Net Zero 2050

June 2021

Ontario Energy Association

About

The Ontario Energy Association (OEA) is the credible and trusted voice of the energy sector. We earn our reputation by being an integral and influential part of energy policy development and decision making in Ontario. We represent Ontario's energy leaders that span the full diversity of the energy industry.

OEA takes a grassroots approach to policy development by combining thorough evidence based research with executive interviews and member polling. This unique approach ensures our policies are not only grounded in rigorous research, but represent the views of the majority of our members. This sound policy foundation allows us to advocate directly with government decision makers to tackle issues of strategic importance to our members.

Together, we are working to build a stronger energy future for Ontario.

OEA

Executive Summary

In November 2020, the Government of Canada introduced a bill that would legislate a process of increasingly stringent 5-year targets to achieve net zero emissions of greenhouse gases (GHGs) by 2050. The OEA supports this objective and intends to leverage our expertise to assist all levels of government achieve this important objective in Ontario while still retaining a reliable and affordable energy supply for our customers.

Reaching net zero by 2050 (NZ2050) will require a major transformation of Ontario's energy system. Currently 48 percent of Ontario's energy use comes from refined petroleum products primarily for transportation, 28 percent from natural gas primarily to heat our homes and buildings and power industry. Sixteen (16) percent currently comes from electricity, four percent comes from biofuels and the remaining four percent from other fossil fuels. Altogether, 80 percent of Ontario's energy consumption and 76 percent of its GHG emissions currently stems from fossil fuel use.

This paper reviews the various elements of our energy system and some of the options available to us to achieve emissions reductions. Altogether, the analysis points to the following key recommendations to set Ontario on an achievable path to NZ2050:

1. Transportation fuel switching

We have all the technology we need today to affordably switch transportation fuels to low or non-emitting sources quickly, while still maintaining affordability.

2. Reduce emissions from natural gas system:

Given the volume of peak energy it provides to heat our buildings, Ontario is going to need its natural gas system for some time, and the ability to leverage this infrastructure to cost-effectively decarbonize Ontario's energy sector. Therefore, efforts should focus on the decarbonization of the natural gas system. This includes using more renewable natural gas, blending blue or green hydrogen into the system, exploring hybrid heating systems with heat pumps and significantly increasing energy efficiency programs to reduce emissions from buildings.

3. Plan to expand the electricity system:

Ontario has made significant investment to develop one of the cleanest electricity systems in the world. Excess energy within this system can be better leveraged and this system will need to be expanded in order to electrify those segments of the economy where it is the most economic option. The pace and scale of this fuel-switching is uncertain, but something we must prepare for.

4. Develop comprehensive, inclusive energy planning, not just electricity policy:

Given that most energy consumption happens outside of the electricity system, Ontario needs a comprehensive energy strategy. This strategy must take into consideration the complementary roles that all energy sources can play in order to meet the low carbon energy needs of the future at the lowest cost.

5. Accelerate hydrogen programs and pilots:

For hard to abate energy use activities, Ontario will need to accelerate our ability to use hydrogen. Significant government resources should be directed towards pilot projects and infrastructure development to allow us to scale this resource to its maximum potential by 2050.

6. Federal, provincial and municipal coordination:

The federal and provincial government should work together on a thoroughly researched, comprehensive and coordinated energy plan for Ontario. And the Ontario government should work with municipalities to ensure their alignment with the comprehensive energy plan and to ensure a common understanding of the cost implications of municipal energy decisions. Coordination will ensure that government policies and programs at all levels are complementary and do not work at cross purposes.

This report is a starting point for what will be an ongoing and evolving dialogue about how to best transition our energy system which will represent largest component of our effort to reach NZ2050.

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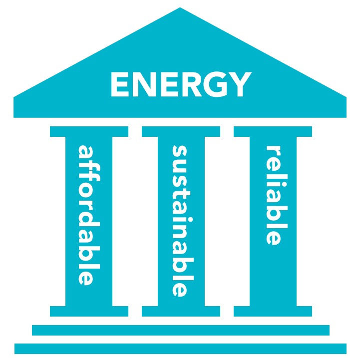
Introduction

Darlington Provincial Park, Ontario

In November 2020, the Government of Canada introduced a bill that would legislate a process of increasingly stringent 5-year targets to achieve net zero greenhouse gas (GHG) emissions by 2050 (NZ2050). The OEA supports this objective and intends to leverage our expertise to assist all levels of government and their agencies to find the optimal pathway to NZ2050 while ensuring that our customers maintain access to affordable and reliable energy.

The purpose of this paper is to discuss the role of Ontario's energy system, including its electricity, natural gas and transportation fuel systems in meeting Ontario's and Canada's climate change objectives. Reaching NZ2050 will require a major transformation of Ontario's energy system. Understanding the magnitude of both the challenge and opportunity is a critical first step for policy makers to ensure we choose a successful and sustainable path towards the goal.

Success will require coordinated planning between all levels of government (federal, provincial, regional and municipal), their agencies, the energy industry, and ultimately all Ontarians who use energy to run their households and businesses. Ultimately, success in Ontario must mean that we pay attention to three core pillars that underpin our energy system: affordability, reliability and sustainability (including emissions). Failure to consider all three as we transition our system will result in the loss of public support for the transition.



This report does not provide a definitive pathway and mix of resources and technologies that will ultimately enable Canada and Ontario meet our NZ2050 goal. Ontario will need to deploy and invest in new technologies and innovation to reach our objective. This report is a starting point for what will be an ongoing and evolving dialogue about how to best transition our energy system which will represent the largest component of our effort to reach NZ2050.

This report also does not delve into non-energy sector technologies that will be a necessary part of an economic transition to NZ2050. For example, there is no discussion of technologies and process improvements such as: direct air capture of CO_2; cement manufacturing processes; steel manufacturing processes; carbon offsets; materials efficiency; etc. Some of these technologies will provide the "net" in net zero as they will ultimately offset the emissions from activities for which we cannot fully eliminate emissions by 2050.

Our Challenge and Opportunity

Ontario currently produces about 163 megatonnes (Mt) of greenhouse gas (GHG) emissions. Of that total, 76 percent (124 Mt) are made up of emissions stemming from energy use. It is clear that the path to net zero must involve a dramatic change in the way Ontario families and businesses use energy and the types of energy we use.

Figure 1 Ontario GHG Emissions 2019 (Mt)

The chart below outlines how Ontario's emissions have changed for selected years since 1990 for various sectors. At the time of writing of this report, Ontario has committed to reducing emission levels by 30 percent below 2005 levels – to 144 Mt, by 2030, in line with national targets. However, on April 22, 2021, Prime Minister Justin Trudeau committed to increase Canada's 2030 target to 40 to 45 percent below 2030, which may result in a revision to Ontario's target.

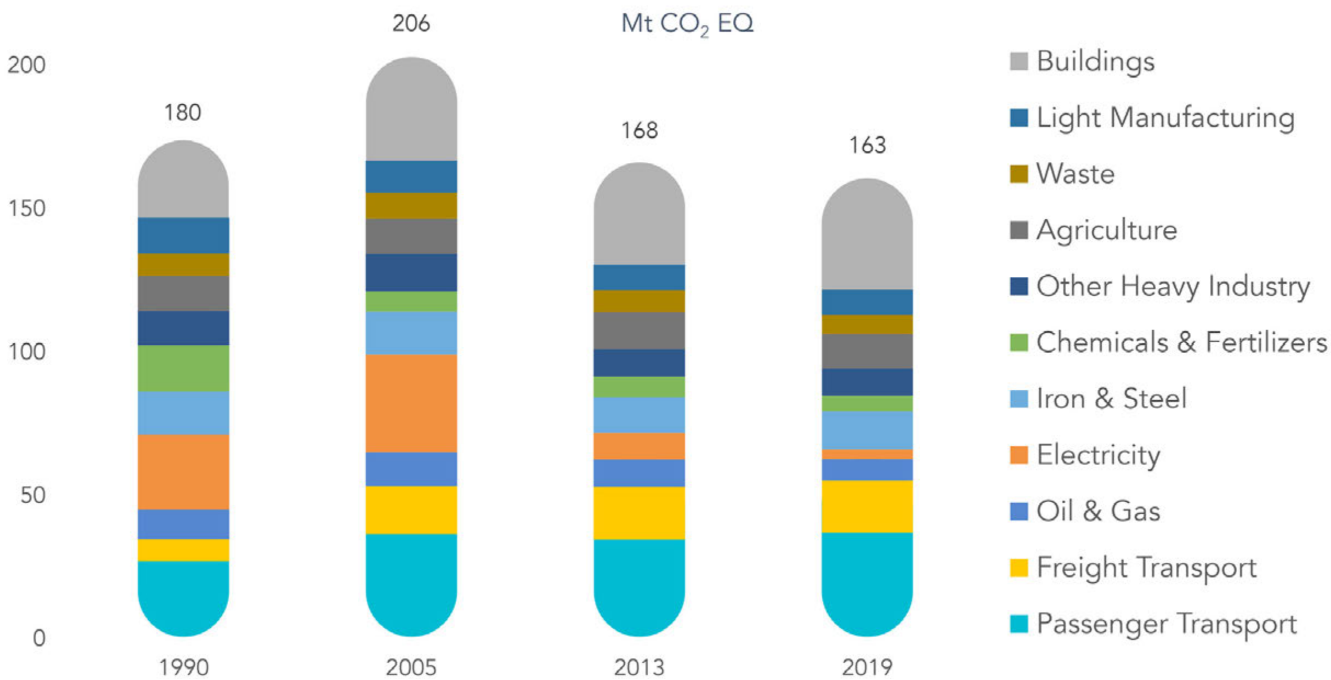


Figure 2 Ontario GHG Emissions by Sector, Selected Years

The chart reveals that Ontario went a long way towards meeting its original 2030 target by closing down all of its coal-fired generation plants by 2014 and dramatically reducing the carbon footprint of the electricity system. However, the gains made in the electricity system were partly offset by significant increases in transportation sector emissions since 1990. That means we still need to reduce total emissions by about 19 Mt in eight years to meet the current Ontario target. Then, under our national framework to reach NZ2050, we must net out the remaining 144 Mt of emissions within 20 years.

Ontario is not alone in the need to expedite emission reductions to meet the 2030 and 2050 targets. Nationally, GHG emissions have increased by 129 Mt since 1990 and have remained stagnant since 2005. In fact, since 2005 Ontario has reduced its emissions more than any other Province.

Figure 3 Emissions by Province in 1990, 2005 and 2019

To continue on the path to decarbonization and meet our goals is going to require a major change in Ontario's energy system. We proceed by providing some background and context as to how we use energy, which is responsible for most of our emissions. Then we examine energy related emissions and reductions options in Ontario's largest emitting sectors. Then we look at the implications for the most likely energy-related technologies and pathways to negate or offset all of these emissions that will be necessary given Ontario's situation. Finally, we discuss what this means for us in terms of planning and coordination between governments, agencies, the energy sector, businesses and citizens.

Context: Our Energy System

Ontario's Energy Demand

Any discussion of a GHG reduction strategy must begin with an examination of how we use energy in Ontario. The largest source of energy consumption in Ontario continues to be refined petroleum products, which accounts for 48 percent of our energy use. This use is dominated by transportation activities, also the largest source of GHG emissions in Ontario.

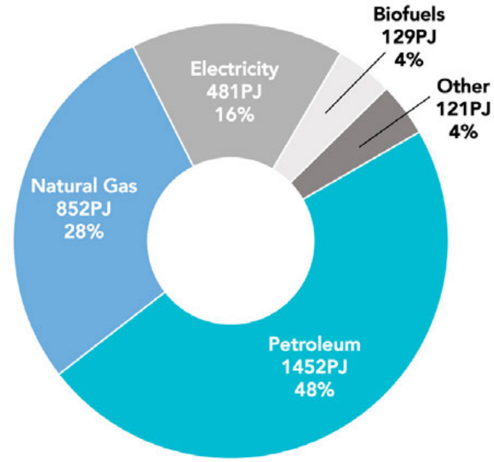


Figure 4 Ontario Energy Use By Fuel Type 2017, Petajoules

In Ontario, the electricity and natural gas systems currently work in a complementary fashion to meet total majority of the annual demand outside the transportation sector. The natural gas system provides fuel for space and water heating in the residential and commercial segments and meets a variety of industrial needs and accounts for 28 percent of our energy usage.

The electricity system makes up 16 percent of Ontario's energy use. Biofuels and other fossil fuels make up the remainder of our energy use. However, the electricity system still seems to dominate the public policy discussions regarding energy use and climate change in Ontario. It is clear that we need to broaden the public discourse in Ontario to consider all energy uses.

Within this context of total energy demand in Ontario, it is important to appreciate the emission intensity of the forms of energy. At 70kg CO_2e/GJ refined petroleum product is the most emission intensive form of energy. Natural gas is approximately 50kg CO_2e/GJ and Ontario's electric system is now less than 0.04 tCO_2e/MWh or approximately 10 kg CO_2e/GJ in fuel energy terms.

Electricity System a Small Part of Ontario GHG Emissions

Ontario's electricity system produced 3.3 megatonnes (Mt) of emissions in 2019 compared to 159.9 Mt for the rest of the economy. This meant the electricity sector accounted for two percent of economy wide GHG emissions.

Figure 5 Ontario GHGg Emissions 2019 (Mt)

Ontario's transportation sector is the largest contributor to provincial GHG emissions. Altogether, transportation, industry and buildings account for 82 percent of the emissions in Ontario. While every sector must do its part, any significant GHG reduction strategy will need to focus on these sectors and fuels if it is to be successful.

