2020

GREEN RIBBON PANEL REPORT

Clean Air, Climate Change and Practical, Innovative Solutions

Policy Enabled Competitive Advantages Tuned for Growth

GROWING ECONOMY.
SUSTAINABLE ENVIRONMENT.
REAL SOLUTIONS.

EXECUTIVE SUMMARY

Countries all around the world are waking up to the reality that climate change is a pressing concern and demands action. Here in Canada, there is a growing consensus that we can and must do more to address the harsh realities of climate change.

This will be no easy task and will require multiple levels of government working together to achieve a common goal. However, solutions exist and removing greenhouse gases (GHG) and other pollutants from our atmosphere will not only reduce the risk of severe weather events, but will also improve air quality, mitigating the risk of serious health issues.

The 2020 Green Ribbon Panel was formed in February of this year by a collection of environmental and economic leaders from across Canada with the primary goal of advancing practical and executable solutions to climate change. The panel examined the role that nuclear and Canada's other clean energy technologies can play in the fight against climate change while creating jobs and growing the economy.

The panel comprised:

- James Scongack, Bruce Power – Chair
- Christopher Hilkene, Pollution Probe
- Steve McCauley, Pollution Probe
- Rocco Rossi, Ontario Chamber of Commerce
- Ashley Challinor, Ontario Chamber of Commerce
- Vanessa Foran, Asthma Canada
- Dennis Darby, Canadian Manufacturers and Exporters
- Mark Fisher, Council of the Great Lakes Region
- Cara Clairman, Plug'n Drive
- Bruce Wallace, Nuclear Innovation Institute
- Robert Stasko, Hydrogen Business Council
- Jeff Parnell, Power Workers Union
- John Sprackett, Power Workers Union
- Scott Travers, Society of United Professionals
- Mitch Twolan, Warden Bruce County

The Panel focused on the role that nuclear and other technologies that anchor Canada's energy sector can play in fighting climate change and growing the economy at home and abroad.

This report is a culmination of the Panel's deliberations and provides a roadmap for Ontario to maintain and strengthen its position as a climate change leader. While the focus of this report is on Ontario, the solution discussed can provide a pathway to improve the energy system for the health and prosperity of Canada.

he findings of this report shine a spotlight on the economic growth and climate change opportunities within the province. They also highlight successful efforts on climate change in the past, and outline other ways for Ontario to lead Canada in GHG emission reductions.

The examples and discussion contained within the report should be seen as an opportunity for Canada to take advantage of Ontario's leadership in pursuit of real action on climate change.

Green Ribbon Panel Principles

To guide the scope of work, the panel developed four principles it believes are necessary to change the conversation around climate, energy, and the economy:

1. Embracing the urgent need to address climate change is the foundation for action;
2. Ontario is well-positioned to build the clean electricity system that can be a cornerstone of Canada's future low-carbon economy;
3. Low-cost, low-carbon emission energy represents a competitive economic advantage for Ontario and Canada; and
4. The enabling policy frameworks must be diverse and require participation from all levels of government and public-private partnerships.

These principles guided the Panel's work and the findings and recommendations that follow.

Clean Air, Climate Change and Practical, Innovative Solutions to Grow the Economy and Reduce GHG Emissions in Ontario.

Canadians have a desire to act on climate change and Ontario has already demonstrated the path to lowering GHG emissions significantly by reducing the number of smog days in the province from 53 in 2005 to zero in 2015. To meet 2030 climate targets and reduce GHG emissions in the rest of the economy, Ontario will need 25% more low-carbon emitting electricity. And yet, electricity sector GHG emissions are projected to rise again due to a move to greater fossil-fuel based generation in the province.

Thankfully, a solution exists. Supported by nuclear generation, a combination of hydrogen, storage, and the wires-and-pipes distribution infrastructure could form a smartly integrated solution for electrification. This solution would smooth out electricity demand, increase the efficient use of assets, enhance system flexibility, and lower electricity costs. In the past decade, Ontario successfully reduced its GHG emissions by displacing coal with nuclear power. The integrated solution will build on Ontario's successes by reducing emissions and improving our air quality.

Investing in Made-In-Ontario Solutions: Policy Enabled Competitive Advantages Tuned for Growth

A Made-in-Ontario, low-emission electricity system provides a path to creating 150,000 new jobs and boosting the local economy.

Investing in a smartly integrated solution of hydrogen, biomass, and nuclear would bring economic benefits in terms of high-quality jobs, strategic investments, trade balance improvements, enhanced innovation, and public health, all while reducing GHG emissions. It would also enable strategic industries like the hydrogen economy, ZEV manufacturing, and zero-emissions trucking, which would bring further jobs, economic growth, innovation, and public health improvements. These would be felt across Ontario, and also extend into the broader Great Lakes region.

Proactive policy engagement will be needed among all levels of government and the private sector to achieve these benefits. Thankfully, Ontario has a solid foundation within Canada to innovate on impactful climate policies and is well placed to deliver these benefits.

Recommendations

The Panel has identified ten immediate recommendations to be pursued within this dynamic environment. These could begin implementation over the next 18-months and serve as short-term steps for the enablement of longer-term objectives.

1. **Leverage Ontario's unique clean energy technologies and existing assets to reduce GHG emissions and lower energy costs.**
    - Enhancing Ontario's existing nuclear and hydro assets forms the foundation for building a smartly integrated electricity solution that can use Ontario's unique advantages to continue its leadership in reducing Canada's emissions.
2. **Focus policy objectives on clear, short-term, tangible actions that prioritize targeted, proven, executable solutions and that embrace the diversity of regions across Canada.**
    - The consensus that policies at all levels of government should tackle climate change requires an action plan to sequentially build upon solutions across the country as we recover from the pandemic.
3. **Develop a pan-Canadian Hydrogen solution that includes integration with Canada's oil and gas sector, further deployment of hydrogen as a transportation fuel, and leveraging of Canada's clean electricity assets.**
    - The federal National Hydrogen Strategy effort presents a pan-Canadian opportunity to offer every province a pathway to reduce emissions.
4. **Pursue electrification of the economy supplemented by the application of hydrogen technologies to incrementally and reliably achieve the necessary GHG emission reductions.**
    - Electrification and hydrogen form the core elements for reducing emissions and along with encouraging the adoption of electrified technologies, can support Ontario-led manufacturing of hydrogen and battery electric vehicles and the supporting infrastructure.

5. **Develop a Green Collar Jobs Strategy to build upon Ontario's major strength in its skilled, diverse labour force to underpin and develop, innovate and execute critical activities and projects.**

   - Ensuring the development of the entire labour force from skilled trades to professionals could create a skills pool that can be leveraged internationally. New perspectives, thinking, and passion will emerge by providing explicit attention to indigenous reconciliation, and removing barriers and creating constructs to more equitably engage women and visible minorities.

6. **Establish Ontario's brand as a clean jurisdiction known for sustainable products.**

   - Supporting Ontario businesses in claiming they are in one of the cleanest jurisdictions in the world can enable their access to new markets and capital that value sustainable products.

7. **Leverage Ontario's status within the Great Lakes region to maximize the benefits of sustainability policies.**

   - Through policymakers working with those in the Great Lakes regions, the highly integrated nature of the two economies can make the region, as well as Ontario, more competitive and sustainable, while maximizing the benefits of sustainability policies by supporting clean investment opportunities.

8. **Engage the federal financial institutions, such as the Canadian Infrastructure Bank, to enhance the economic contributions of Ontario's domestic advantages.**

   - The federal government continues to make it a priority area to provide capital and create co-investment opportunities for the private sector. Ontario's domestic advantages, such as in manufacturing and low carbon electricity, can be supported by unlocking investment opportunities, reducing red tape, and removing trade barriers, especially interprovincially.

9. **Create a federal Next Generation Energy Innovation Fund to place focus on the development of demonstration projects for Canada's future clean energy game-changers.**

   - Long term annual funding is necessary for clean energy developments such as fusion, hydrogen, small modular reactors, and to leverage the value of the federal government's ownership of CANDU large scale reactor technology. Such funding can establish clean energy infrastructure zones and provide certainty to the investment community to develop globally competitive Canadian-made innovations.

10. **Consider how future public revenue from carbon pricing policy schemes should be revenue neutral to government and targeted at enhancing the competitiveness of trade-exposed sectors.**

    - While not a focus of this report, it became apparent that as the recommendations were developed, some principles regarding carbon pricing policies should be considered going forward such as rebating carbon proceeds to reduce the electricity costs for manufacturers and large industrial firms.

