-	-	-	0%	-
Natural Gas	2,383	2,089	1,768	1,171	1,677	2%	-30%
Oil	91	107	130	74	96	0%	6%
Total	65,664	60,101	71,424	72,030	69,295	100%	6%

Table A3.12 Power Generation (GWh) 2005-2022							
Alberta						Share	Growth
	2005	2010	2015	2020	2022	2022	05-22
Hydro / Wave / Tidal	2,316	1,620	1,977	2,431	1,651	2%	-29%
Wind	741	1,629	4,089	5,453	10,161	12%	1,271%
Biomass / Geothermal	1,725	1,909	2,120	1,785	1,938	2%	12%
Solar	-	-	-	178	2,807	3%	-
Nuclear	-	-	-	-	-	0%	-
Coal & Coke	43,581	37,567	38,469	28,141	14,179	17%	-67%
Natural Gas	19,569	27,595	33,998	41,400	55,005	64%	181%
Oil	509	27	80	16	16	0%	-97%
Total	68,441	70,346	80,733	79,403	85,757	100%	25%

Table A3.13 Power Generation (GWh) 2005-2022							
Saskatchewan						Share	Growth
	2005	2010	2015	2020	2022	2022	05-22
Hydro / Wave / Tidal	4,573	3,866	3,426	3,389	3,924	16%	-14%
Wind	92	507	620	821	672	3%	630%
Biomass / Geothermal	-	-	-	109	257	1%	-
Solar	-	-	-	32	149	1%	-
Nuclear	-	-	-	-	-	0%	-
Coal & Coke	13,158	13,510	12,024	8,169	8,017	33%	-39%
Natural Gas	1,896	2,504	7,348	10,914	11,345	47%	498%
Oil	18	21	2	1	1	0%	-94%
Total	19,737	20,408	23,420	23,436	24,364	100%	23%

Table A3.14 Power Generation (GWh) 2005-2022							
Manitoba						Share	Growth
	2005	2010	2015	2020	2022	2022	05-22
Hydro / Wave / Tidal	36,440	33,269	34,774	36,142	29,880	97%	-18%
Wind	53	343	903	939	537	2%	914%
Biomass / Geothermal	27	-	82	80	79	0%	188%
Solar	-	-	-	8	17	0%	-
Nuclear	-	-	-	-	-	-	-
Coal & Coke	413	44	62	-	-	0%	-100%
Natural Gas	42	99	119	21	176	1%	324%
Oil	8	2	6	16	16	0%	97%
Total	36,984	33,757	35,946	37,206	30,706	100%	-17%

Table A3.15 Power Generation (GWh) 2005-2022							
Ontario						Share	Growth
	2005	2010	2015	2020	2022	2022	05-22
Hydro / Wave / Tidal	35,480	32,555	35,043	39,005	36,156	23%	2%
Wind	26	2,800	11,396	13,169	17,885	11%	68,687%
Biomass / Geothermal	808	735	937	1,100	1,071	1%	33%
Solar	-	123	1,425	5,636	7,991	5%	6,397%
Nuclear	77,969	81,975	91,769	87,845	82,259	52%	6%
Coal & Coke	28,734	10,337	-	-	-	0%	-100%
Natural Gas	13,283	16,886	16,218	11,039	12,753	8%	-4%
Oil	310	73	657	85	85	0%	-73%
Total	156,609	145,484	157,446	157,880	158,201	100%	1%

Table A3.16 Power Generation (GWh) 2005-2022							
Quebec						Share	Growth
	2005	2010	2015	2020	2022	2022	05-22
Hydro / Wave / Tidal	173,113	177,402	194,413	194,227	196,306	92%	13%
Wind	416	1,535	6,421	11,323	14,323	7%	3,343%
Biomass / Geothermal	646	844	925	1,309	1,593	1%	147%
Solar	-	-	1	31	30	0%	
Nuclear	4,322	3,552	-	-	-	0%	-100%
Coal & Coke	-	-	-	-	-	0%	
Natural Gas	269	222	141	87	325	0%	21%
Oil	180	586	532	557	615	0%	241%
Total	178,945	184,141	202,434	207,534	213,191	100%	19%

Table A3.17 Power Generation (GWh) 2005-2022							
New Brunswick						Share	Growth
	2005	2010	2015	2020	2022	2022	05-22
Hydro / Wave / Tidal	3,875	3,325	2,615	2,572	2,738	21%	-29%
Wind	-	389	792	903	1,100	9%	183%
Biomass / Geothermal	610	585	309	562	225	2%	-63%
Solar	-	-	-	2	2	0%	-
Nuclear	4,378	-	4,277	4,800	5,083	39%	16%
Coal & Coke	3,101	2,308	1,734	1,171	1,600	12%	-48%
Natural Gas	1,980	2,035	3,143	1,347	2,094	16%	6%
Oil	3,623	2,546	1,070	41	61	0%	-98%
Total	17,567	11,188	13,940	11,398	12,902	100%	-27%

Table A3.18 Power Generation (GWh) 2005-2022							
Newfoundland and Labrador						Share	Growth
	2005	2010	2015	2020	2022	2022	05-22
Hydro / Wave / Tidal	40,741	40,287	39,686	38,147	44,311	99%	9%
Wind	-	183	172	195	195	0%	6%
Biomass / Geothermal	-	-	-	-	-	0%	-
Solar	-	-	-	1	1	0%	-
Nuclear	-	-	-	-	-	0%	-
Coal & Coke	-	-	-	-	-	0%	-
Natural Gas	267	455	225	250	125	0%	-53%
Oil	1,306	1,017	1,670	869	169	0%	-87%
Total	42,315	41,942	41,753	39,461	44,800	100%	6%

Table A3.19 Power Generation (GWh) 2005-2022							
Nova Scotia						Share	Growth
	2005	2010	2015	2020	2022	2022	05-22
Hydro / Wave / Tidal	926	1,008	979	756	978	11%	6%
Wind	85	387	804	925	2,155	25%	2,435%
Biomass / Geothermal	318	378	427	259	354	4%	11%
Solar	-	-	-	2	2	0%	-
Nuclear	-	-	-	-	-	0%	-
Coal & Coke	8,375	7,493	4,854	4,433	3,900	45%	-53%
Natural Gas	165	2,111	2,630	1,663	1,195	14%	624%
Oil	1,912	564	492	35	-	0%	-100%
Total	11,781	11,941	10,186	8,074	8,583	100%	-27%

Table A3.20 Power Generation (GWh) 2005-2022							
Prince Edward Island						Share	Growth
	2005	2010	2015	2020	2022	2022	05-22
Hydro / Wave / Tidal	-	-	-	-	-	0%	-
Wind	40	458	606	700	1,003	97%	2,406%
Biomass / Geothermal	-	5	3	2	8	1%	-
Solar	-	-	-	1	1	0%	-
Nuclear	-	-	-	-	-	0%	-
Coal & Coke	-	-	-	-	-	0%	-
Natural Gas	-	-	-	-	-	0%	-
Oil	1	-	7	5	21	2%	2,267%
Total	41	463	616	707	1,032	100%	2,423%

Appendix B: List of interviewees

Vince Brescia, CEO, Ontario Energy Association

Nancy Southern, CEO, ATCO

Building Industry and Land Development Association

Bob Masterson, CEO, Chemistry Industry Association of Canada

JB Allard, President, Quebec Association of Industrial Consumers of Electricity

Dennis Darby, CEO, Canadian Manufacturers and Exporters

Mike Bradley, Mayor, City of Sarnia

Keith Currie, President, Canadian Federation of Agriculture

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