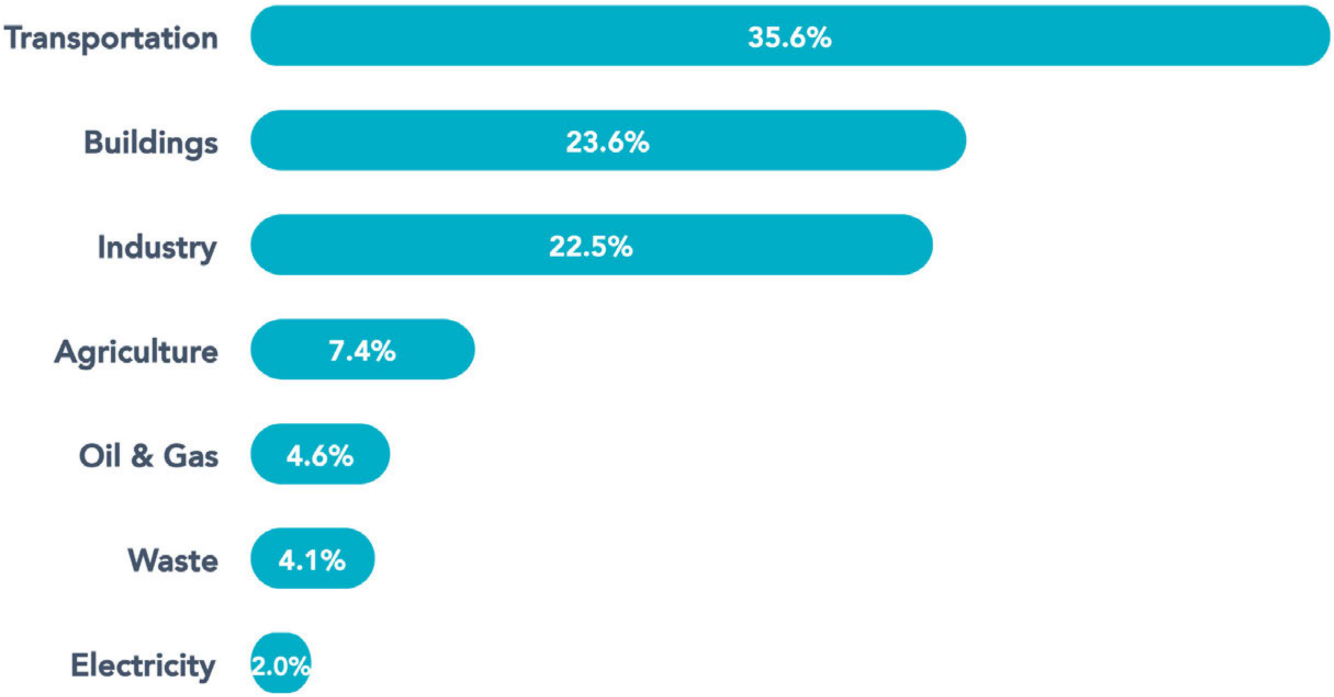


Figure 6 Ontario GHG Emissions By Sector, 2019

Ontario Successfully Greened Its Electricity Sector

The reason emissions from Ontario's electricity sector are so low is a result of the specific public policy actions taken to reduce emissions from this sector. First, the government made a commitment to phase out its coal fired generation plants. It was able to do this by replacing the system functionality provided by the coal plants (i.e. reliable contributor to peak capacity) with natural gas plants. Then, enabled by the additional capabilities of the natural gas plants (quick and responsive peaking capability), the province moved to add significant intermittent renewable power to the system. The province also expanded nuclear and hydro capacity somewhat.

The emission reductions from the supply-side of Ontario's electricity system have been dramatic and well publicized, however the impact of conservation demand management (CDM) has been equally impressive. Annual electrical demand has declined by 10% over the past 15 years, and coupled with the reduction in emissions intensity on the supply side, has resulted in an 90% reduction of electricity generation emissions, or -30 $MtCO_2e$ from 2005 levels. This transition alone represents Canada's largest contribution to GHG emissions reductions to date. This is something Ontarians should be proud of.

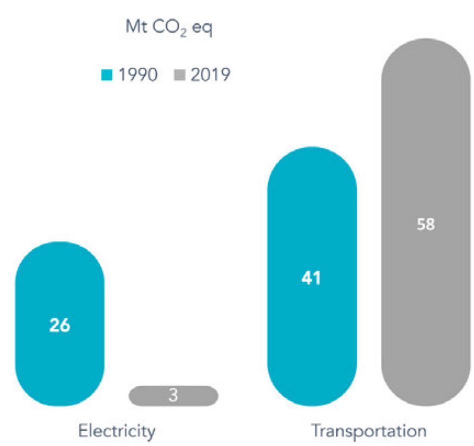


Figure 7 Ontario Electricity Versus Transportation Emissions

Notwithstanding this success, it is worth noting that 75 percent of these GHG reductions were offset by increases in emissions from the transportation sector since 1990. This is a reminder that Ontario needs to focus on economy wide emissions, and move beyond a historic policy focus primarily on the electricity system.

Ontario Now Has One of the Cleanest Electricity Systems in the World

As a result of Ontario's proactive policies, Ontario now has one of the cleanest electricity systems in the world. The two charts below show how Ontario's electricity system emissions compare with other places in the world.

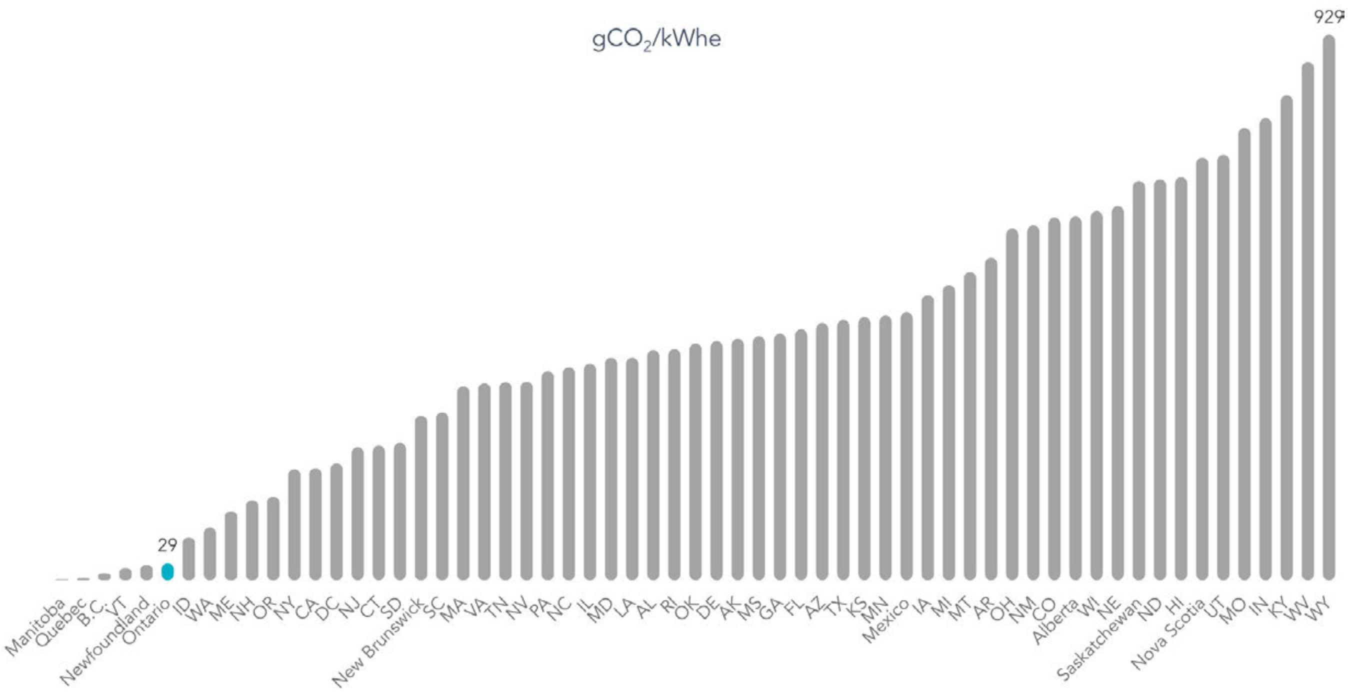


Figure 8 Carbon Intensity of Electricity System, North America, 2018

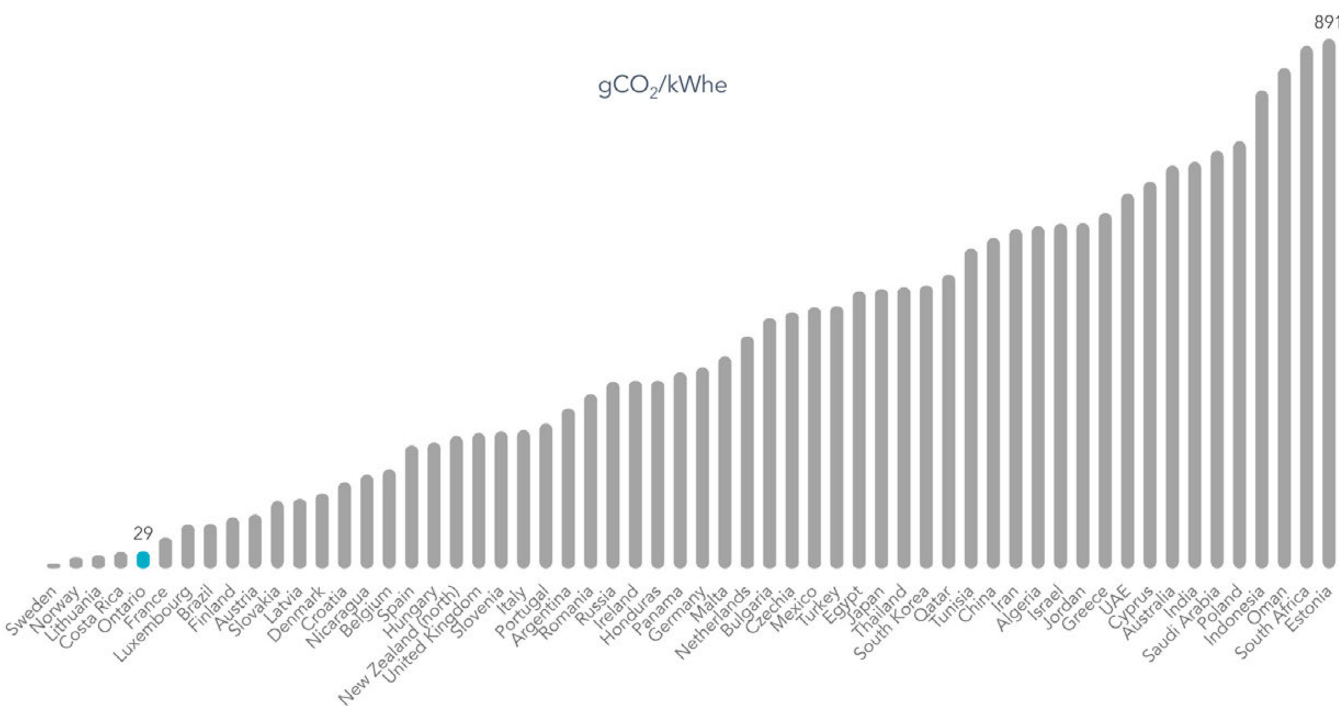


Figure 9 Carbon Intensity of Electricity System, International, 2018-20

With respect to climate change objectives, the question for Ontario becomes how we can best leverage this clean energy source and other low and zero emissions energy sources to help reduce emissions from other sectors in a way that maintains energy affordability, reliability and gives Ontario companies a competitive advantage. We explore some of these options later in this paper.

The Size of Ontario's Natural Gas System in Perspective

Ontario's natural gas system provides almost double the energy Ontarians get from electricity. However, for peak winter heating needs the natural gas system provides about three times the winter peak effective capacity of the electricity system. This is shown in Figure 10 where we have converted the energy volume of the natural gas system from Gigajoules (GJ), its typical energy measure, to gigawatts (GW) to allow a comparison of the peak energy capacity of both systems.

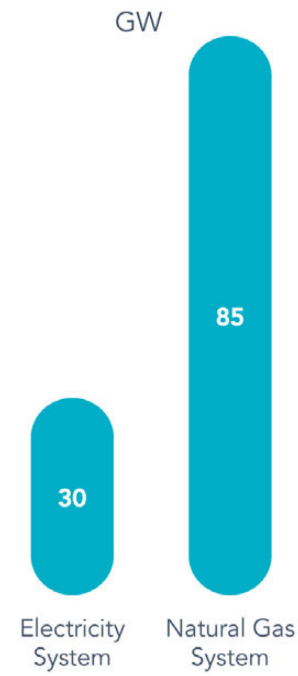


Figure 10 Ontario 2020 Peak Winter Capacity

The Ontario electricity system is expected to be short between 2,000 and 4,000 MWs of capacity after 2023 through 2040, even under the assumption that all expiring generation contracts are continued, and also assuming that there is no accelerated expansion of EVs. The addition of any additional load impacting the electricity peak will require expansion of the electricity system.

Therefore, even with considerable reduction in demand resulting from conservation demand management and demand response, Ontario would need to expand the electricity system's effective capacity by 200 to 300 percent of its current capacity to meet our peak needs resulting from an attempt at electrification of natural gas alone. There would be some significant infrastructure planning and engineering challenges associated with a system expansion of this size. Firstly, the additional capacity would need to be both reliable (adding to the effective capacity of the system) and non-emitting (see the box below). Secondly, there would have to be a massive expansion of Ontario's electricity transmission and distribution infrastructure. A major planning process would be necessary, accompanied by an extensive consultation process.

What Would Be Required to Replace Natural Gas Heat with Electric Heat Across Ontario?

As noted above, this would require a 200-300 percent increase in the capacity of our electricity system. No one resource could likely supply that much energy or meet various differing system needs (e.g. peaking, baseload, etc.). However here are some examples that give a sense of the orders of magnitude of the energy required:

- Dozens of new nuclear power plants
- 30,000 to 50,000 wind turbines (requiring approximately 1.3 million acres for siting) paired with long duration energy storage

This does not account for the electricity system expansion required for electrification needs in the transportation, industrial and manufacturing sectors to achieve decarbonization in those sectors. Natural gas and transport fuel loads have similar significant scale but meet significantly different demand and have very different load profiles. The difference in load profile makes the natural gas system significantly more difficult to electrify than that of transport fuels, from the perspective of the electric grid. The scale of this undertaking informs the OEA's view that we should maintain and decarbonize our natural gas system and reserve our electricity capacity growth capabilities for other sectors of the economy.

Any shift to a significantly more electric centric building heat system will require a considerable time frame to plan for and deliver the required expansion of infrastructure. The cost of this much infrastructure, even if it could all be built within the next 28 years, would be expensive and therefore have significant implications for energy affordability for Ontarians.[1] There would also be a large budgetary impact on the provincial government if existing electricity subsidy levels are maintained: these subsidies currently cost approximately $7 billion annually and would have to be carried through to the expanded system. Alternatively, leveraging the existing natural gas system presents a significant opportunity for the distribution of renewable natural gas without creating expensive new energy infrastructure. As explored later in this paper, blending RNG and Hydrogen into low cost natural gas presents a cost-effective means of decarbonizing while leveraging existing energy infrastructure.