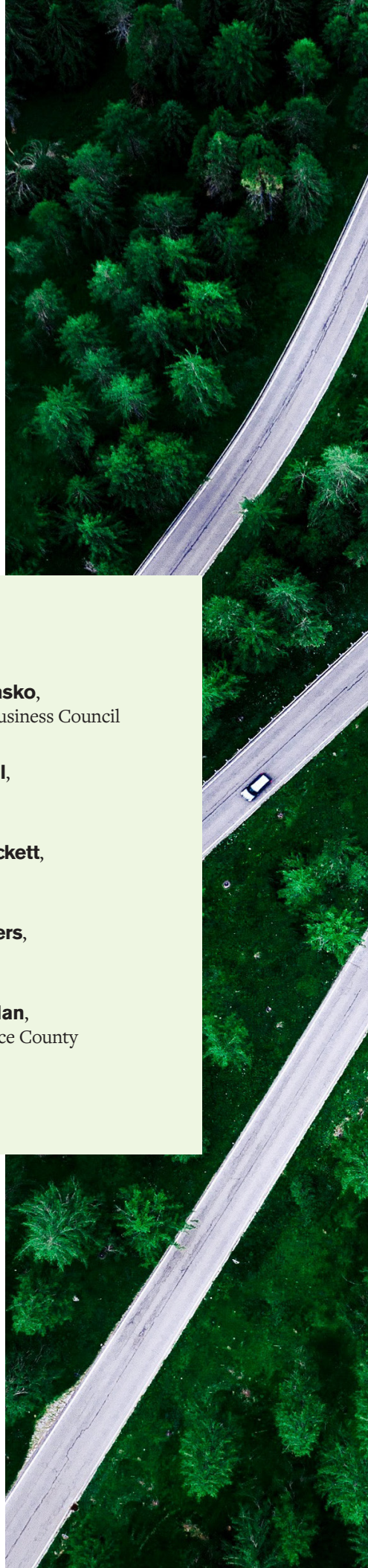

Attawapiskat L.
Cat Lake
Red Lake
Trout L.
Albany
Lake
St Joseph
Lac
Seul
Sioux
Lookout
Mojikit L.
ONTARI
Kenora
Dryden
Lake
Nipigon
Lake of
the Woods
Long L.
Rainy
Lake
Rainy
Fort
Frances
Thunder
Bay
Lake Superior
Lake Michigan

CONTENTS

SECTION 1

GREEN RIBBON PANEL PRINCIPLES

The 2020 Green Ribbon Panel was formed in February of this year by a collection of environmental and economic leaders from across Canada. The primary goal was to advance practical and executable solutions, including the role that nuclear and Canada's other clean energy technologies can play in the fight against climate change while growing our economy.



THE GREEN RIBBON PANEL PARTICIPANTS INCLUDED:

James Scongack,
Bruce Power - Chair

Christopher Hilkene,
Pollution Probe

Steve McCauley,
Pollution Probe

Rocco Rossi,
Ontario Chamber of Commerce

Ashley Challinor,
Ontario Chamber of Commerce

Vanessa Foran,
Asthma Canada

Dennis Darby,
Canadian Manufacturers and Exporters

Mark Fisher,
Council of the Great Lakes Region

Cara Clairman,
Plug'n Drive

Bruce Wallace,
Nuclear Innovation Institute

Robert Stasko,
Hydrogen Business Council

Jeff Parnell,
PWU

John Sprackett,
PWU

Scott Travers,
The Society

Mitch Twolan,
Warden Bruce County

To guide this work, the Panel developed a set of principles and priorities that it believes will bring about a necessary change in the conversation around climate, energy, and the economy.

The Panel believes these principles will help stakeholders better focus on the collaboration required to help avoid and mitigate the negative impacts of climate change and to create the competitive conditions and opportunities that will underpin prosperity and growth in the economy.

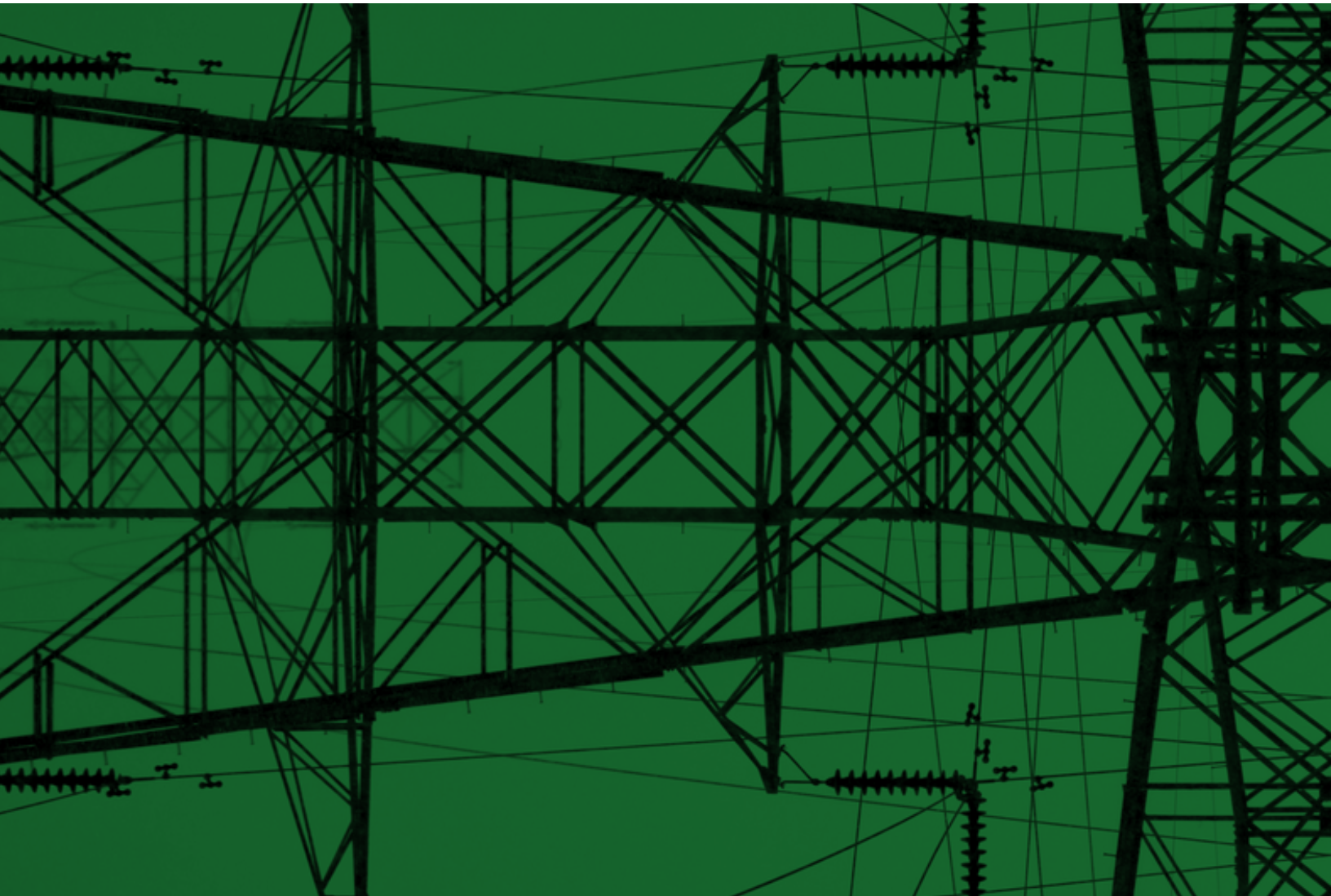
The Principles adopted by the Panel fall into four categories:

1. Embracing the urgent need to address climate change is the foundation for action

- Climate change is a real threat that must be addressed now through action that is proven to produce results.
- Decarbonizing the economy via increased electrification is pivotal to the success of critical economic sectors such as transportation (trucking, transit and electric vehicles), buildings (HVAC) and industry (process heat).
- Combatting climate change through electrification is paramount to cleaning our air and removing toxic pollutants.
- A clean electricity system can be leveraged in the production of hydrogen as a clean fuel.

2. Ontario is well-positioned to build the clean electricity system that can be a cornerstone of Canada's future low-carbon economy.

- Canada's low-carbon emitting electricity supply mix should be sustained and enhanced to ensure long-term, low-carbon energy security and export opportunities.
- Ontario is uniquely positioned to help create sustainable solutions given its historic broad energy mix, clean energy technology sector and successful replacement of coal generation with nuclear.
- Existing and developing nuclear and hydrogen technologies are well-suited to meeting Ontario specific low emission energy demands going forward, not only in the electricity system but within priority sectors of the economy.
- Leveraging a clean electricity system through new or existing hydro pump storage capability in Canada and the role of other renewable sources.