This all suggests that there is no single "magic bullet" for Ontario to meet its GHG reduction objectives. Multiple technological and resource solutions are going to be necessary to decarbonize Ontario's economy. Ontario will also need to stage its actions. Some sectors and economic activities are much easier to decarbonize affordably with current technology, including much of the transportation sector. We can move quickly and make progress in those sectors first. For other sectors it will take us time to develop the infrastructure, technology and experience necessary to undergo transition.

[1] A study prepared for the Canadian Gas Association found that electrification of the natural gas system nationally would cost about $1.4 trillion between 2020 and 2050. ICF. *Implications of Policy-Driven Electrification in Canada*. October 2019.

Affordability

As mentioned in the introduction, energy affordability is one of the three important pillars that will underpin our success. Energy costs are important considerations for families and businesses. Data on household expenditures on energy is readily available in Canada. Given that it is households and voters who ultimately must provide ongoing support for our transition to a low carbon economy, we explore household expenditure and affordability issues here.

Household Expenditures on Energy

Total economy wide household expenditures on energy have been increasing over the past four decades. Household spending on home electricity and heating fuels has remained relatively constant at about $10 billion annually since 1981, in spite of population growth throughout this period. This means they have been declining on a per capita basis. In contrast, household direct expenditures on transportation fuels (excluding indirect energy expenditures through public transit) has practically doubled from about $10 billion to almost $20 billion in 2019.

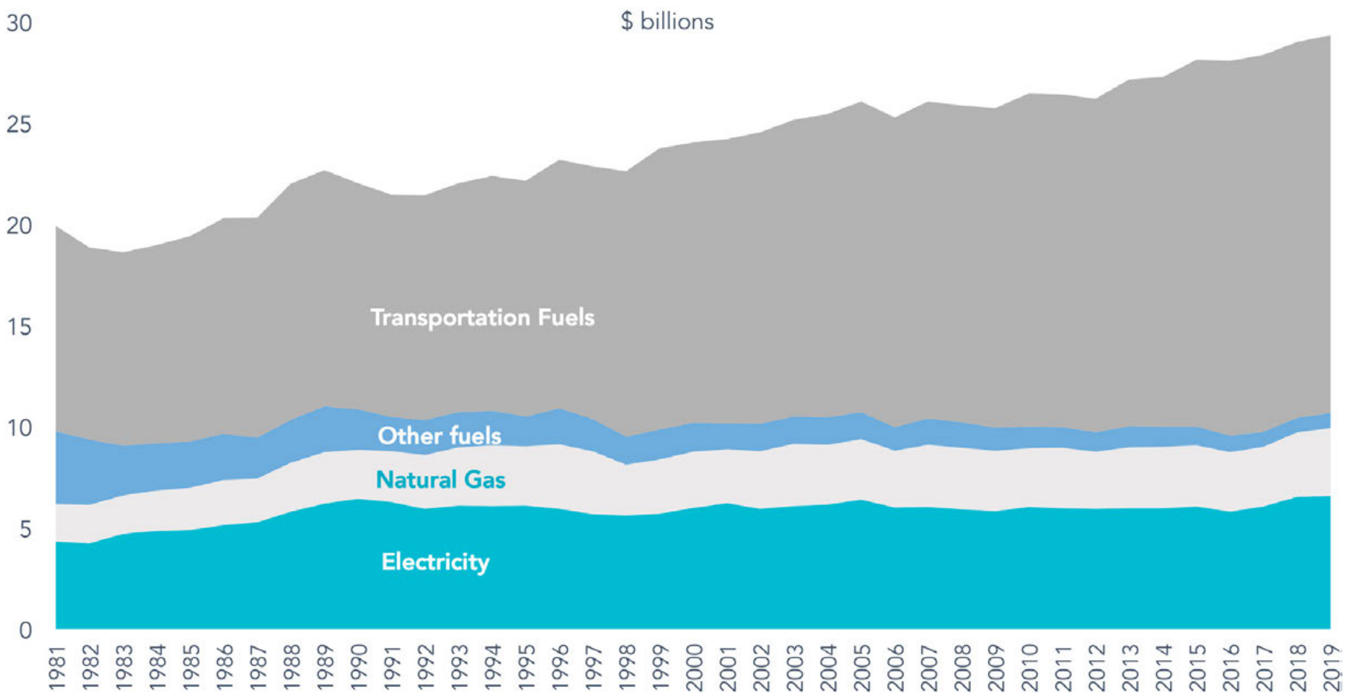


Figure 11 Ontario Household Energy Expenditures

However, because of growth in household income, and population growth, energy costs as a percent of total household expenditures has been declining. In 1981, household spending on home energy and transportation fuels was 12.8 per cent of total expenditures (which roughly track with income over time). This percentage has been declining steadily since 1981, and total energy spending was 6.3 per cent of total expenditures in 2019, half of what it was in 1981. Ontario households have been benefitting from improving energy affordability over the past four decades.

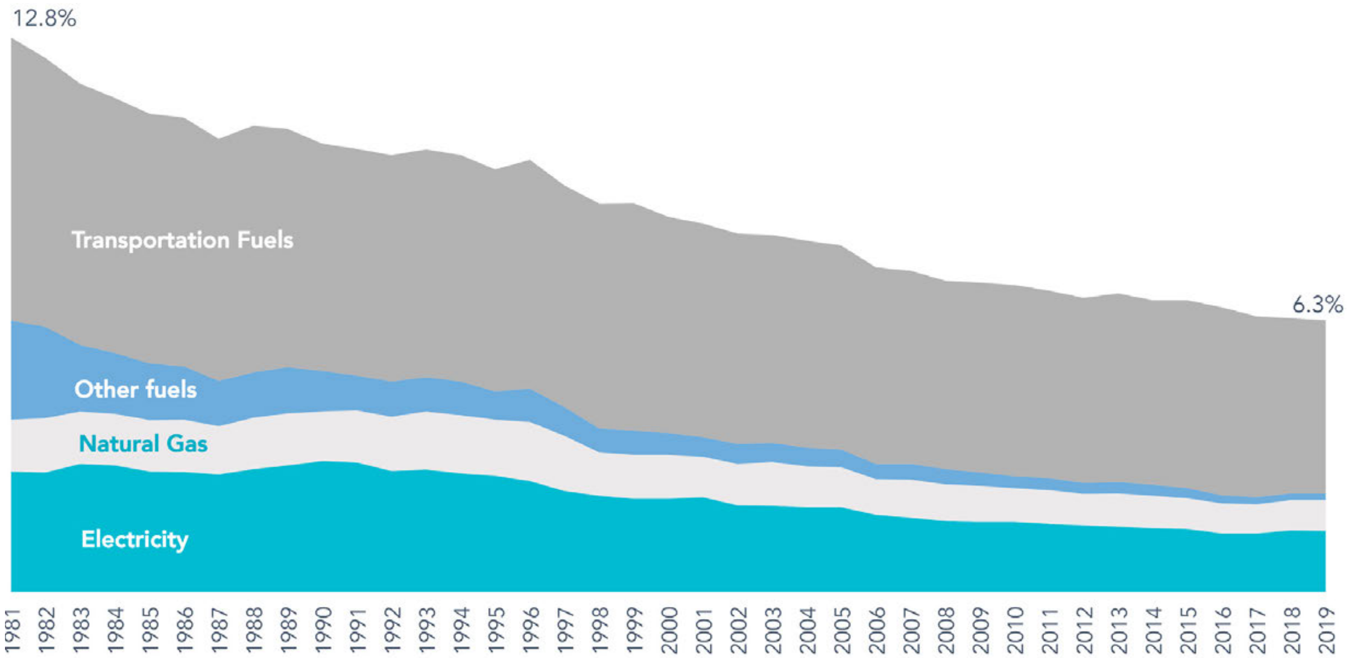


Figure 12 Energy % Of Total Household Spending, Ontario

Energy Affordability Important to Ontarians

Notwithstanding the improvements in overall energy affordability for Ontarians, we have strong recent evidence that Ontarians care deeply about energy affordability, and have showed a particular sensitivity to electricity affordability. Earlier we reviewed the tremendous success Ontario has had in greening its electricity system. However, achieving this came at a cost. First there was the capital cost to replace the coal plants with new natural gas plants. Then there was the capital cost of building a significant volume of new wind and solar generation. Finally, there is also the cost of refurbishing the Darlington and Bruce nuclear facilities which provide the largest portion of Ontario's non-emitting power.

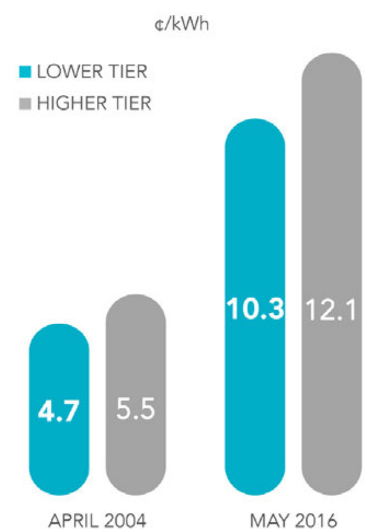


Figure 13 Ontario Residential Tiered Electricity Rates

These electrical de-carbonization costs reduced emissions, and provided an estimated $3 billion in health benefits for Ontarians as well.[2] In 2020 the renewable solar and wind contracts added $3.6B in cost to Ontario's electricity system while supplying 12.6 TWhs of electrical energy. The 12.6 TWhs of intermittent energy provided by solar and wind displaced a mix of natural gas (predominantly) and non-emitting baseload generation. It therefore resulted in approximately 4-6 $MtCO_2e$ of emission reductions.

Electricity rates had to increase in order to pay for all these new investments. As the chart opposite shows, Ontario's residential electricity rates more than doubled between 2004 and 2016. While Ontario's electricity rates remained very affordable for most households even with these

2 DSS Management Consultants Inc. & RWDI Air Inc. *Cost Benefit Analysis: Replacing Ontario's Coal Fired Electricity Generation.* Prepared for Ontario Ministry of Energy. April, 2005.

increases[3], there was a very severe public backlash in response to the increases that began to show up on people's electricity bills.

By 2016, electricity rates had become the number one issue in the minds of Ontario voters. The issue became a major problem for the government at the time. The reaction was not limited to low-income households who were most impacted: it ran across all types of households and businesses. The reaction was so severe that electricity rates became one of the primary issues of the 2018 Ontario election campaign. And in response to negative voter reaction to electricity rate increases, provincial taxpayers are now spending over $7 billion annually to subsidize electricity rates, making electricity subsidies one of Ontario's largest government programs.

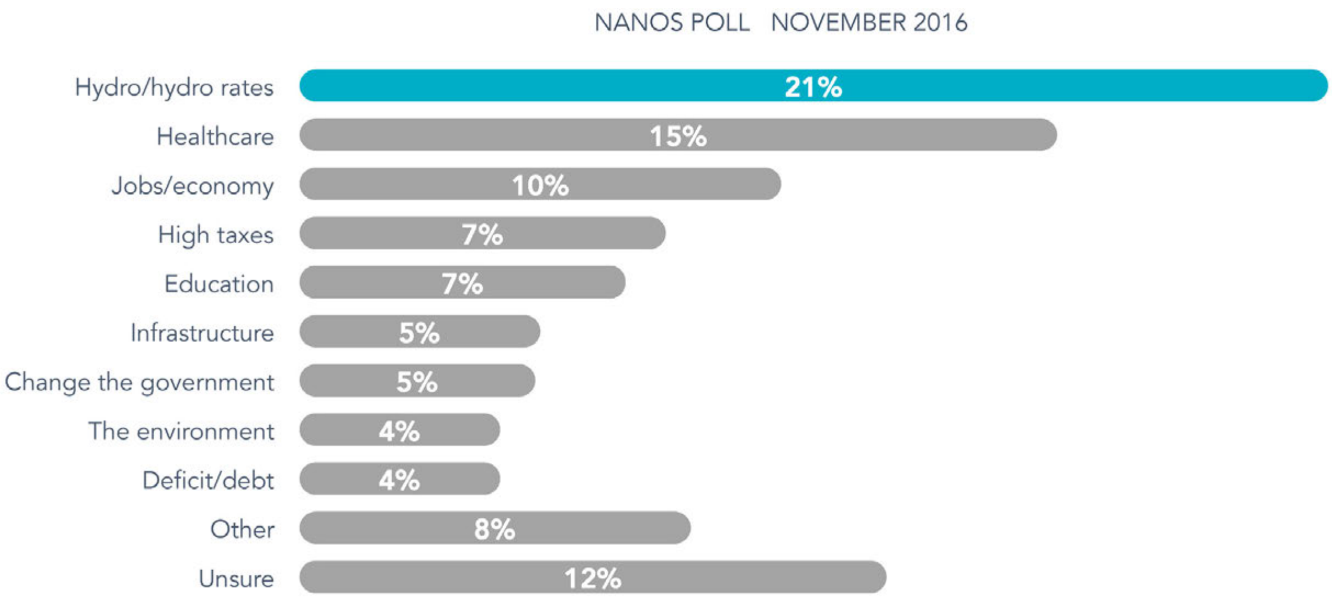


Figure 14 "What Is Your Most Important Provincial Issue of Concern?"

This experience provides helpful guidance for our pending much larger initiative to reach NZ2050. Ongoing efforts must be made throughout the transition process to keep the public informed about the transition plans to maintain public support for the initiative.

More recently, the Ontario government has moved to address energy affordability concerns for some Ontarians through its Natural Gas Expansion Program to bring natural gas to areas that do not have access to the distribution system. The program is intended to "make life more affordable for families and businesses, and will help increase economic development and job opportunities for these communities."[4] The government estimates that the program will save customers an estimated $250-1500 per year.[5] The program has been very popular and well received with communities that previously did not have access to natural gas.[6]

[3] Ontario's residential electricity rates, even without the current significant subsidies, are equivalent to average U.S rates. As a percentage of income, Ontario's kWh rates are among the lowest in the world. The OEA's paper entitled *Help Those Who Need Help* provides a comparison of Ontario's residential rates to those around the world.

[4] https://www.ontario.ca/page/natural-gas-expansion-program

[5] Ibid.

[6] See for example, https://www.owensoundsuntimes.com/news/local-news/southern-bruce-natural-gas-project-begins-servicing-residents

Reliability

The other important pillar from our three legged stool of success is energy reliability. People often take reliability for granted, as we have been fortunate to become used to a very reliable energy system. However, people are reminded of its importance when major events occur and we come to realize how important energy supply is to our daily lives. Whether it's the 2003 blackout, the 2012 Ontario ice storm, an extended polar vortex or the recent events in Texas, each time these events occur it reminds us how important it is for the health of our citizens to plan and structure our energy systems to maintain energy supply and restore it quickly if it is interrupted. Ontarians will not likely maintain support an energy transition if it results in compromises to energy reliability.

Electricity System Reliability

Ontarians have gotten used to a very reliable electricity grid. This reliability comes from a unique blend of resources that work in a complementary fashion to ensure the continuity of electricity supply. Nuclear power currently provides 28 percent of our capacity, and 60 percent of our total energy consumption. Nuclear power provides reliable ongoing baseload emissions free power for our system. Nuclear's share of total energy consumption will decline once the Pickering nuclear reactor is shut down in 2026 and its 3,100 MW of capacity and 24 TWh of energy output are no longer available.

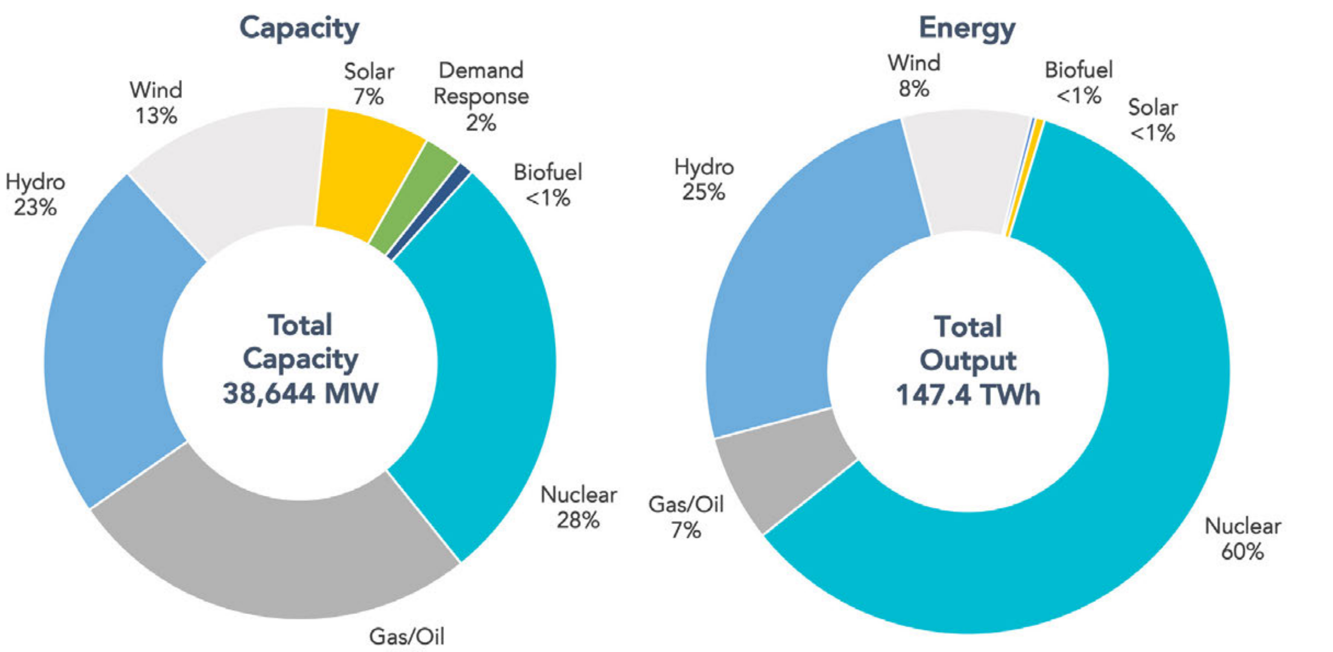


Figure 15 Ontario Electriicty System Capacity Vs. Energy 2020

Hydro power provides 23 percent of our capacity and 25 percent of the total energy we use. Wind and solar together provide 20 percent of our capacity and nine (9) percent of our total energy supply. One of the reasons that Ontario has been able to add such a significant component of wind and solar renewables is due to the capabilities and role played by natural gas fired generation in providing backup reliability services to the grid. Natural gas generation provides 23 percent of the electricity system's capacity, yet only provides 7 percent of the annual electrical energy. That is because the natural gas generators typically only run when the system has peak needs that cannot be met by the mix of other resources. It is the presence of the natural gas generators that has enabled Ontario to add such a large capacity of renewables while achieving an electrical grid that was 96 percent emissions free in 2017.

The chart below provides an example of the peak reliability services that natural gas generation has provided so far this year. When system needs are low, during mild weather, natural gas generation often times provides less than one percent of system needs. However, when we have a major power need, such as during the polar vortex event this past February, natural gas generation provided up to 27 percent of our power needs at the peak. This flexibility and peaking capability of our natural gas fired generators is a valuable asset. We will need this capability as Ontario moves to transition to a low carbon economy and an increasing percentage of our economy is reliant on our low emissions electricity system.

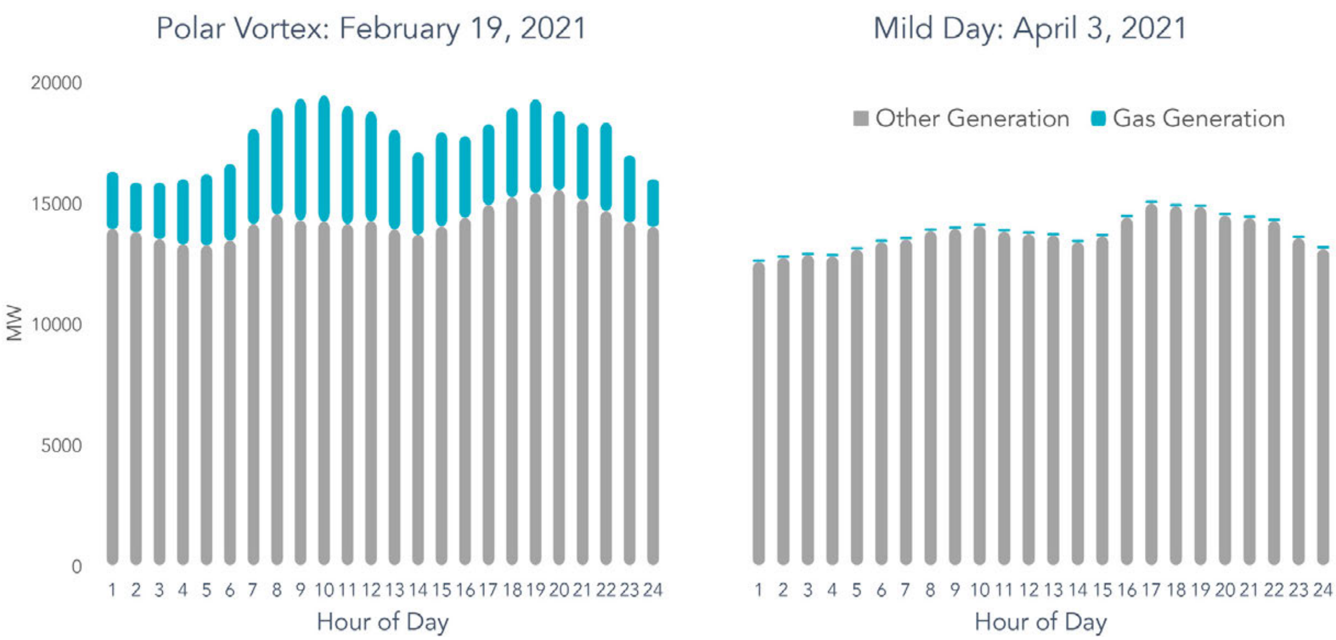


Figure 16 Gas Generation System Reliability Example

Natural Gas System Reliability

Ontario's natural gas system also provides a reliable supply of energy during Ontario's cold winter months. Ontario's Dawn Hub storage system currently can store about 280 billion cubic feet of natural gas that reliably ensures Ontarians can heat their homes and buildings for an extended period. Our path to decarbonization must ensure that we continue to provide reliable energy to heat our homes and buildings during Ontario's cold winter months.

As Ontario continues down the transition path, there are many additional resources and technologies that can be incorporated into the energy system that will ensure the continuation of reliable energy. We discuss some of those resources and technologies later in this report.

Transportation

Buildings

Mississauga, Ontario

Industry

Key Sector Emissions

Earlier we saw that GHG emissions in Ontario are primarily driven by the following sectors:

- Transportation (36%)
- Buildings (24%)
- Industry (23%)

Altogether these sectors account for about 82 percent of Ontario's emissions, much of this stemming from energy use. In the following sections we examine the emissions from each sector and discuss some of the options for reducing and eliminating emissions.

TRANSPORTATION SECTOR

The transportation sector is the largest end user of energy and largest source of greenhouse gas emissions in Ontario. On an annual basis the sector consumes 1000 PJs of refined petroleum product and emits 58 $MtCO_2e$ per year, the average gasoline fired personal vehicle emits approximately 4 tCO_2e per year. The sector accounts for 36 percent of total Ontario emissions

Reducing emissions from the transportation sector should be the first priority for Ontario. One key reason is that the technologies needed to dramatically reduce or eliminate emissions from this sector are readily available, scalable and affordable. There is no need to wait for new technological development in the transportation sector to begin achieving significant emissions reductions.

Since 1990, annual emissions from the transportation sector have increased from 41 Mt in 1990 to 58 Mt in 2019, an increase of 17 Mt. Those increases were driven by increases in passenger vehicle emissions and heavy transportation emissions. In this section we will review some of the options available to Ontario to begin reducing emissions today and to ultimately bring emissions to minimum levels for NZ2050.

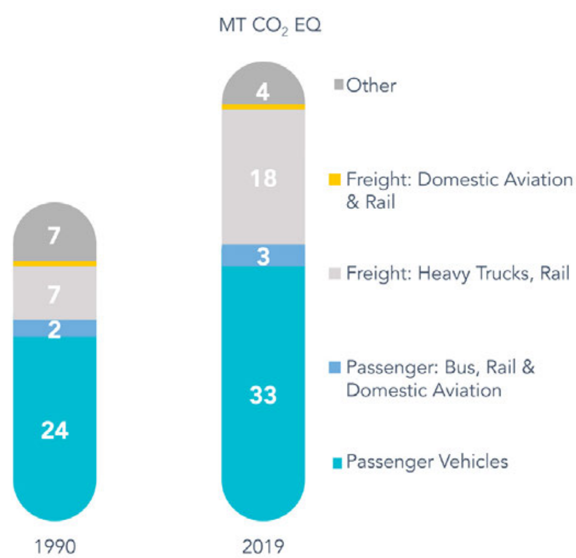


Figure 17 Ontario Transportation Emissions

Electric Vehicles (EVs)

Lighter vehicles (e.g. passenger vehicles and vans) represent an excellent opportunity to leverage Ontario's excess supply of non-emitting electrical energy by switching from higher emitting fossil fuel powered vehicles and equipment to electrically powered vehicles (EVs). This transition would largely eliminate emissions from passenger vehicles, and also increase the overall efficiency of Ontario's energy system.

One reason for this is that EVs are more efficient at utilizing the energy input into the vehicle, as shown in the chart below. This means that we will not need the same amount of energy in the electricity system to replace the petroleum energy currently being used by passenger vehicles. A second reason is that with "managed charging", EVs can be charged during off-peak times, when Ontario has excess non-emitting electricity capacity that can be utilized at a very low cost. This would allow the cost of fueling vehicles to be kept low, maintaining or even possibly lowering transportation costs for Ontarians.

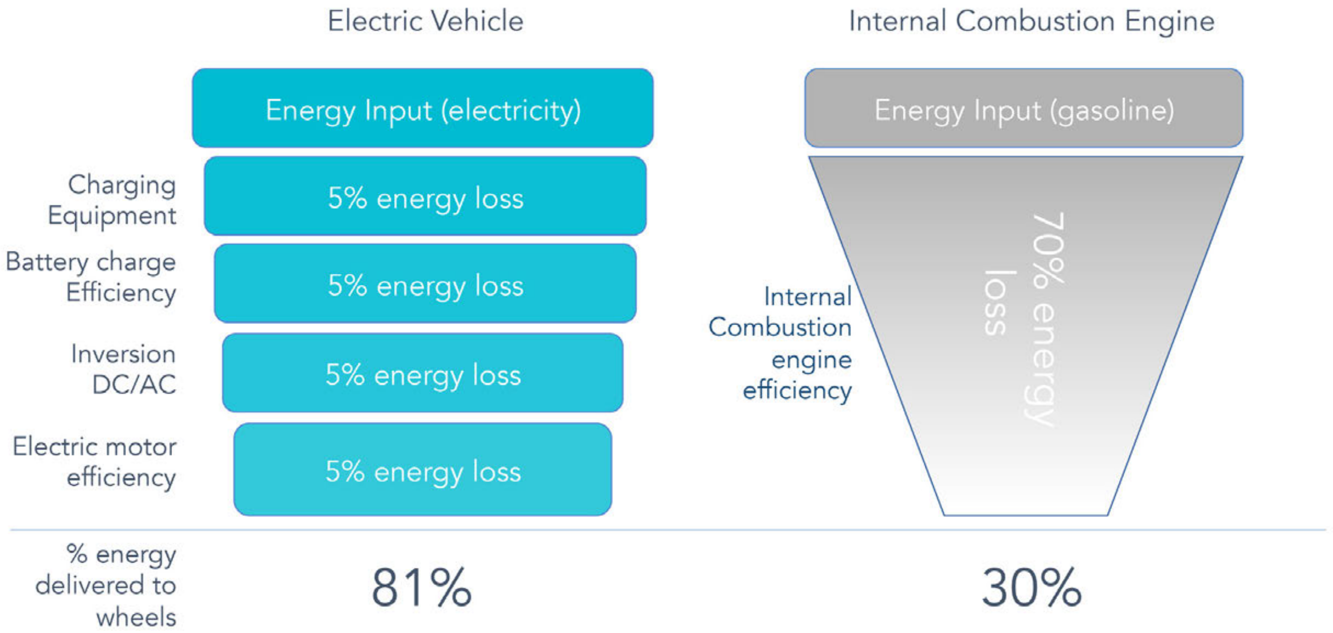


Figure 18 EVs Versus Internal Combusion Enginge Efficiency

"Managed charging" as described above will require the use of technology, policy and regulatory tools that either incent or direct that charging take place at off-peak times for the electricity system. This could involve price signals (e.g. time-of-use rates that fully reflect the marginal cost of new electricity capacity), incentives, or intelligent charging infrastructure that ensures vehicles are charged during off-peak.