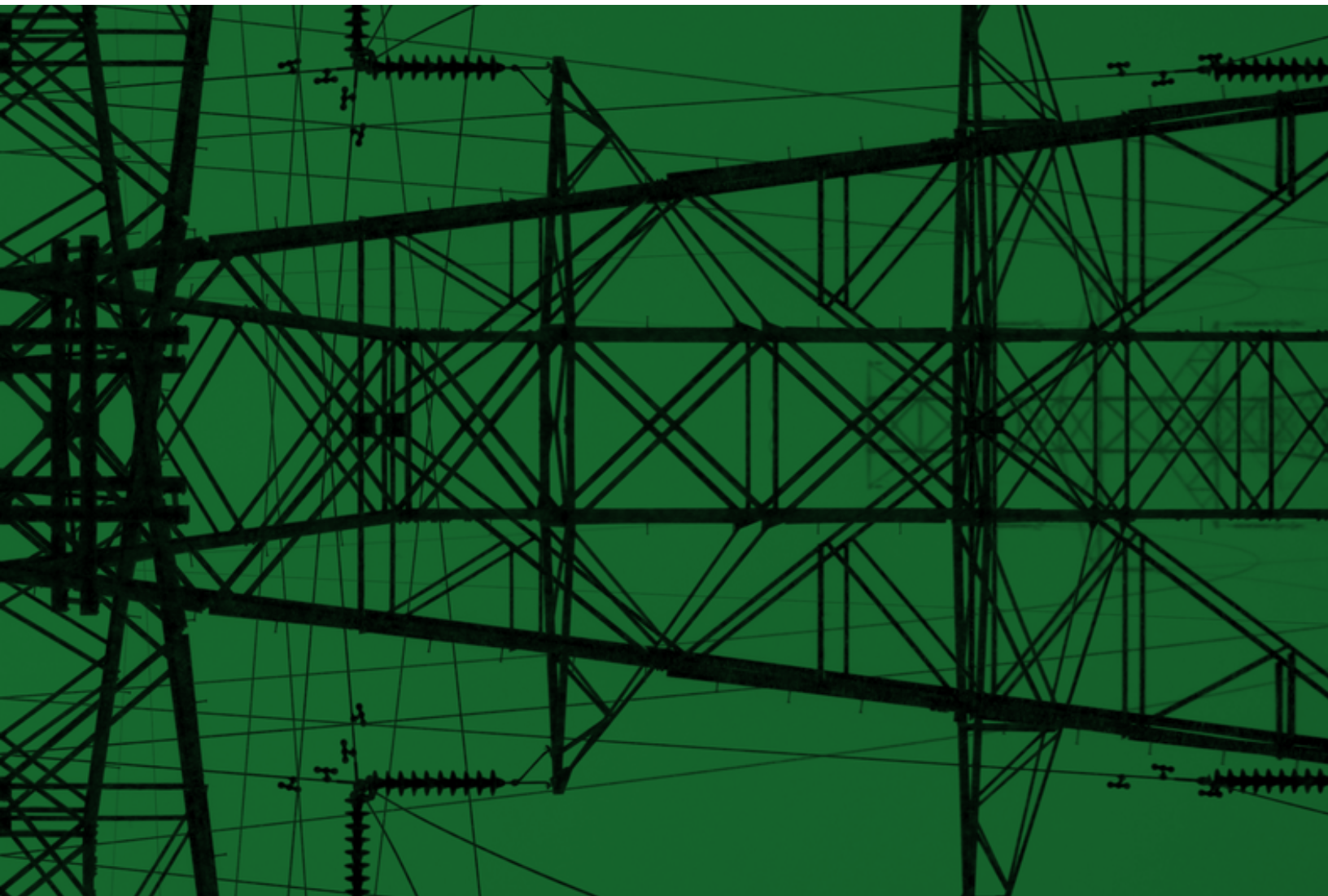


3. **Low-cost, low-carbon emission energy represents a competitive economic advantage for Ontario and Canada.**

- Ontario's unique position within the highly-integrated Great Lakes Economic Region represents a strategic advantage for several key economic sectors and for enhancing exports.
- Economic growth must be achieved in a balanced manner that provides benefits across the province and Canada.
- Economic spinoff benefits will result through job creation and trade, but also low emission energy/green sources will have a positive effect on health for our citizens — which in turn lowers government expenses.
- Clean technology solutions can be exported to help other countries reduce emissions from electricity generation.

4. **Enabling policy frameworks must be diverse and require participation from all levels of government and Public-Private partnerships.**

- The supportive policy framework should be predictable, stable, transparent, and evidence-based.
- Achieving economically beneficial climate change mitigation will require multi-faceted policy levers to support behavioural change, financing, regulation, labour force capability and infrastructure development.
- Recommendations must acknowledge the current fiscal challenges facing Canada and Ontario today, e.g. Covid-19 Pandemic.



SECTION 2

CLEAN AIR, CLIMATE CHANGE AND PRACTICAL, INNOVATIVE SOLUTIONS

to grow the economy *and* reduce GHG emissions in Ontario.

GROWING ECONOMY.
SUSTAINABLE ENVIRONMENT.
REAL SOLUTIONS.

ONTARIO'S 2030 EMISSION TARGETS REQUIRE 25% MORE ELECTRICITY THAN WE HAVE TODAY.

The significant infrastructure choices must create sustainable jobs and clean air, now and tomorrow.

OVERVIEW

Ontario has done much to reduce its greenhouse gas (GHG) emissions from the electricity system, but there is more we must do while adapting to population growth, economic recovery post-COVID, and a changing climate. Made-in-Ontario solutions coordinated with multiple levels of Government can create sustainable jobs and remove GHG emissions and other pollutants from our atmosphere.

Actions to mitigate climate change will drive economic growth, reduce risk of extreme weather and improve air quality, benefiting public health. This section shows how a combination of different technologies with complementary features can allow Ontario to electrify at a low cost, while providing the GHG reductions and clean air demanded by Ontarians.

KEY FINDINGS AND THEMES:

- Canadians have a desire to act on climate change.
  - Emissions are produced from all sectors of our province, and through a combination of direct and indirect electrification technologies GHG emissions can be reduced.
- Nuclear enabled the world's largest GHG-reduction initiative by closing coal-fired generation plants to clean Ontario's air.
  - Nuclear was responsible for 89 per cent of the emissions and pollution reduction achieved by displacing the use of coal in Ontario. The number of smog days were successfully reduced from 53 in 2005 to zero in 2015.
- Emission reduction policies drive a need for more electricity generation.
  - To achieve Ontario's 2030 climate plan GHG emissions reduction target of 22 megatonnes (Mt) will require 37 Terawatt hours (TWh) of additional generation. This is 25 per cent more electricity than Ontario uses today, equivalent to powering 4.1 million households per annum and much of the output from the Bruce Power nuclear site.
- Reducing GHG emissions through electrification is only possible with low-carbon emitting electricity.
  - The currently forecasted use of fossil fuel-fired generation would increase power-sector GHG emissions by 15 Mt, erasing most of the 22 Mt targeted by Ontario's climate plan;
  - This underscores the importance of nuclear refurbishment projects as a base for achieving our climate change objectives;
  - With 93 per cent of our electricity provided by non-emitting sources of supply, such as nuclear, hydro, and biomass, Ontario is well positioned to build a future clean electricity system.
- Ontario's unique Made-in-Ontario technologies offer a potential low-cost clean energy advantage and sustainable jobs.
  - Reliable, flexible and low-carbon nuclear electricity could form the backbone of a durable, integrated electrification solution;
  - The emerging hydrogen economy and energy storage technologies smooth demand and enable greater and efficient use of low-cost baseload power;
  - Investments in nuclear will provide Ontario with a reliable source of low-cost electricity and jobs for decades.
- The costs of energy in a smartly integrated Made-in-Ontario energy system could be 28 per cent lower than Ontario's existing energy costs and half that of alternatives.
  - We have the key to low-cost electrification by bringing together different technologies with complementary features. Smart integration of Ontario's nuclear, hydrogen and storage technologies with its "wires and pipes" distribution system and unique natural gas storage capacity offers a competitive cost advantage.
  - These home-grown Made-in-Ontario solutions will create jobs by keeping our energy dollars in the province.

COUNTRIES ALL AROUND THE WORLD ARE WAKING UP TO THE PRESSING CONCERN THAT CLIMATE CHANGE DEMANDS ACTION.

Here in Canada, there is a growing consensus that we can and must do more to address the harsh realities of climate change.

THE DESIRE TO ACT

The consequences of our changing climate are known to be real and severe.

The cost of climate change to global health is substantial: a conservative estimate from the World Health Organization (WHO) places it between $2-4 (US) billion in damages per year by 2030.[1]

Countries around the world are recognizing that climate change is a pressing concern that demands action. Canada is no different, and a national consensus is growing that we can and must do more to address the realities of a changing climate.

Ontario has done much to reduce its electricity system's GHG emissions, but there is more we can do. Advancing practical and executable solutions, including the role of nuclear and Canada's other clean energy technologies, requires action today.

In order to act and deliver tangible results on climate change, Ontario must continue to play a leadership role and encourage the rest of Canada to pursue a reliable, affordable, diverse supply mix that supports both existing needs and growth.

The Green Ribbon Panel hopes that this report can provide a roadmap for Ontario to remain a climate leader in Canada, and continue to improve its energy system for the health and prosperity of the province.

Exhibit 1: Canadians opinions on climate change
(*% of Canadians surveyed*)

Sources: Ipsos

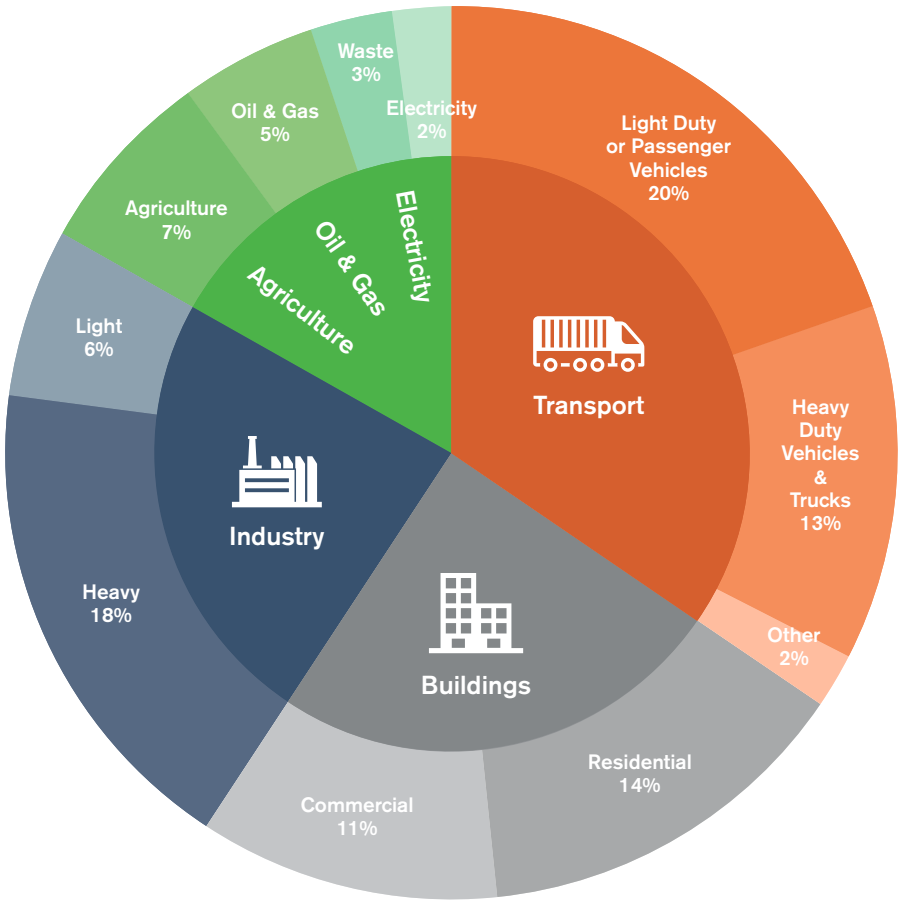
1 WHO, 2018.