Another option for zero emissions passenger vehicles comes from hydrogen fuel cell electric vehicles (FCEVs). While these are available in Canada, they are relatively rare, and currently have limited current refuelling options. That is not to say that this technology does not have the potential to expand and capture a significant portion of the market sometime in the future. We discuss FCEVs further in the next section, as they may play a very important role in the future of heavy transportation.

As vehicles get heavier, and have larger distances to travel (e.g. long haul transport), EVs can become a less viable option with current technologies. This is because the battery size requirements become too large and heavy to be practical, or charging frequency and associated lost productivity become prohibitive. While there are significant advancements in battery and heavy duty fleet electro-technologies being made, it is important to remain open to all de-carbonization pathways. For this reason, we explore some of the other technologies that will help us reduce emissions for these vehicles.

Passenger Vehicle Electrification

Given the market uptake forecast and efficiency of the electric vehicle (EV) coupled with the low emissions intensity and readiness of the Ontario electricity system the adoption of the EV has the potential to create significant reduction of both primary energy demand and GHG emissions. Ontario has approximately 8.5 million light duty vehicles of which approximately 50,000 are electric. By 2050 aggressive EV adoption forecasts estimate that all but 200,000 of these could be electrified.

The average personal EV consumes 4 MWhs of electricity annually and based on the emissions intensity of Ontario's current electricity system would emit almost no GHG emissions. With managed charging, ensuring EVs charged off peak and when the Ontario grid was long on non-emitting renewables the EV would be zero emitting.

8.5M EVs will require upwards of 50-60 TWhs per year of energy by 2050. Given some simplified assumptions related to EV charging habits, the energy demand of this fleet of EVs would create an incremental winter peak of 12-13 GW.

However, with the deployment of readily available and evolving technology such as EV charging infrastructure, managed charging technology, management system software for advanced distribution and EV and distributed energy resource systems, as well as vehicle to grid and vehicle to home/building functionality, the peak demand of this fleet of EVs could be minimized. The load could be optimized and controlled – minimizing the impact on the grid (to 5-7 GWs) and particularly to the distribution system – while maximizing the economic and environmental attributes of vehicle fleet modernization.

Meeting this added 50-60 TWhs of demand for electric energy and 5-7 GW of incremental demand at peak would still require significant investment in the Ontario grid. However, the impact could be modest and actually reduce overall vehicle energy and operational cost in comparison to the current internal combustion engine refined petroleum product costs, ensuring economic and environmental benefits of the transition.

Hydrogen Fuel Cell Electric Vehicles (FCEVs)

Hydrogen for transportation has been recognized by Canada, US, EU and Asia as a must to enable decarbonization of areas of industry that are difficult to decarbonize and cannot be served by batteries. High mileage and heavy-duty transportation including heavy duty trucking, mass transit, trains, shipping and aviation where time is of the essence requires an alternative zero emission solution. Hydrogen fuel cells can meet this need as they can replace gasoline and diesel-fired internal combustion engines, are net-zero and can work for heavy-duty transportation. The International Energy Agency (IEA) predicts hydrogen will be the largest fuel source for heavy-freight trucks in its decarbonization scenarios.[7] The merits of a FCEV have been proven around the world using Canadian technologies. FCEVs match the range offered by their diesel counterparts and offer higher efficiencies with zero emissions.

Carbon Neutral Compressed Natural Gas (CNG) & Renewable Natural Gas (RNG) Blend For Heavy Transportation

There are limits to the ability of our electricity system to replace all the capacity of our gas system, and limits to the capability of electric trucks to effectively replace all current internal combustion engine capabilities (e.g. long haul transportation). In these instances we can take advantage of the capabilities of our natural gas system to quickly and cost effectively reduce emissions dramatically in the transportation sector. RNG has the same range as diesel engines with a lower cost than electric alternatives, and there is also the option to be carbon-neutral or carbon-negative if RNG is solely being used to fuel the transportation. RNG can be compressed and used to fuel CNG vehicles, which provides a zero-emission option for vehicles in the heavy transportation sector, particularly in return to base fleets such as buses and garbage trucks.

City of Hamilton carbon-negative bus

[7] International Energy Agency. *Energy Technology Perspectives 2020*. Revised version, February 2021. p.263

Biofuels

Biofuels are currently blended with petroleum fuels used for transportation in Ontario. Biofuels include ethanol and biomass-based diesel fuel (biodiesel). They are cleaner burning than gasoline and diesel fuel and therefore reduce emissions from the transportation sector. Ethanol is made from the sugars in grains (e.g. corn, barley) and in other agricultural products (e.g. beets, potato skins, rice, yard clippings, etc.).

In November 2020, the Ontario government announced a plan to phase in an increase in the minimum biofuel content in regular gasoline from 10 percent to 15 percent by 2030, having the equivalent impact of taking 300,000 cars off the road every year.[8] Looking past 2030, further advances in biofuel standards and use has the potential to contribute to further emissions reductions.

Energy Efficiency and Consumer Behavior

The fuel efficiency of new automotive vehicles has been improving steadily since 2005 and has improved significantly over the cars manufactured in 1975.[9] However, consumer response to more efficient vehicles has been to increase the size of vehicles we drive. Since 2010 in Ontario, passenger car sales have declined from 46 percent of total vehicle sales to 21 percent, while light trucks (SUVs, vans, light trucks) have increased from 54 percent to 79 percent of sales.[10]

A recent study by the International Energy Agency (IEA) found that Canadian vehicles have the highest emissions per kilometer driven of any country in the world.[11]

Much of this can be explained by Canadian vehicles having the second highest curb weight after the U.S., found in the same study.[12]

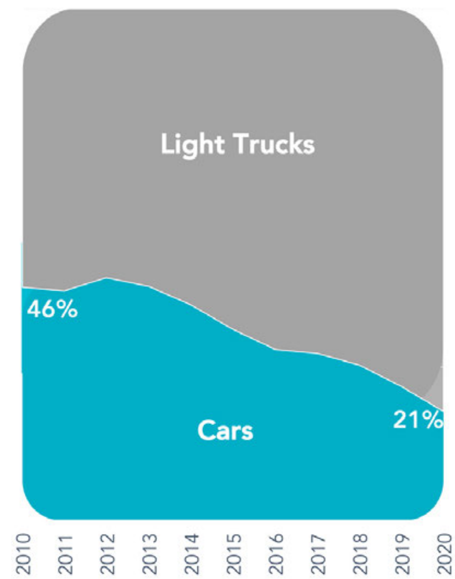


Figure 19 Ontario Passenger Vehicle Sales Percent

[8] https://news.ontario.ca/en/release/59352/ontario-to-be-national-leader-and-require-cleaner-and-greener-gasoline-1
[9] U.S. Environmental Protection Agency. 2020 EPA Automotive Trends Report. January 2021.
[10] Source: OEA based on Statistics Canada Table 20-10-0002-01.
[11] International Energy Agency. Fuel Economy in Major Car Markets. March 2019.
[12] Ibid.

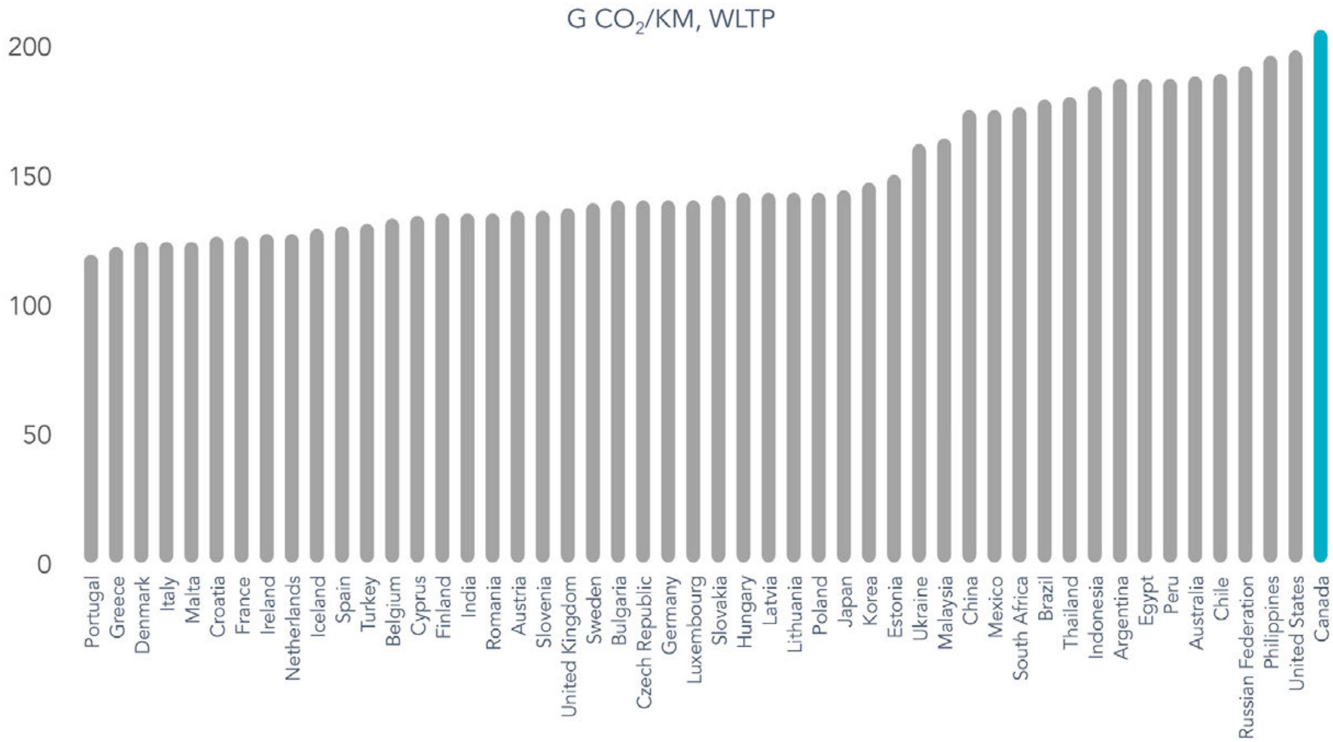


Figure 20 Average CO_2 Emissions Per Kilometer By Country 2017

This demonstrates that technology alone cannot reduce and eliminate emissions in the transportation sector, or other sectors for that matter. Consumer behavior will also impact on our success. In the energy sector, decades of consistent policy support[13] and marketing have created a culture of conservation with respect to energy consumption amongst Ontarians. Polling and focus groups undertaken by the OEA have shown consistent support amongst Ontarians for energy conservation in their homes.

Going forward, Ontario will need to extend this culture to our decisions regarding transportation. This goes beyond vehicle efficiency. This includes decisions consumers make daily regarding their transportation needs including, what mode of transportation to use (walk, bike, ride-share, municipal transit) or whether a trip is required at all (can an e-meeting or phone call suffice?), and the energy efficiency of the vehicles they purchase.

[13] https://energyregulationquarterly.ca/articles/the-past-present-and-future-of-energy-conservation-in-ontario#sthash.mbdp3EV0.dpbs

BUILDINGS SECTOR

The second largest source of emissions in the Ontario economy comes from the building sector. In 2019 buildings accounted for 39 Mt of emissions, or 24 percent of total emissions in Ontario. Most of these emissions stem from the natural gas used to heat the majority of buildings in the province. In 2017, natural gas was the main heating fuel used by 66 percent of households in Ontario.[14]

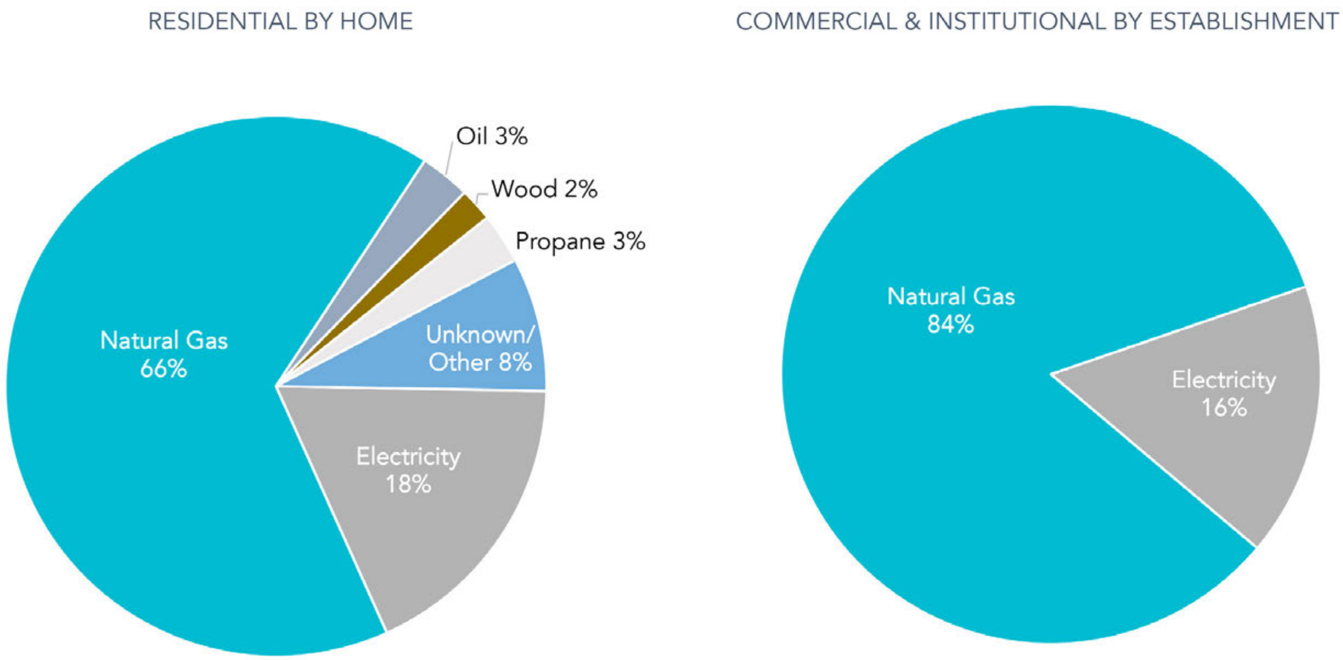


Figure 21 Ontario Space Heating By Fuel Type

In commercial and institutional buildings in Ontario, natural gas is the space heating fuel used by about 84 percent of establishments. Natural gas is the dominant fuel used to heat Ontario's buildings.