WHERE DO ONTARIO'S GHG EMISSIONS COME FROM?

Emissions are produced from all sectors of our province, with the single largest source being transportation at 35 per cent of Ontario's GHG emissions and the primary source of other air contaminants affecting our health. A combination of direct and indirect electrification technologies can reduce GHG emissions across the economy.

Thanks largely to our nuclear generating stations, Ontario's electricity system accounts for merely two per cent of our GHG emissions. The transportation sector is primed for direct electrification due to the growing market share of electric vehicles, and indirect electrification through emerging hydrogen vehicle technologies.[2] Buildings and industry, the second and third-largest sources of emissions are also candidates for both direct electrification such as with heat pumps, and indirect electrification through hydrogen.

Exhibit 2: Ontario's GHG emissions breakdown – 2018
(% of GHG emissions by sector, 165 Mt total)



Source: Government of Canada, 2019b

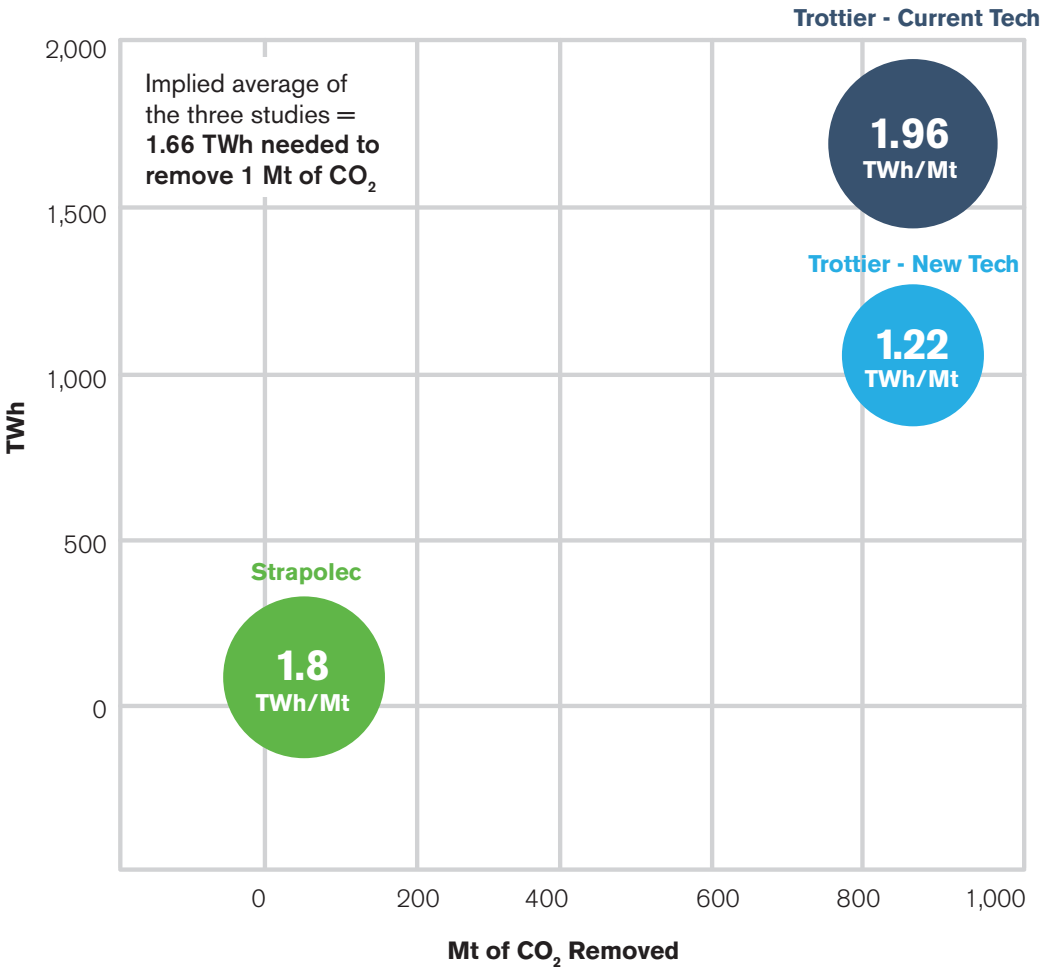
2 Plug'N Drive, 2020.

THE PATH TO REDUCED GHG EMISSIONS AND IMPROVED AIR QUALITY IN ONTARIO

As the clear path to lower emissions, electrification creates greater demand for clean electricity: potentially almost triple what Ontario has today.

Several studies have shown that deploying all emission reduction strategies available coupled with adequate direct and indirect electrification of the economy can achieve the needed emission reductions.[3] The electrification translates to about 1.66 TWh of electricity being required for every megatonne (Mt) of GHG emissions reduced, as seen in Exhibit 3. To fully electrify Ontario's economy could require 280 TWh more electricity than today, almost tripling the demand on Ontario's grid.

Exhibit 3: Electrification demand implied by GHG-emission reduction
(*TWh of new electricity consumption needed to remove 1Mt of CO2*)



Sources: Strapolec, 2016a; Trottier Energy Futures Project, 2016; Strapolec analysis. Note that Trottier - New Tech includes the use of biomass with carbon capture and storage, while Strapolec and Trottier - Current Tech do not employ any carbon capture technologies.

[3] *IESO, 2016 Outlook F; Environmental Commissioner of Ontario, 2016; Trottier Energy Futures Project, 2016; Strapolec, 2016.*

THE WORLD'S LARGEST GHG-REDUCTION INITIATIVE USED NUCLEAR GENERATION TO CLEAN ONTARIO'S AIR.

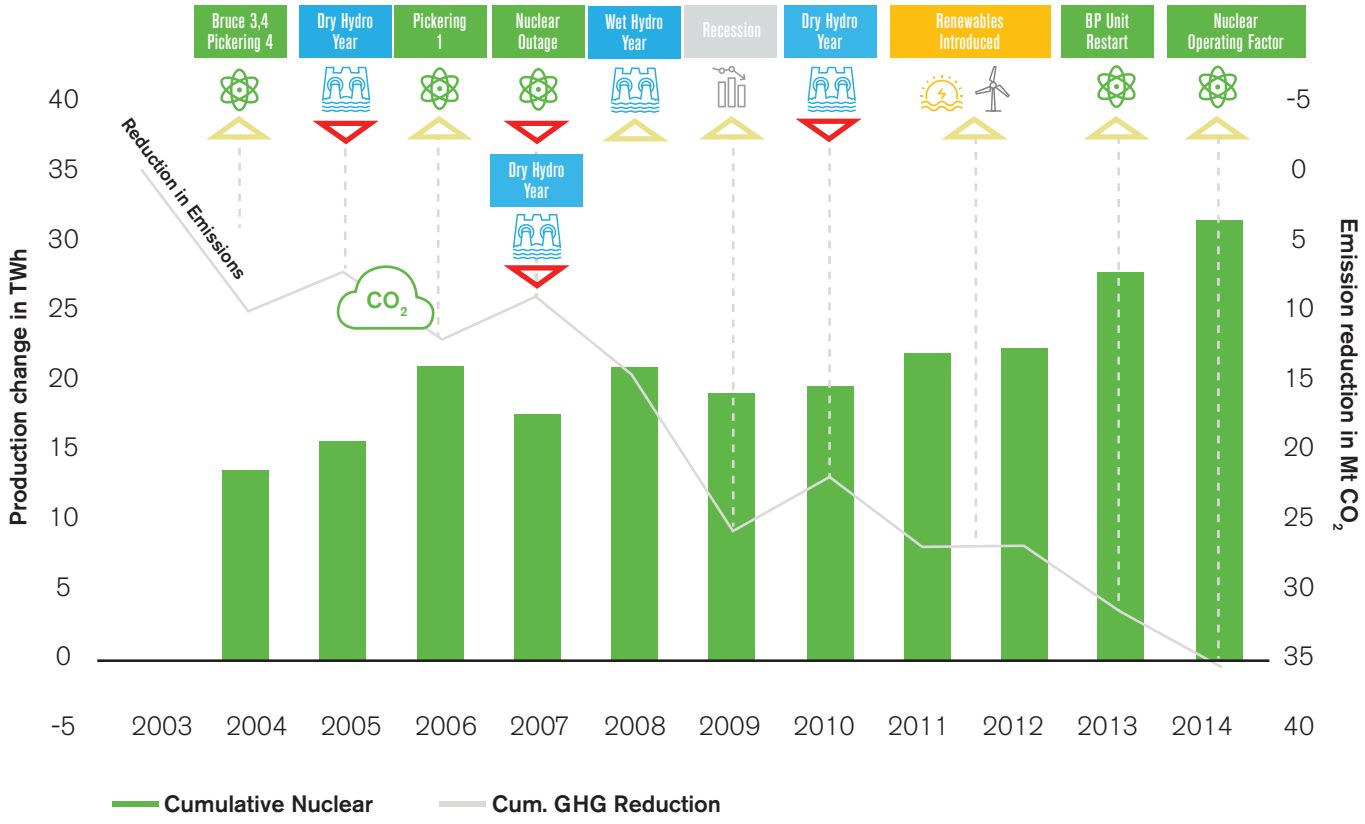
Nuclear was responsible for 89 per cent of the GHG-emissions reduction achieved by displacing coal in Ontario, and has successfully reduced the number of smog days in the province from 53 in 2005 to zero in 2015.

WE HAVE DONE THIS BEFORE

Ontario's coal phase-out program that cleaned our air stands out as one of the largest and most successful GHG and pollution reduction policies worldwide.

To achieve this transformation, 35 TWh of low GHG-emission generation were added to Ontario's supply mix, with nuclear generation accounting for 32 TWh or 89 per cent of that supply. Between 2003 and 2008, coal was gradually replaced by clean nuclear generation. After the recession impacts realized in 2009, despite the introduction of renewables in 2011 and 2012, further emissions reductions were not realized until Bruce Power Units 1 and 2 were restarted and came fully online in 2013. All told, Ontario's GHG emissions decreased by 35 Mt and air quality greatly improved, with the number of smog days declining from 53 in 2005 to zero in 2015.

Exhibit 4: Changes in electricity supply and GHG emissions
(*Production change in TWh vs. emission reduction in CO2 in Mt; Indexed to 2003*)



Source: IESO data; Strapolec, 2015; Strapolec analysis.
Note: After coal was fully retired, Ontario power sector GHG emissions only reduced by 0.5 Mt from 2014 to 2016 as renewables were rolled out.

EMISSION-REDUCTION POLICIES HAVE IMPLICATIONS ON ELECTRICITY DEMAND.

37 TWh is needed to achieve the 22 Mt GHG-emissions reduction targeted in Ontario's climate plan for 2030 — 25 per cent more electricity than we use today.

WE HAVE TO DO IT AGAIN

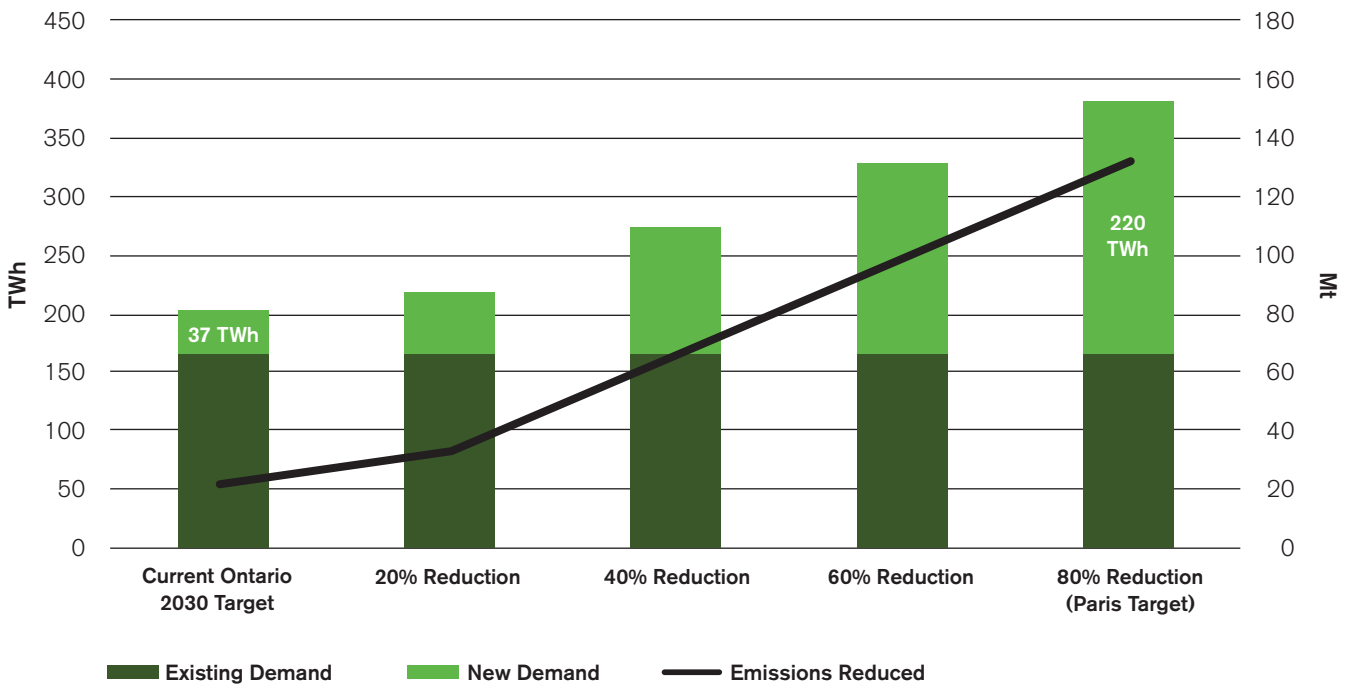
Ontario must use clean electricity to reduce its emissions again.

Ontario's climate objective is to reduce its emissions by 30 per cent below 2005 levels. With current emissions projections and actuals, this means a reduction of 22 Mt by 2030.[4]

Based on the aforementioned need for 1.66 TWh of electricity to achieve 1 Mt of GHG-emission reductions through electrification, Ontario would need 37 TWh of new generation to achieve the 22 Mt GHG emissions reduction implied by its climate plan. This is 25 per cent more electricity than Ontario uses today, equivalent to almost 90 per cent of the Bruce Power eight nuclear reactor site output and powering 4.1 million households per annum.

In the long run, to achieve the Paris agreement target of 80 per cent below 1990 levels, nearly 220 TWh of additional electricity generation would be needed, as seen in Exhibit 5.

Exhibit 5: Electricity required by GHG emissions reduction objective
(*TWh, Mt*)



Source: IESO, 2020; Government of Ontario, 2018; Strapolec Analysis

[4] *Government of Ontario, 2018; IESO, 2020.*

ONTARIO'S GHG EMISSION REDUCTION ACHIEVEMENTS ARE AT RISK

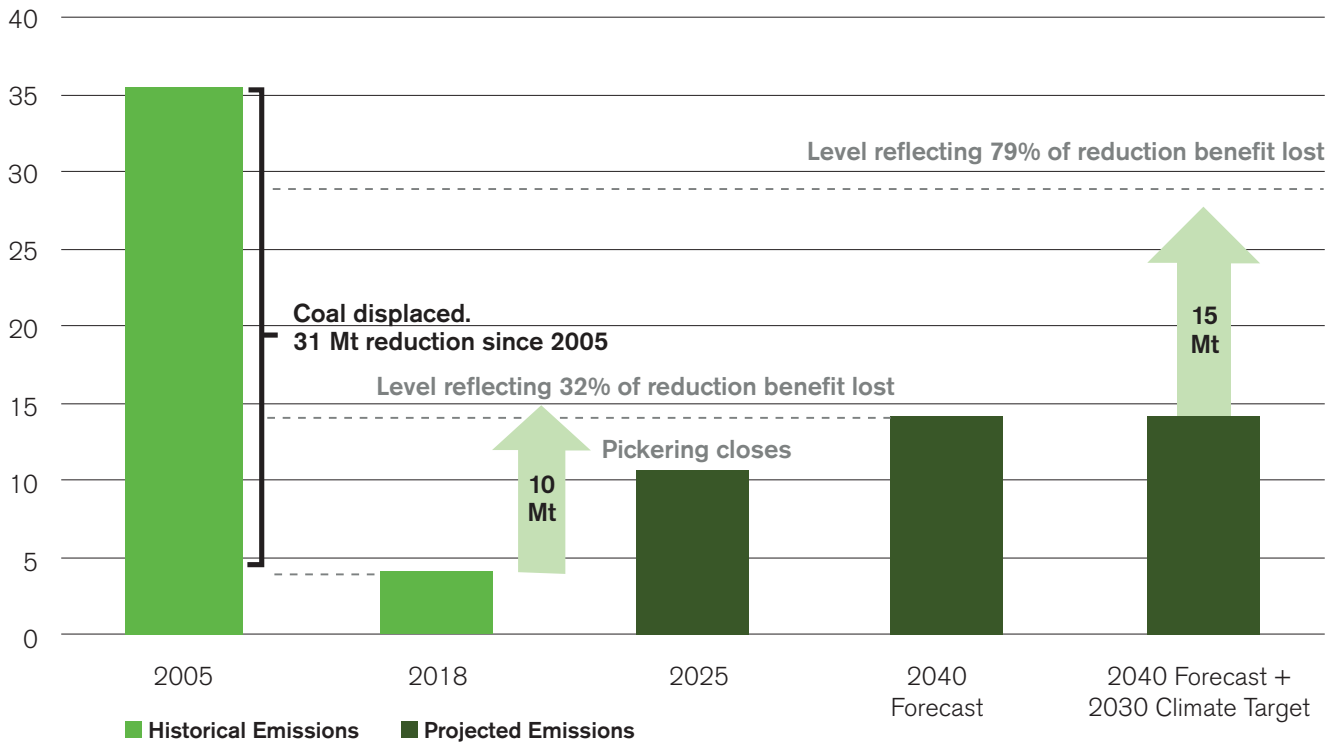
To realize the benefits of electrification, Ontario will need zero-emission electricity resources, however none are yet planned.