Given Ontario's cold climate and winters, natural gas provides a high level of peak heat energy to Ontarians when the weather gets cold. As we saw earlier in this report, it would take a 200-300 percent increase in our current electricity system if we were to attempt to replace this natural gas with electrical energy given buildings current energy needs. Given this, and the fact that the electricity system will need to expand to absorb a significant share of emissions from the transportation and industrial sectors, it does not seem practical to begin implementing policies either provincially or municipally to replace existing natural gas heat with electricity.

Attempting this large scale transition of transportation, industrial and building fuel all to electricity at the same time would likely have massive implications for energy affordability, reliability, physical practicality and neighbourhood acceptance of mass infrastructure development.

[14] Note that this represents the percentage of households where natural gas was the primary heating fuel, not the percentage of energy used for heating by all households.

There are options available to us to achieve significant emissions reductions in the building sector and its predominant heating source, the natural gas system. We should keep an open mind about the potential for this system, with continuing technological change, to become a major part of our emissions reduction strategy. To be successful, Ontario should remain technology agnostic to ensure that potential practical and affordable solutions are not ruled out before being explored.

What follows is a discussion of some of the options and considerations related to reducing emissions in the building sector.

Renewable Natural Gas (RNG)

Renewable natural gas (RNG) recovered from waste sites and other methane emissions sources is currently being injected into Ontario's natural gas system and reducing the system's carbon footprint. RNG is a made-in-Ontario clean energy supply, which reduces emissions, stimulates regional economic development and creates local jobs. Because RNG eliminates methane emissions, this new source of energy can actually be carbon negative. This can continue to be expanded to decarbonize the natural gas system, as well as reducing methane emissions from waste sources. Developing aligned codes and standards, domestically and internationally, will ensure RNG and hydrogen's safe and efficient development and transportation.

Stormfisher RNG facility

Blending Hydrogen

Ontario already has a project in place demonstrating that zero carbon hydrogen can be blended into the natural gas system. This power-to-gas facility is the first and largest of its kind in North America, and is used to balance the electrical grid, generating hydrogen through electrolysis.[15] Ontario can take advantage of its existing province-wide natural gas infrastructure to deliver this clean energy to customers. When combined with increasing RNG there is the potential for significant reductions in emissions in Ontario's natural gas system to complement other provincial emissions reductions strategies.

One of the quickest and most cost-effective means of decarbonizing much of Ontario's existing energy systems, while preserving their resiliency, is scaling up hydrogen and RNG production and injection. Blending a mere one percent (1%) by volume hydrogen into the supply of each of Enbridge Gas' 3.8 million customers would reduce GHG emissions by 100,000 tonnes, the equivalent of removing almost 22,000 cars from the road per year. This would drive significant GHG reductions and would support further private sector investment and innovation by transforming and decarbonizing our existing natural gas grids. To make this happen, the Government needs to direct the OEB to allow the recovery of hydrogen purchased for blending at costs different than the input cost of natural gas.

Markham Power-to-Gas facility

[15] https://www.enbridge.com/stories/2020/november/enbridge-gas-and-hydrogenics-groundbreaking-hydrogen-blending-project-ontario

Energy Efficiency / Demand Side Management (DSM)

Energy efficiency also has been proven to reduce GHG emissions in a very cost-effective way. The utility-led demand side management (DSM) programs that operate under a policy framework managed by the OEB are energy efficiency programs that have a proven track record of delivering energy savings and GHG reductions cost effectively. These programs play a central role in stimulating the market by offering programs, approaches and technologies that engage many actors in the energy efficiency sector including product and service providers, and governments.

DSM has the potential to be expanded to further improve the carbon footprint of the natural gas system. DSM programming has been utilized to help the industry build capacity and experience to prepare the market for advancements in regulatory, building code and energy efficiency equipment standards enhancements, and utilities are a natural and trusted partner to deliver such programs. A 2019 study by Navigant (now Guidehouse) found that with the cumulative adoption of a series of energy efficiency measures, DSM programs have an achievable potential to reduce gas consumption by 5,485 million cubic metres by 2038, with associated emissions reductions of 10,672 KT CO_2, and benefits outweighing costs by a ratio of 3 to 1 (using the "Total Resource Cost" test which is the ratio of avoided costs, including a 15% adder for non-energy benefits like environmental and social, to program costs).[16]

In addition to DSM programs, there are also energy efficiency activities led by the IESO, by the federal government, and by consumers acting independently to reduce their energy costs.[17] Coordination of all these programs and activities will be required to ensure energy efficiency efforts are complementary, to help customers navigate what can be a confusing landscape with education, and protect customers from unethical business practices. These efforts should leverage the trust and influence that utilities have given their customer-facing relationship and influence as a source of information and advice.

Hybrid Heating – Pairing Air Source Heat Pumps with Natural Gas

Air source heat pumps are an existing technology that transfers heat from the air outside into a building, or vice versa, usually using a refrigerant. In Ontario, for many months of the year these can be used to heat buildings. However, in the coldest months of the year in Ontario, these systems do not provide sufficient heating capability. Therefore, pairing this technology with our existing natural gas system would allow for a significant further reduction in GHG emissions from buildings. This will require an additional capital investment in buildings but remains a viable option to significantly reduce emissions in Ontario's buildings.

[16] Navigant. *2019 Integrated Ontario Electricity and Natural Gas Achievable Potential Study.* Prepared for the Independent Electricity System Operator and Ontario Energy Board. December 10, 2019.

[17] With Canada's carbon tax scheduled to rise to $170 by 2030, this pricing signal can be expected to increase the incentive for energy efficiency expenditures by households and business on its own.

Natural Gas Heat Pumps

Natural gas heat pumps work on the same principle as the electric air source heat pumps described above. These systems could reduce gas consumption and hence GHG emissions by 20 – 40 % by replacing conventional gas furnaces and hot water heaters.

Thermal Energy Storage

Thermal energy storage (TES) is a technology that stores energy by either heating or cooling a storage medium so that the energy can be used at a later time for heating or cooling. In doing so, TES decouples heating and cooling needs from the immediate power supply availability. This capability allows for greater use and optimization of variable renewable energy sources like wind and solar. TES encompasses a wide array of technologies, including:[18]

- "Sensible heat storage" that uses water, ceramic bricks, rocks, concrete, molten salts, and underground storage and is most commercially advanced;
- "Latent heat storage" uses "phase change materials" (PCMs) like paraffins, salt hydrates and fatty acids;[19]
- "Thermochemical heat storage" which includes chemical looping, salt hydration and absorption systems; and
- "Mechanical-thermal coupled systems" including compressed air energy storage and liquid air energy storage.

Water tank TES is already commonly used in buildings globally.[20]

Codes and Standards

In Ontario, building codes and standards for new construction and renovation are set by the provincial government (the federal building code does not apply in Ontario). In addition, under the Municipal Act, municipalities are able to add additional standards as they see fit. Every year, Ontario adds new construction at a rate of one to two percent of the total building stock. A 2009 survey of commercial and industrial buildings found that 46 percent were renovated between 2005 and 2009. This means that if codes and standards are enhanced to improve energy efficiency for new buildings and renovations, they can contribute to reduced emissions in buildings.

[18] International Renewable Energy Agency. *Innovation Outlook: Thermal Energy Storage*. IREA, Abu Dhabi. 2020. P.53

[19] https://www.ctc-n.org/technologies/phase-change-materials-thermal-energy-storage

[20] International Renewable Energy Agency. I*nnovation Outlook: Thermal Energy Storage*. IREA, Abu Dhabi. 2020. P.12

Stranded Assets

By greening the natural gas system with RNG and hydrogen, and continuing to focus on energy efficiency and technologies such as hybrid heating and natural gas heat pumps, Ontario's natural gas systems can remain critically useful, while lowering GHG emissions and continuing to provide reliable and affordable energy for Ontarians. There are implications for Ontario energy users of any plan to strand a significant component of natural gas assets. These assets become stranded if governments adopt policies that restrict the use of natural gas. If assets are stranded on the Ontario system, the cost of those assets still must be paid for. What this means for the customer is that natural gas rates will go up significantly because the fixed costs of those assets remain on the system, but there is less natural gas volume based revenue to pay for them. As a result, the price per cubic metre of natural gas must increase. This needs to be kept in mind in any comprehensive energy plan.

INDUSTRIAL & MANUFACTURING SECTORS

The third and fourth largest source of emission in Ontario come from industry - heavy industry and light manufacturing - which together accounted for 22.5 percent of emissions in 2018. Total emissions have declined considerably in both sectors since 1990. Most notably, the chemicals and fertilizers sector has seen a dramatic reduction in its emissions profile from 16 Mt in 1990 to 5 Mt in 2018. This reduction is primarily attributable to the installation of emissions reductions technology in a single adipic acid plant in 1997 and the ultimate the shutdown of the plant in 2009.[21] Light manufacturing has also seen a significant reduction in emissions, although some of this may be attributable to declines in manufacturing that occurred in Ontario during the 2008 and 2009 recession.

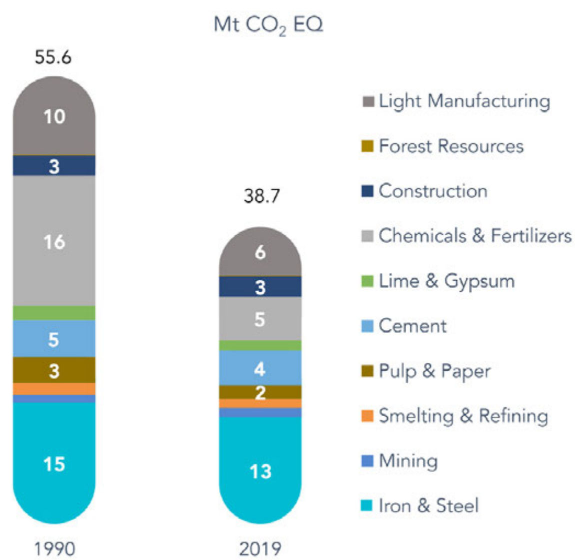


Figure 22 Ontario Industrial Emissions

Some of the emissions that stem from industrial and manufacturing activity relate to chemical reactions over and above energy use – sometimes referred to as process emissions. For example, cement production uses high heat energy to convert limestone ($CaCO_3$) to lime (CaO), releasing carbon dioxide (CO_2) in the process. Similarly, steel production uses significant amounts of energy (often from coal) to heat blast furnaces and reduce iron oxides to iron, releasing CO_2 in the process. As these industries explore emissions reduction options, they will be looking to the energy sector to provide alternatives for the energy component of production. Using carbon capture, utilization storage (CCUS), or finding alternative inputs and manufacturing processes that reduce or eliminate emissions based on chemical reactions, will be necessary for non-energy-related emissions.

[21] Environmental Commissioner of Ontario. *Ontario's Climate Act From Plan to Progress*. Annual Greenhouse Gas Progress Report 2017. p.35

Regardless of any government action, more and more companies are making public commitments to reduce emissions. The World Business Council on Sustainable Development, which includes 200 of the world's largest companies, has set a goal of NZ2050 for its members. Recently, international banks and financial institutions with more than $70 trillion in assets launched the Glasgow Financial Alliance for Net Zero (GFANZ) and have pledged to take action to ensure their portfolios align with climate objectives.[22] The Climate Action 100+ is a group of global investors with $52 trillion in assets in 33 markets who have established a common agenda for emissions reductions, improved governance and strengthened climate-related financial disclosure.[23] Canada's steel producers have committed to achieve net zero emissions by 2050.[24] These are just a few examples of private initiatives, independent of government, that will also be driving transition in the energy sector.

It is clear that Ontario's businesses are going to be taking action to reduce their emissions, whether of their own volition or under increasing pressure from investors, bankers and consumers. As they do so, they will be seeking solutions and new technologies from Ontario's energy sector. Some of this will necessarily appear as increased demand for Ontario's clean electricity as a substitute for current energy sources. Some of it from energy efficiency, whether in industrial processes or for their buildings. In other cases it will come from newer technologies like carbon capture and storage. And hydrogen will have a significant role to play in reducing emissions in hard to abate industrial activities like steel production.[25]

In the next few sections, we discuss three of the key elements of change related to Ontario's energy consumption that will likely be necessary to achieve NZ2050.

[22] https://unfccc.int/news/new-financial-alliance-for-net-zero-emissions-launches
[23] https://www.climateaction100.org/
[24] https://canada.constructconnect.com/dcn/news/associations/2020/10/canadian-steel-industry-aims-for-net-zero-by-2050
[25] https://www.mckinsey.com/industries/metals-and-mining/our-insights/decarbonization-challenge-for-steel

Technologies and Pathways

Humber River
Arch Bridge, Toronto

Detailed discussions of NZ2050 often invoke a discussion of some of the technologies and pathways necessary to achieve the goal. It is beyond the scope of this report to undertake an examination and evaluation of all the various technologies which have the potential to make a contribution towards NZ2050 specifically for Ontario. The focus of this report is on what our near term priorities should be to put us on a sustainable path to NZ2050. However, there are a number of international and Canadian studies which have examined in detail, on an economic sector-by-sector basis, the various potential pathways and technologies that have the greatest potential. We provide a high level summary of some of these studies and findings in this section, and use that research to guide a discussion of the primary technologies and pathways that are expected to be most relevant to Ontario's situation.

The IEA has examined in detail the energy technology implications of NZ2050 from a global perspective in its Energy Technology Perspectives 2020 report. As has also been found in this report, they conclude that "achieving net-zero emissions requires a radical transformation in the way we supply, transform and use energy."[26] While it examines a wide array of technologies, the IEA report highlights the following key energy-related technologies/pathways as critical for the path to NZ2050:

- Electrification: final electricity demand more than doubles globally;
- Hydrogen: a massive expansion of hydrogen production;
- Carbon Capture, Utilization and Storage (CCUS): the IEA indicates CCUS is a crucial technology for the production of low-carbon fuels, to remove CO_2 and vital for low carbon hydrogen production;
- Low carbon fuels: the IEA believes synthetic fuels (e.g. ammonia and synthetic hydrocarbon fuels) and bioenergy will play a significant role.[27]

A recent study by large group at Princeton University examined five potential pathways to NZ2050 for the United States. Their interim report identified the following key pillars necessary to support a transition to NZ2050:

1. End-use energy efficiency and electrification;
2. Clean electricity: wind & solar generation, transmission, firm power;
3. Bioenergy and other zero-carbon fuels and feedstocks;
4. CO_2 capture, utilization, and storage;
5. Reduced non-CO_2 emissions;
6. Enhanced land sinks.[28]

[26] International Energy Agency. *Energy Technology Perspectives 2020.* Revised version, February 2021.
[27] Ibid.
[28] Eric Larson et al. *Net-Zero America.* Interim Report. Potential Pathways, Infrastructure, and Impacts. Princeton University and Andlinger Center for Energy and the Environment. December 15, 2020 (v2).