Ontario reduced its GHG emissions by displacing coal with nuclear generation. However, our electricity system will rely upon natural gas after the Pickering Nuclear Generating Station closes. With that reliance on natural gas, two outcomes arise: the oft-cited tool for emission reduction, surplus baseload generation (SBG), will evaporate; and the projected demand forecast for Ontario shows electricity sector emissions are to rise by 10 Mt, cancelling-out 32 per cent of our emission reduction progress achieved from the coal plant closures, as shown in Exhibit 6.[5]

Without a policy change, the 37 TWh of new electricity demand from electrification may be met by natural gas, causing GHG emissions to increase by a further 15 Mt. This would not only defeat the targeted 22 Mt of reduction by 2030 but also eliminate 79 per cent of Ontario's hard-earned gains from displacing coal.[6]

This underscores the importance of the current nuclear refurbishment projects, which will sustain a crucial component of Ontario's clean electricity supply. Despite this we require a different solution to meet the challenge of climate change. Fortunately, further Made-in-Ontario solutions exist to meet this need.

Exhibit 6: Ontario GHG emissions – Historical and current plans
($Mt\ CO_2$)



Source: IESO, 2020.

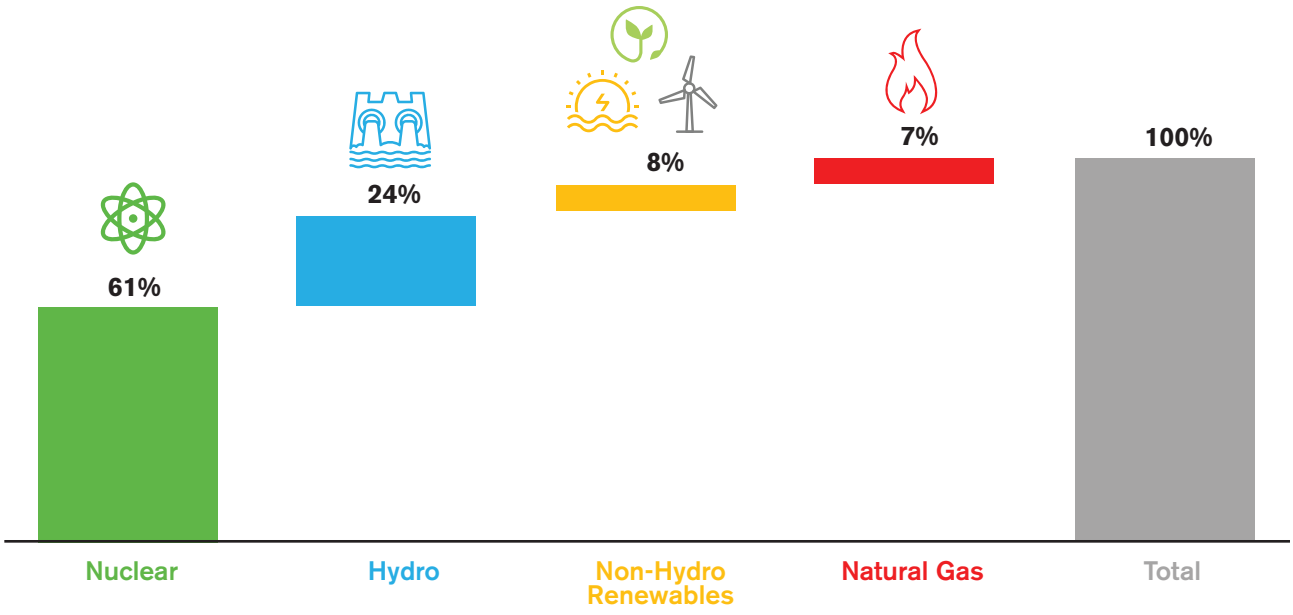
[5] *IESO, 2020, Data Tables*

ONTARIO IS WELL POSITIONED TO BUILD ON ITS CLEAN ELECTRICITY SYSTEM

With a wide variety of clean energy options at its disposal, Ontario is in a strong position to meet the coming challenges.

Our resources include zero-emitting nuclear and hydro facilities that provide us with flexible baseload supplies that meet our needs through all four seasons. We have non-hydro-renewables in the form of solar, wind, and biomass that help thin out the use of natural gas to help reduce emissions. Biomass is a low-emission alternative for performing similar functions to natural gas, such as providing peaking supply. Combined, 93% of Ontario's electricity system is emission free. With our unique low GHG-emitting energy mix as a base to build from, a suite of technologies offer promise to provide clean solutions to Ontario's energy needs.

Exhibit 7: Ontario's electricity supply mix 2018
(% of grid supply; Total = 146TWh)



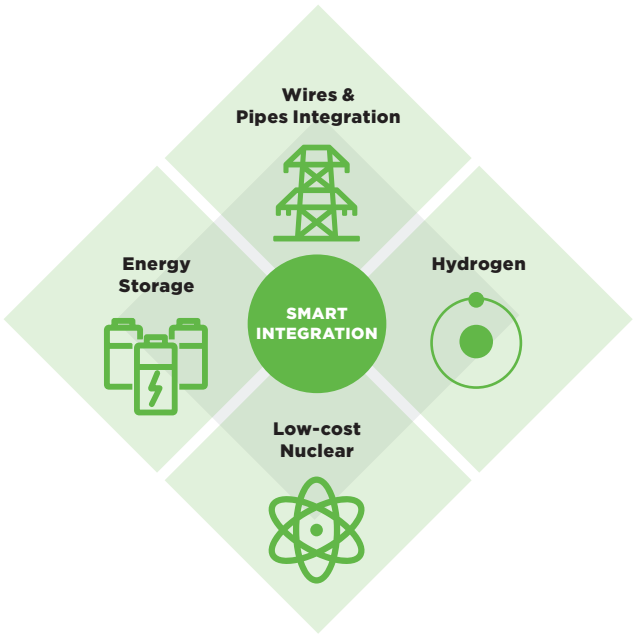
Source: IESO, 2019a.

WE HAVE A MADE-IN-ONTARIO INTEGRATED SOLUTION

An integrated solution using Made-in-Ontario technologies can provide Ontario with the clean electricity needed for electrification, while also delivering savings on our electricity bills.

The key to low-cost electrification is to bring together different technologies with complementary features. Ontario has a suite of technologies that can be smartly integrated, all enabled by its low-cost nuclear generation as shown in Exhibit 8.

Exhibit 8: Integration enabled by four paradigm shifts



THE ROLE OF NUCLEAR

As a reliable, flexible, and low-cost source of low carbon electricity, nuclear can form the backbone of an integrated electrification solution. In Ontario, a $26-billion infrastructure project will extend the operating lives of both Darlington Nuclear Reactor and Bruce Power generating station to 2055 and 2064, respectively, resulting in decades of low-cost electricity while simultaneously creating tens of thousands of direct and indirect jobs.

Not only will these refurbishments provide an economic boost to Ontario and Canada as a whole but, as stated in 2017 by Ontario's Financial Accountability Officer, "there are currently no alternative generation portfolios that could provide the same supply of low GHG emissions baseload electricity generation at a comparable price to the Base Case Nuclear Refurbishment Plan".[7]

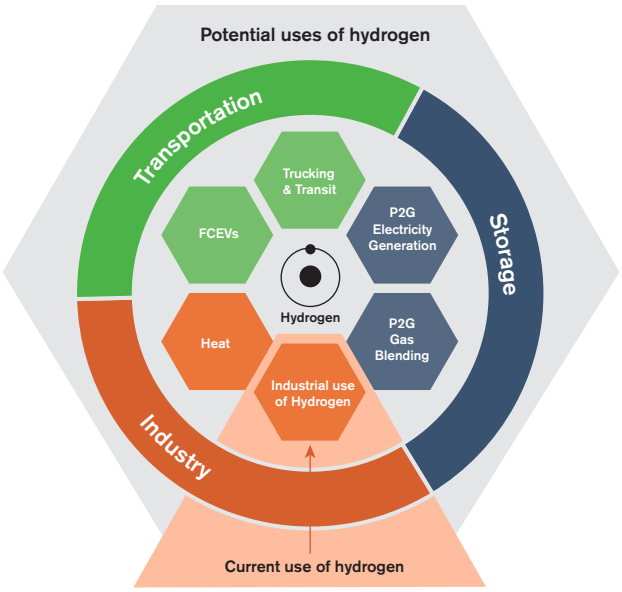
HYDROGEN

Hydrogen is a clean fuel that can be produced using electricity, allowing it to be used as an indirect electrification approach to reducing emissions in just about all sectors, as shown in Exhibit 9. Due to its many advantages and applications, some estimates suggest hydrogen could be used to eliminate up to 25 per cent of GHG emissions in Ontario.[8]

Hydrogen performs best when matched with a reliable baseload supply for electrolysis, such as nuclear power. Electrolysis is the process of using electricity to split water into hydrogen and oxygen. This reaction takes place in a machine called an electrolyser, and requires large amounts of electricity. This production can also be throttled, allowing it to be used as a flexible load.

Many Ontario companies have pioneered hydrogen production and fuel cell technology, meaning it is a solution that supports both our climate change objectives and the local economy.