For a Canadian context, the Canadian Institute for Climate Choices reviewed a wide array of potential technologies in its report prepared for the Canadian government entitled Canada's Net Zero Future. The report enumerates a number of "safe bets" which are defined to be emissions reducing technologies and solutions that are already commercially available and face no major constraints to widespread implementation. They also identify "wild cards" which are defined to be solutions that may come to play a significant and important role on the path to net zero, but whose ultimate prospects remain uncertain.[29]

In a 2015 report, the CMC Low Carbon Pathways Group examined pathways to deep decarbonization in Canada. Their analysis identified the following six decarbonization pathways:

1. Decarbonized electrification: Low-emitting electricity captures a larger share of total energy use and provides low-cost fuel-switching for some fossil fuel-based end uses.
2. Energy efficiency: Expanding current energy savings trends in buildings, vehicles and industry
3. Reduce, cap and utilize non-energy emissions: Two areas of focus are capping and burning of methane from landfills, and reductions from the oil and gas sector.
4. Zero emission transport fuels: Electric batteries, non-food crop biofuels and hydrogen power our personal and freight transport fleets.
5. Decarbonize industrial processes: This is a key area identified for specifically Canadian investment and innovation.
6. Structural economic change: the transition will result in structural economic impacts that will have regional implications.[30]

In March 2021, SNC Lavalin released its Engineering Net Zero technical report for Canada. The report reviews emissions and technological options on a sector-by-sector basis for Canada. This report identifies the following recommended pathways in the Canadian context:

1. Expanding net zero electricity generation: Hydro, nuclear, CCUS and energy storage are emphasized
2. Electrification timing: the timing of electrification is critical and must align with the supply of zero carbon electricity
3. Comprehensive planning: initiatives should be coordinated under a comprehensive Canadian plan with inter-provincial collaboration
4. Industry engagement: policy makers and businesses must collaborate to ensure a stable investment path

[29] Canadian Institute for Climate Choices. *Canada's Net Zero Future.* Finding Our Way in the Global Transition. February 2021.
[30] Bataille, C. et al. *Pathways to deep decarbonization in Canada.* SDSN - IDDRI. 2015

5. Commit to innovation: there is an urgent need to start deploying pilot and demonstration projects, as many NZ2050 technologies are in their early stages of development
6. Hydrogen and alternative fuels: energy intensive industrial processes will require hydrogen and alternative fuels, necessitating a stable hydrogen market
7. Indigenous participation: the transition will necessarily involve indigenous communities will require the empowerment and participation of local communities
8. Social change: Canadians will have to adapt their behavior and consumption patterns[31]

In Ontario, in 2018 the Ontario Ministry of Environment, Conservation and Parks released A Made-in-Ontario Environment Plan. The plan outlined targets for emissions reductions by sector to reach the province's overall 2030 emissions reduction target. These are summarized in the chart below. Looking beyond 2030 out to 2050 may provide guidance to our actions today to meet our 2030 goals. Given the magnitude of the NZ2050 transition, there may be implications for staging and prioritization as we seek to maintain affordability and reliability in transition.

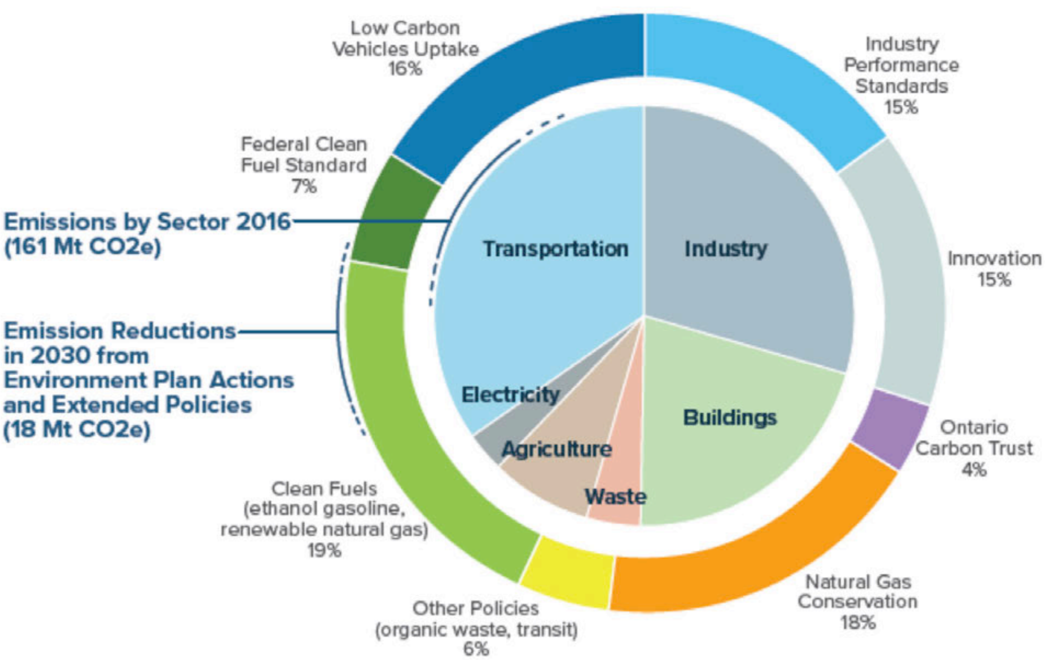


Figure 23 Ontario Planned Emissions Reductions By Sector By 2030

[31] SNC-Lavalin. *Engineering Net Zero: Canadian Technical Report.* March 2021.

Based on the international, Canadian and Ontario-based research, it is evident that many technologies are already fully advanced and available to allow us reduce and eliminate emissions affordably. We already have enough experience with these technologies to provide some certainty that they can be scaled while still maintaining energy affordability. Things like emissions free vehicles, energy efficiency programs, heat pumps, non-emitting electricity, energy storage and renewable natural gas are examples of technologies we are using today that can be scaled.

> "Almost half the emissions cuts required to move us on a path to net zero by 2050 may need to come from technologies that are not on the market yet."
>
> Dr. Faith Birol, Executive Director, IEA [32]

However, the further we look out past 2030, the more uncertainty there is as to which technologies will be most competitive and effective in helping us meet our target. This points to the need to remain technology agnostic today as to the potential resources we will ultimately use. In the near term, we should focus on those affordable and readily available options available to us now to help us move quickly to reduce emissions. In the longer term, more options will become available to us as we gain experience with newer technologies.

ELECTRICITY SYSTEM

Our previous analysis of the transportation, industrial and manufacturing sectors made it clear that there will necessarily be increases in demand for electricity as those sectors seek to reduce emissions. While the exact timing and scale of this electricity demand increase is uncertain, the need for increased electrical energy and capacity seems a certainty.

Leveraging Ontario's Low-Emitting Electricity System to Reduce Emissions

With Ontario having made its electricity system one of the cleanest in the world, this system can be leveraged and grown to replace much higher emitting fuel uses. Ontario currently has an excess supply of non-emitting electrical energy which provides an opportunity to fuel switch from higher emitting fossil fuel powered vehicles and equipment with electrically driven alternatives. This can result in significantly lower emissions as well as better value created from domestic usage of intermittent renewables as opposed to exporting this excess energy.

[32] https://www.iea.org/commentaries/net-zero-by-2050-plan-for-energy-sector-is-coming

Beneficial electrification is a targeted measure aimed at driving emission reductions affordably and reliably. The key factor to making electrification 'beneficial' for Ontario is to avoid or minimize an increase in peak demand (MW). Increases in peak demand generally require investments in new generation, transmission and distribution to increase system peak capacity, potentially increasing costs for end users. Conversely, adding new off-peak load (MWh) can reduce average system cost ($/unit of energy) and better leverage existing non-emitting capacity with limited impacts on system costs.

There are a multitude of options available to expand the capacity of Ontario's electricity system to manage the increase in demand that materializes from decarbonization activities. We highlight some of them below. This is not meant to be an exhaustive list of all potential electricity system expansion options. Nor is this list meant to compare the pros and cons of any particular option. The length or brevity of any resource mentioned should not be interpreted as reflective of an opinion on that resource's relative merits versus any other resources. Rather, these are just some brief highlights and examples of the many options available to us.

Overnight Charging of Electric Vehicles (EVs)

One simple and very cost-effective way to increase the utilization of Ontario's clean electricity grid quickly is to put in place a series of policies that incentivize overnight charging of electric vehicles. The transportation system remains Ontario's largest source of emissions. Ontario's electricity system has significant underutilized capacity at night. Therefore, Ontario's electricity grid will be able to absorb a large volume of EV charging at night, without major grid infrastructure upgrades required. If EVs are charged at other times, it will require infrastructure upgrades to increase grid capacity, and peaking generation services to meet EV charging needs.

Energy Storage

Energy storage will be an important pillar for Ontario's future electricity supply mix. Ontario's electricity system current has more capacity than it can utilize, particularly at night when wind, hydro and nuclear resources have capacity but there is no demand. There is a significant opportunity in Ontario to increase the capacity of our system with energy storage. Energy storage will also be a necessary component to leverage and maximize the value of any significant addition of intermittent renewables to the system. Pairing storage with renewables ensures that the energy supply will be reliable for end users. Energy storage's tremendous advantage is that it can be paired with any energy source to improve its capability and functioning.

NRStor Minto Flywheel Facility

Demand Response

Ontario has been very successful in developing a new capacity auction in which demand response resources compete to provide low cost energy capacity to our system. Demand response aggregators bring together electricity users who are willing to reduce their consumption in times of peak need. By reducing peak demand, the reliance on expensive, under-utilized peaking resources is reduced and in most cases carbon emissions are lowered. This resource has the potential to grow and to cost-effectively enhance Ontario's grid capacity with existing aggregation strategies. In addition, Ontario currently does not have a rate structure strategy that effectively allows residential demand response to be viable, but residential air conditioning use during our summer peak may be one of the largest drivers of capacity costs. This has significant future potential.

Energy Efficiency (EE)

Ontario's grid capacity can be enhanced through increased energy efficiency. Energy efficiency is a proven low-cost system resource in Ontario. As we look to expand the capability of our electricity system to replace carbon fuels, energy efficiency will have significant cost-effective potential. A 2019 study by Navigant (now Guidehouse) found that by 2038, Ontario could reduce its electricity system peak by up to 3,000 MW for under $0.04 kWh for a set of incremental energy efficiency measures.[33] The IESO recently launched a first-ever energy efficiency auction pilot program with a unique approach that incentivizes reduction in peak electricity demand through a competitive market-based procurement mechanism, providing a new vehicle for energy efficiency in Ontario.

[33] Navigant. *2019 Integrated Ontario Electricity and Natural Gas Achievable Potential Study.* Prepared for the Independent Electricity System Operator and Ontario Energy Board. December 10, 2019.

Distributed Energy Resources (DERs)

Falling costs have increased the competitiveness of smaller electricity generation resources that have the ability to enhance the capacity of Ontario's grid. DERs can be incorporated into the grid in such a way that they represent a lower cost alternative for ratepayers. Expanding DERs in Ontario is not a simple matter. To do so will require policies and project evaluations that ensure their deployment is beneficial: that they do not strand assets and increase costs for current electricity ratepayers. DERs might include solar, wind, batteries, combined heat and power (CHP) and other resources. Grid enhancements (i.e. capital costs) will also be necessary to allow Ontario's grid to handle more two way energy flows, larger and more sudden system flow changes as DERs begin or stop providing energy services. Microgrids that remain connected to the larger system but facilitate sharing local generation are a form of DER that may enhance our capacity.

Consider Role for Existing Natural Gas Fired Generators

Recently concerns have been raised about the future emissions profile of Ontario's existing natural gas generation plants and the resulting impact on Ontario's emissions reductions objectives. The OEA commissioned a separate study by Power Advisory LLP[34] to examine the role natural gas plants fulfil in Ontario's electricity system and the implications of a policy to eliminate them by 2030, as has been publicly proposed by some organizations. Power Advisory found that replacing all of the gas plants in that timeframe was not physically feasible, and that it would cost over $60 billion even if you could.

Napanee Generating Station

[34] Power Advisory LLP. *Implications of Shutting down Ontario's Gas-Fired Generators by 2030.* Prepared for the Ontario Energy Association. April 2021.

The Power Advisory research suggests that Ontario's current fleet of natural gas generators might have an ongoing role to play in helping us decarbonize our economy. Electricity is currently Ontario's cleanest energy source. We will need to expand our electricity system in order to decarbonize our economy. This points to the need for additional research as to the role of the gas plants in Ontario's overall GHG reductions strategy prior to implementing any government policy mandates regarding their future. This research should not be done in isolation with a sole focus on the electricity sector.

Imports

Some groups have called for Ontario to increase its imports of green electricity, from Manitoba or more commonly proposed from Hydro Quebec, both of whom produce most of their power from hydro. This is certainly one way for Ontario to increase its electricity grid capacity. The Power Advisory study mentioned above provides some recent analysis of the potential for expanding imports of power from Hydro Quebec through existing transmission lines, or by adding new transmission capability.[35]

To date Hydro Quebec has never offered Ontario "firm" capacity – capacity that we can rely on when we have peak system needs. If Hydro Quebec is willing to publicly offer such terms to Ontario, so it can be evaluated against alternatives, then this is something that should be explored on behalf of consumers in terms of its ability to meet expected needs and cost. This alternative will require upgrades to existing transmission lines for small increases in capacity, or more storage to take advantage of existing transmission, and new transmission lines for any significant increase in capacity.[36] Given the planning and local consultation challenges in building new transmission infrastructure, any such plan will need significant lead time before this additional power will be available.

Develop/Procure More Generation Capacity

Ontario will clearly have to develop new electricity generation capacity as the demands for electricity fuel switching increase. It is not the purpose of this paper to delineate, analyse, compare, contrast and define the role and magnitude of individual electricity generation resources. The brevity of this section should not be interpreted as an indication that generation expansion will play only a minor role. To the contrary, given the scale of the NZ2050 objective, there will clearly be a need for significant new generation in Ontario's future.