Exhibit 9: Current and potential uses of hydrogen



[7] *Financial Accountability Office, 2017.*
[8] *Strapolec analysis*

STORAGE

Storage is a critical part of the supply mix in an integrated electrification solution. It can be used to shift generation from times when it is created to times when it is needed, presenting a "flattened demand" to the grid. This reduces the need for variable generation capabilities currently provided by gas-fired generation, as seen in Exhibit 10.

Right now, storage holds great potential for cost savings and as a Made-in-Ontario solution to combat climate change. Some examples being piloted in Ontario include:

Lithium-ion Batteries

Uses technologies being advanced in the EV industry and adapted to electricity system purposes, as well as second-life EV batteries.

Pumped Hydro Storage

Uses electricity to pump water up to a reservoir for release through a turbine when needed.

Compressed Air Energy Storage (CAES)

Compresses air for storage in a pressurized vessel for release through a turbine when needed.

Power to Gas (P2G)

Uses electricity to produce hydrogen through electrolysis, which can then be stored for future use in many applications including ancillary services and electricity generation using fuel cells.

INTEGRATING THE 'WIRES AND PIPES'

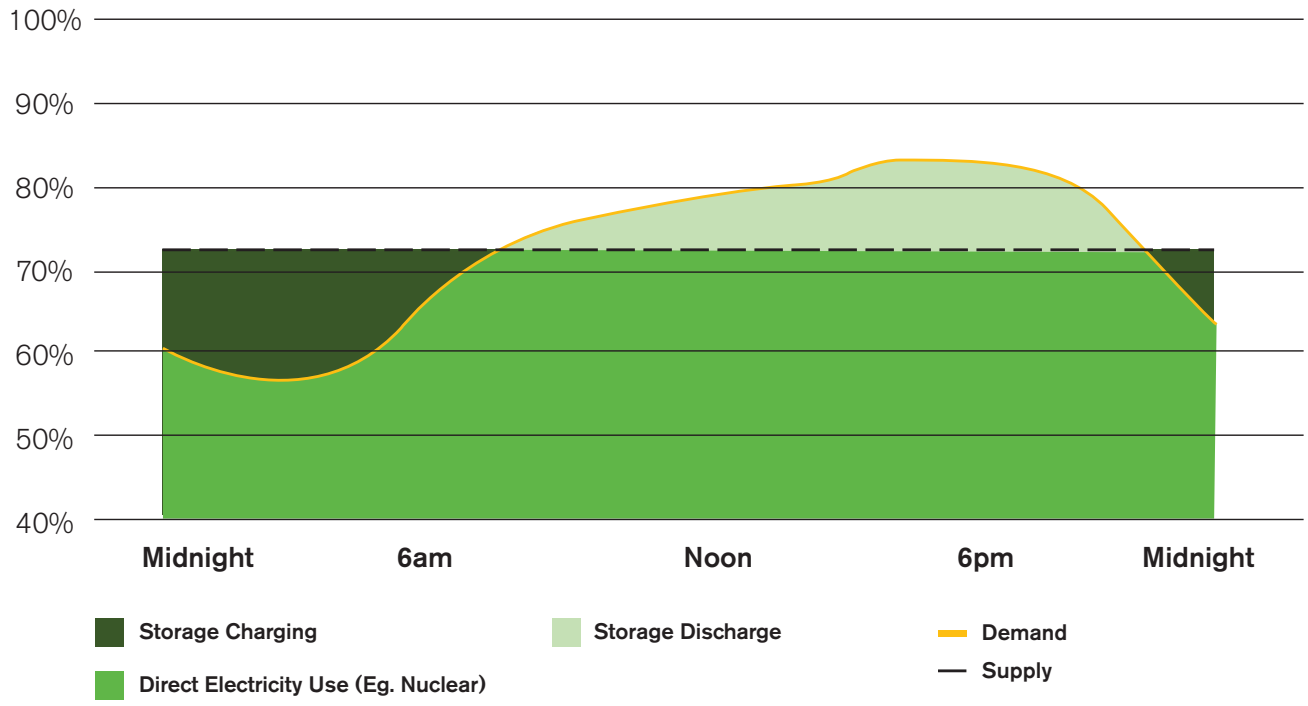
Integration of 'wires and pipes' means integrating the electricity and natural gas systems to make efficient use of natural gas infrastructure during the transition to electrification.

For example, hybrid natural gas and electric heating solutions for buildings can be used as a new form of winter peaking capacity for the electricity system, where furnaces use electricity by default, but can switch to natural gas during peaks, saving the electricity system the need to build peak generation.

Ontario can also take advantage of its natural gas storage caverns by mixing in hydrogen, creating a less carbon-intensive fuel blend. This hydrogen-infused natural gas can then be transferred around the province or exported to the U.S. using existing infrastructure.

By integrating wires and pipes, Ontario can use its existing natural gas infrastructure to facilitate electrification and reduce emissions.

Exhibit 10: Storage helps to flatten the daily demand variation
(*Per cent of maximum demand*)



Source: Strapolec, 2019b.

THE COST OF A SMARTLY INTEGRATED SOLUTION COULD BE 28% LESS THAN ONTARIO'S CURRENT ELECTRICITY SYSTEM.

THE SMARTLY INTEGRATED SOLUTION COULD MEET THE ADDITIONAL DEMAND FROM ELECTRIFICATION AT HALF THE COST OF A RENEWABLES-BASED ALTERNATIVE

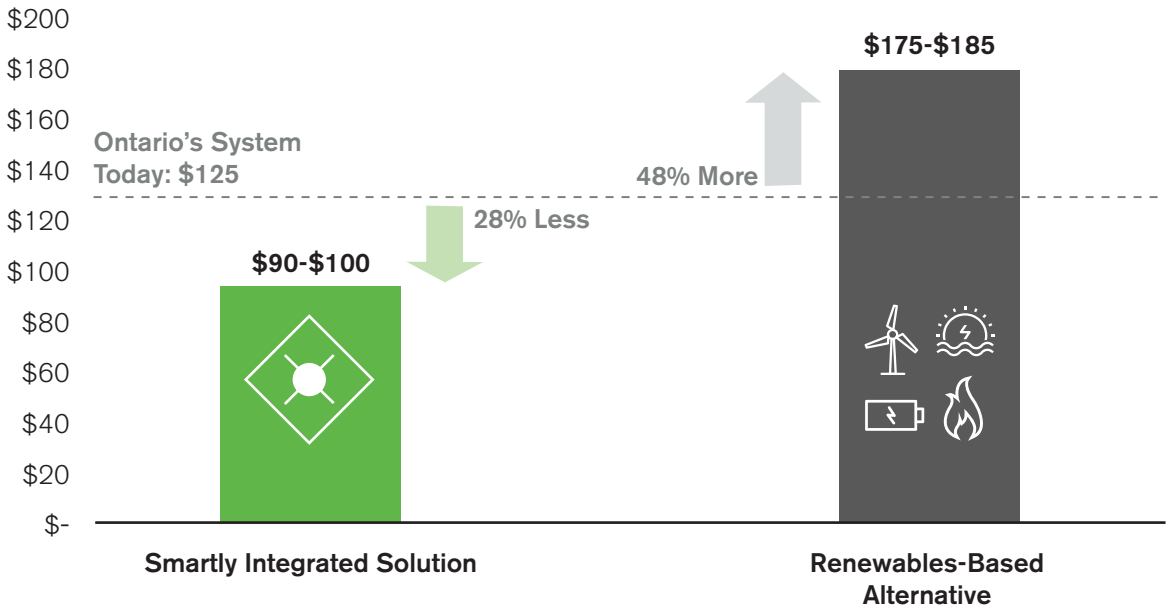
Ontario will need to make informed choices about how to meet the electricity demand implied by its emissions reduction targets.

HYDRO/NUCLEAR COST: $66/MWH
REST OF GENERATION COST: $223/MWH

Presently, Ontario's electricity system is a combination of nuclear, hydroelectric, biomass, renewables and gas-fired generation. While nuclear and hydro are low cost, the other forms of generation cost 3.4 times more and drive Ontario's system costs. As the demand for electrification increases, Ontario has two choices. On one hand, we could choose to rely on a predominantly renewables-based alternative with natural gas back-up which, given the high cost of the intermittency of renewables, will be 48 per cent more costly than Ontario's current electricity system.[9, 10]

Or, on the other hand, we could pursue a smartly integrated solution that could, thanks to the extensive use of nuclear generation, be up to 28 per cent less costly than Ontario's system today and half the costs of the renewables-based alternative. This solution would smooth out demand for electricity, increase the efficient use of all assets, including storage, enhance system flexibility, and ultimately result in less generation, distribution and transmission costs.

Exhibit 11: Electricity Energy Costs in Ontario: Smart Solution & Renewables-based Alternative
($/MWh)



Source: Strapolec, 2016b; IESO, 2019c. Note: Both options assume the existing nuclear and hydro baseload are available.

[9] *Strapolec, 2016b.*

[10] *Renewables based alternative derived from IESO, 2016.*

INVESTMENTS IN A SMARTLY INTEGRATED NUCLEAR SOLUTION WILL PROVIDE ONTARIO WITH A RELIABLE SOURCE OF LOW-COST ELECTRICITY AND JOBS FOR DECADES.

SUMMARY

Ontario has done much to reduce its electricity sector's GHG emissions, but much more must be done. These efforts will take place in the context of population growth, economic recovery post-COVID-19, and a changing climate, which present new challenges and opportunities.