Below is a list of just some of the zero emissions technologies which could make up some portion of this expansion. We have avoided providing descriptions and comparisons of attributes of each resource lest it be inadvertently be perceived that the OEA favours one resource over another.

[35] Ibid.
[36] Ibid.

- Wind
- Solar
- Energy storage
- Wind or solar paired with storage
- Traditional nuclear reactors
- Small modular reactors (SMRs)
- Hydro

Northland Power, Grand Bend

The OEA would like to see competitive processes used, wherever possible, to procure new resources as they are needed to ensure consumers get the lowest cost reliable clean energy. However, in Ontario, nuclear policy and strategy has always been directed by the provincial government and has often been driven by economic policy objectives as much as energy policy. Ontario has developed a significant nuclear industry, expertise and associated supply chain. The provincial government has stated its objective to leverage this expertise to make Ontario a leader in the expected significant expansion of the international SMR market. This will include leveraging this technology at home. The OEA recognizes that the role and extent of nuclear energy along Ontario's path towards NZ2050 will likely be determined by the provincial government. As electricity system expansion needs are identified going forward, the government should clearly and transparently articulate the role it intends to direct for nuclear power to allow other resources to plan accordingly.

Transmission and Distribution System Expansion

Any plans for a significant increase in generation capacity or imports will require a proportionate need for increased transmission and distribution capacity. New infrastructure will be required to reliably deliver this additional electricity from generators to loads, to allow for system optimization, and accommodate increases in two-way power flows. Numerous studies in the U.S. have concluded that transmission will play a critical role in decarbonizing their economy. A study by MIT found that expanded transmission allows for optimization across geography, reducing system costs in decarbonization strategies by as much as 46 percent.[37] Similarly, Princeton's Net Zero America study found that high voltage capacity will need to expand by about 60% by 2030 and triple by 2050 to connect new resources with demand.[38] Similarly, as the overall system load increases, the capacity and capability of the distribution system will also need to be expanded.

These expansions will naturally come with increased costs to pay for new system infrastructure and system capabilities to handle and optimize a more complex grid. However, these new costs will be replacing costs associated with other systems to deliver consumers an alternate energy source. Therefore, they will not necessarily represent an increase in energy costs for the end user. In fact, increased electricity use and further system optimization may result in end use efficiencies and cost reductions.

These long-lived key assets require long-lead times to both plan and build-out, involving intensive major planning processes, regulatory approvals, and extensive consultation processes. Therefore, it is imperative that work begin well before needs materialize to ensure this essential transmission and distribution infrastructure expansion will be ready on time in order to meet our 2050 targets.

Hydro One towers, Cherrywood, Ontario

[37] Patrick Brown & Audwin Botterud. *Joule*. Article 1. Volume 5, Issue 1, P115-134. *The Value of Inter-Regional Coordination and Transmission in Decarbonizing the U.S. Electricity System.* December 11, 2020.

[38] Eric Larson et al. *Net-Zero America.* Interim Report. Potential Pathways, Infrastructure, and Impacts. Princeton University and Andlinger Center for Energy and the Environment. December 15, 2020 (v2).

HYDROGEN

Hydrogen is increasingly being seen around the world as a critical component of the world's transition to a low carbon economy. The IEA sees it as the most promising option to decarbonize "hard to abate" sectors such as heavy transportation, chemicals, and iron and steel production.[39] They anticipate hydrogen production will increase significantly in the next 30 to 50 years.[40] In the past few years, the following countries have announced hydrogen strategies: Australia; Austria; Belgium; China; Chile; European Union; Finland; France; Germany; India; Italy; Japan; Netherlands; New Zealand; Norway; Portugal; Saudi Arabia; Scotland; South Africa; South Korea; Spain; United Arab Emirates; United Kingdom.[41] Many other countries have hydrogen strategies under development.

In December 2020, the Canadian government released its Hydrogen Strategy for Canada as a key pillar of the national net zero 2050 strategy. The federal strategy suggests we can leverage Canadian expertise to deliver up to 30 percent of Canada's end-use energy by 2050.[42] This gives a sense as to the significance of the role hydrogen will play on our path to NZ2050.

[39] International Energy Agency. *EnergyTechnology Perspectives 2020.* Revised version, February 2021. p.109
[40] Ibid. p.110
[41] https://www.powermag.com/countries-roll-out-green-hydrogen-strategies-electrolyzer-targets/ and https://www.h2bulletin.com/countries-hydrogen-economy-goals-policies/
[42] Natural Resources Canada. *Hydrogen Strategy for Canada.* Seizing the Opportunities for Hydrogen. December 2020. p.IX.

The Ontario government released a complementary discussion paper in November 2020 to inform its developing hydrogen strategy as well. The Ontario discussion paper identifies opportunities to leverage Ontario's existing capabilities which include the following:

- Two global electrolyser firms with facilities in Ontario;
- Fuel cell and component makers in Ontario;
- A hydrogen bus manufacturer with operations in Ontario;
- Hydrogen powered forklifts in use in distribution centres;
- A pilot project to inject hydrogen into its natural gas system in Markham; and
- A company that currently makes hydrogen from both natural gas and electricity.[43]

This existing capability, when combined with Ontario's many regional and infrastructure assets, points to a tremendous opportunity for Ontario to be a global leader in hydrogen production and use.

The OEA is very supportive of the efforts by both governments to develop a path and strategy for greater deployment of hydrogen. Expanding our use of hydrogen can be achieved by leveraging existing infrastructure (e.g. natural gas system) and will likely also require the development of new infrastructure to store and distribute this fuel to customers. To do this in a way that does not economically disadvantage Canadian companies will require significant government support to help the energy sector build up capacity until such time as a large scale of production and consumption lowers costs to a level more affordable for end users. Pilot projects and initial deployments to help us develop experience in utilizing this clean resource should be accelerated, to increase our ability to incorporate and scale this resource to its fullest potential by 2050.

[43] Government of Ontario. *Ontario Low-Carbon Hydrogen Strategy Discussion Paper.* November 2020.

CARBON CAPTURE UTLIZATION AND STORAGE

Carbon Capture Utilization and Storage (CCUS) solutions represent significant opportunities to deeply decarbonize hard to abate vital sectors of the economy. CCUS solutions can unlock ancillary clean energy opportunities, like blue hydrogen production or low-carbon petrochemical developments and presents a viable approach to decarbonize cement and steel manufacturing. Experts agree that widespread CCUS deployment is needed for Canada and the world to achieve net-zero by 2050. Three of the four UN climate scenarios that limit average temperature rises to 1.5 degrees include a role for CCUS. As Federal Natural Resources Minister O'Regan noted "carbon capture technology creates jobs, lowers emissions and increases Canadian competitiveness. It's how we get to net zero."[44] This is entirely consistent with IEA analysis that says, globally, "reaching net zero will be virtually impossible without CCUS."[45] In some instances, pairing CCUS with sustainable biomass generates negative CO_2 emissions to help offset emissions elsewhere in the economy.[46] In order for Canada to reach net zero by 2050 governments and industry need to get behind CCUS now and in a big way. Developing CCUS on the scale needed to meet climate goals requires an industry approach to realize economies of scale.

ALTERNATIVE CLEAN FUELS

Reaching NZ2050 will likely require a significant increase in alternative low-carbon fuels in the form of bioenergy, biofuels, biogas, biomethane, hydrogen and hydrogen-based fuels (ammonia and synthetic fuels). We briefly discussed biofuels in the Transportation Sector section. Biofuels can provide an alternative to petroleum-based diesel and gasoline and can replace conventional fuels, limiting the need for changes to fuel distribution networks and vehicles.

Biogas and biomethane were also discussed previously in the Transportation Sector section with respect to RNG. It can be produced from organic waste, animal manure, municipal solid waste, and wastewater sludge. Through biomass gasification and methanation (the conversion of carbon monoxide and CO_2 to methane through hydrogenation), biogas can be converted into biomethane, with the CO_2 captured and stored, resulting in negative emissions.

Finally, NZ2050 will require an expansion of ammonia and synthetic hydrocarbon fuels. The higher volumetric energy density of these fuels may be required for feasibility in replacing current shipping and air transportation fuels. Expanded use of these fuels will be related to ongoing production cost improvements and strict training. We will also have to leverage and expand our existing experience, capacity and regulatory systems to deal with the toxicity of some of these fuels.

[44] https://www.newswire.ca/news-releases/canada-and-alberta-launch-steering-committee-to-advance-ccus-896087073.html
[45] International Energy Agency. *Energy Technology Perspectives 2020.* Revised version, February 2021. p.13
[46] Ibid. p.138

BEHAVIOURAL CHANGE

Our behaviour can have a significant impact on our emissions footprint generally, including choices we make that impact how we use energy. As discussed earlier, Ontario has had great success in developing a culture of conservation behaviour that has demonstrably reduced the amount of electricity and natural gas we use at home and at work. We also saw how behavioural practices have resulted in increasing transportation emissions even when technological advancement has resulted in much more efficient vehicles. Reaching NZ2050 will require Ontarians to build on this progress by adapting our behavior to continually reduce our emissions profile through all of our activities and purchases. Governments and the energy sector need to work together to provide ongoing education of citizens and customers to make them aware of the role they can play in reducing their individual emissions and the options available to them to help them do so. And we must all work together to build a culture of emissions consciousness just as we have successfully built a culture of conservation with respect to household energy consumption within our homes.

OTHER TECHNOLOGIES

The previous sections focused on some of the key energy-related technologies and pathways that are expected to play a prominent role on our path to NZ2050. This was not an exhaustive list of potential energy-related technologies. For example, geothermal energy is an existing technology that can provide emissions free heating and cooling for homes. There is a significantly sized deep lake water cooling system in the City of Toronto that is estimated to avoid 79,000 tonnes of CO_2 and free up 61 MW of power on Toronto's electricity system.[47] This technology can be expanded in Toronto and utilized in other jurisdictions.

There may be other technologies we have not discussed that with further research and development will show great potential as we get closer to NZ2050. We should remain technology agnostic going forward and evaluate all evolving technologies based on their cost, feasibility and scalability.

[47] http://buildipedia.com/aec-pros/engineering-news/torontos-deep-lake-water-cooling-system

Comprehensive Planning and Coordination

This report has outlined the scale of the energy sector transformation in Ontario required by Canada's commitment to NZ2050. The energy sector transformation necessitated by moving towards NZ2050 in Canada and Ontario will encompass one of the largest infrastructure initiatives in the country's and province's history. There is tremendous opportunity for Ontarians given this scale. There will also be tremendous challenges. An initiative of this scale will require comprehensive energy planning. It will also require governments to coordinate their efforts to ensure they are not working at cross purposes. Each of these is discussed briefly below.

Comprehensive Energy Planning

Most energy consumption currently happens outside of the electricity system in Ontario. Therefore, Ontario will need to develop a comprehensive energy strategy to take us to NZ2050. That is not to say that a single strategy should be developed today that outlines all the pathways and technologies that will achieve NZ2050. As we have seen in this report, we still have much work to do to gain experience with developing technologies that could become prominent parts of our energy system (e.g. hydrogen, SMRs, CCUS, etc.). Rather, Ontario needs to develop an ongoing and evolving comprehensive energy plan that adapts to our increasing experience with alternatives. This strategy must take into consideration the complementary roles that all energy sources can play in order to meet the low carbon energy needs of the future at the lowest cost.

A first step in comprehensive energy planning in Ontario will be to eliminate energy siloes. The Ministry of Energy, Northern Development & Mines on occasion reviews and sets policy for fuels in a discussion that is somewhat separate from other energy planning. Our natural gas system is overseen by the Ontario Energy Board (OEB), with occasional provincial policy intervention in areas of provincial interest. And the electricity system is currently planned by the provincial government, with the IESO operating the system, arranging procurement, and the OEB overseeing utilities and rate regulated assets. All of these efforts need to be coordinated under a broader energy framework.

Government Coordination

To successfully develop and implement the various transition strategies outlined above, all levels of government will have to coordinate. Success will require that one level of government is not working at cross purposes with another level of government. The federal and provincial governments should coordinate their policies and programs to ensure that they enhance a comprehensive energy plan for Ontario. And the Ontario government should be coordinating with regional and municipal governments to ensure that local emissions reductions strategies and initiatives are coordinated, fully-costed and complimentary to the provincial energy strategy.

Conclusion

This report has provided some background on the way Ontarians use energy currently, and some of the options and issues associated with transitioning to a net zero economy by 2050. The analysis makes it clear that our path to NZ2050 requires Ontario to now turn its policy focus to energy use more broadly, in contrast with our historic focus primarily on electricity. In particular, we need to now focus on our consumption of fossil fuels which make up 80 percent of our energy use.[48]

The analysis suggests that Ontario should make transportation fuel switching its highest priority. Firstly, the transportation sector is our largest source of emissions. The analysis shows us that fuel switching will be much easier to implement for transportation uses because, with existing technology coupled with the right policies and managed charging, the electricity system will be able to replace a large volume of petroleum consumption without requiring massive new infrastructure. We have all the technologies we need today to affordably decarbonize our transportation system.

The analysis also suggests that replacing our natural gas system would be a massive undertaking in Ontario. A big reason for this is the extremely high volume of peak energy capacity that is required to heat our homes and buildings in the winter. Because of this, we are going to need to continue to rely on our gas system and the highly efficient heating technology currently deployed in homes and buildings. This suggests that our policies toward our natural gas system should focus on reducing its GHG emissions intensity through things like renewable natural gas, hydrogen blending, hybrid heating systems and energy efficiency initiatives for buildings and industry to reduce consumption and therefore emissions.

Finally, the analysis very clearly points to the need for a comprehensive energy strategy for Ontario that considers all fuels and maps a pathway to net-zero 2050. The OEA would like to see the federal and Ontario government work collaboratively on a detailed and comprehensive energy plan for Ontario. We would also like to see the province work with municipalities to ensure that local efforts towards the same objective are complementary. The OEA intends leverage its expertise to support all levels of government in this effort.

[48] The recommendations contained in OEA papers represent the advice of the OEA as an organization. They are not meant to represent the positions or opinions of individual OEA members, OEA Board members, or their organizations. The OEA has a broad range of members, and there may not always be a 100 percent consensus on all positions and recommendations. Accordingly, the positions and opinions of individual members and their organizations may not be reflected in this report.

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