This section has demonstrated that the key to low-cost electrification is to bring together different technologies with complementary features. Thanks to extensive use of nuclear generation, the electrification of the economy through an integrated solution of hydrogen, storage, and the wires-and-pipes distribution infrastructure could build the energy system of tomorrow at half the cost of a renewables-based alternative. Together, these solutions would smooth out demand for electricity, increase the efficient use of assets, provide savings in terms of enhanced system flexibility, and ultimately result in less generation, distribution, and transmission costs.

As a reliable, flexible, and low-cost source of low-carbon electricity, nuclear forms the backbone of this integrated solution. Investments in nuclear and the other home-grown Made-in-Ontario technologies will provide Ontario with a reliable source of low-cost electricity and jobs for decades, keeping our energy dollars in the province and bringing us long-term benefits.

Reducing Ontario's GHG emissions and other pollutants from the atmosphere will have additional benefits to human health. In the past decade, Ontario successfully reduced the number of smog days in the province from 53 in 2005 to zero in 2015 by displacing coal. The integrated solution will build on this success story by reducing Ontario's emissions and improving our air quality.

SECTION 3

INVESTING IN MADE-IN-ONTARIO SOLUTIONS

Policy enabled competitive advantages tuned *for growth*

GROWING ECONOMY.
SUSTAINABLE ENVIRONMENT.
REAL SOLUTIONS.

A MADE–IN-ONTARIO, LOW-EMISSION ELECTRICITY SOLUTION COUPLED WITH EFFECTIVE POLICIES CAN CREATE AND SUSTAIN 150,000 JOBS WHILE ACHIEVING CLIMATE GOALS.

Leveraging Ontario's economic integration within the Great Lakes region *can maximize the benefits of Ontario's leadership.*

OVERVIEW

Investments in policy-enabled, Made-in-Ontario energy, manufacturing and infrastructure solutions for the emerging low GHG emission economy can deliver direct economic benefits while combatting climate change and cleaning our air.

In Section 2, we established that an integrated suite of technologies underpinned by nuclear and hydrogen would produce low cost, low emission electricity and deliver the needed clean air and GHG emission reductions for Ontario and Canada. This section demonstrates how the choices we make in Ontario will have a positive impact across the country, by examining the economic growth and regional benefits that can be enabled by well-developed policy decisions.

KEY FINDINGS AND THEMES:

- Smartly integrating nuclear, hydrogen, storage, and wires-and-pipes solutions would directly deliver economic benefits to Ontario and Canada.
  - Investment in domestic nuclear, hydrogen, and biomass energy solutions could alone create 50,000 jobs.
- Low cost, low emission electricity provided by nuclear power and Ontario's suite of low emissions technologies not only enables strategic domestic manufacturing and infrastructure solutions, but is also a competitive advantage that can be used to attract further investment.
  - A low-cost advantage could improve competitiveness of Ontario's manufacturing sector, spur growth in Ontario's vehicle manufacturing industry, and enable a transformation of the transportation sector.
- Investments in Made-in-Ontario technologies for the new economy would nurture an innovation ecosystem in Ontario.
  - Investments in strategic industries such as nuclear, hydrogen and zero-emissions vehicles (ZEV) would develop a skilled workforce, facilitate new products and enable growth, catalyzing a lasting competitive advantage.
  - Over 100,000 jobs could be sustained in Ontario's vehicle manufacturing industry.
- Focusing on domestic energy solutions and strategic industries would generate widespread benefits across all regions of Ontario.
  - Ontarians would benefit from improved public health, energy security, innovation, and job creation.
- Ontario is highly integrated within the Great Lakes region, the 3rd largest economy in the world.
  - Ontario's key GHG emission reduction strategies are relevant to the neighboring Great Lakes states.
  - Through an integrated approach within the Great Lakes region, Ontario can maximize the benefits of its leadership.
- Successful policy action requires collaboration between business and government.
  - Climate policy development is complex and requires collaboration.
  - Benefits are dependent on proactive policy and engagement at all levels of government and across the private sector.
- Ontario has a sound foundation within Canada to innovate on proactive, impactful climate policies.
  - Supportive policies take several forms, and together can enable a cohesive response.
- Impactful climate policies integrate proven policy design principles.
  - Available design principles encompassing economic signals, R&D support, and performance standards can enable strategic industries.

SMARTLY INTEGRATED NUCLEAR, HYDROGEN, STORAGE, AND WIRES-AND-PIPES ENERGY SOLUTIONS WOULD DIRECTLY DELIVER ECONOMIC BENEFITS TO ONTARIO AND CANADA.

Homegrown innovations could enable almost *50,000 jobs and world-leading* solutions for the new economy.

INVESTMENT IN DOMESTIC ENERGY SOLUTIONS WOULD BRING JOBS AND GROWTH

The Made-in-Ontario hydrogen, biomass and nuclear sectors could bring almost 50,000 jobs and economic growth to Ontario.

A smartly integrated nuclear, hydrogen, storage, and wires-and-pipes energy solution is not only a source of low-cost and low-GHG emission electricity, but would also deliver economic benefits in the form of high-quality jobs, strategic investments, improved trade balance, enhanced innovation, and public health.

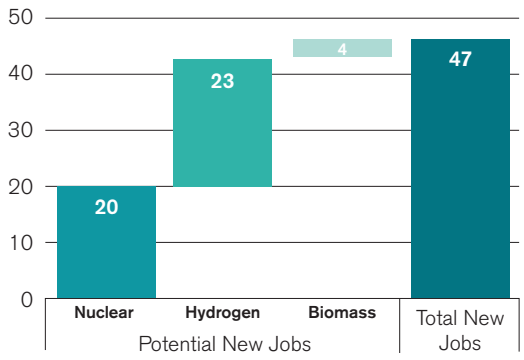
Nuclear

Canada's nuclear sector is a major source of employment in Canada, providing over 30,000 jobs across the country. [1] In Ontario, the life extension of Bruce Power and Darlington is estimated to bring another 14,000 jobs annually. [2] The nuclear sector also has large indirect job benefits and supports other industries: over 250 companies in Canada are part of the nuclear supply chain, and overlap with other key Canadian manufacturing sectors. Smart integration would require additional nuclear capacity, potentially bringing further benefits including up to 20,000 more annual direct jobs. Canada has potential in advanced nuclear technologies such as Small Modular Reactors (SMRs) and fusion, which if successfully developed, could spur further economic growth.

Biomass

Biomass is a carbon-neutral energy source available in Northern Ontario from its forestry sector and its by-products, and can be used to produce electricity. There is sufficient biomass potential in Ontario to supply 3.4 TWh of electricity annually, the development of which could provide over 3,500 high-quality, full-time jobs in Northern communities. [3]

Exhibit 1: Jobs Created by Integrated Energy Solution (*Thousands of Jobs*)



Source: Strapolec, 2019; Durham Workforce Authority, 2013; Bruce Power, 2020b; Hydrogenics, 2018a; Hydrogenics, 2018b; Pembina Institute, 2011.

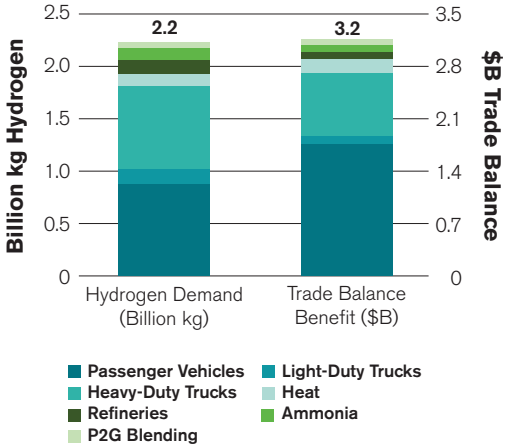
[1] *NRCan, 2016*
[2] *Bruce Power, 2020a; CBoC, 2015*
[3] *Pembina Institute, 2011*
[4] *NRCan, 2020*
[5] *Strapolec analysis*

Hydrogen

With over 100 Canadian companies in the hydrogen and fuel cell sector, Canada is already among the world's top-ten hydrogen technology providers. [4] Ontario can build on this expertise, and develop a hydrogen economy that can reduce GHG emissions by serving many applications. Addressing climate goals could require as much as 2.2 billion kgs of hydrogen annually. Meeting this demand could boost the domestic electrolyser manufacturing industry and provide as many as 23,000 high-quality jobs in Ontario annually, while generating $2.5 billion of spend per year. Ontario-produced hydrogen could also displace fossil fuel imports from the U.S., potentially improving Ontario's trade balance by $3.2 billion per year. Ontario could become a leading global exporter of this technology. [5]

Hydrogen presents an opportunity for national unity, with provinces across the country and the federal government currently working on a National Hydrogen Strategy. Combined with the hydrogen expertise that exists across the country, these efforts could develop a clean energy sector that is truly pan-Canadian.

Exhibit 2: Jobs Created by Integrated Energy Solution (*Thousands of Jobs*)



Source: Strapolec Analysis. Note: Electricity demand is 47.7 TWh per billion kg of hydrogen produced. 6.84 GW of electrolyzers are required to produce 1 billion kg of hydrogen.

LOW-COST, LOW-EMISSION ELECTRICITY ENABLES STRATEGIC DOMESTIC MANUFACTURING AND INFRASTRUCTURE SOLUTIONS.

Low-cost electricity and a hydrogen economy *benefit not only manufacturing, but all of Ontario*'s goods-producing sectors.

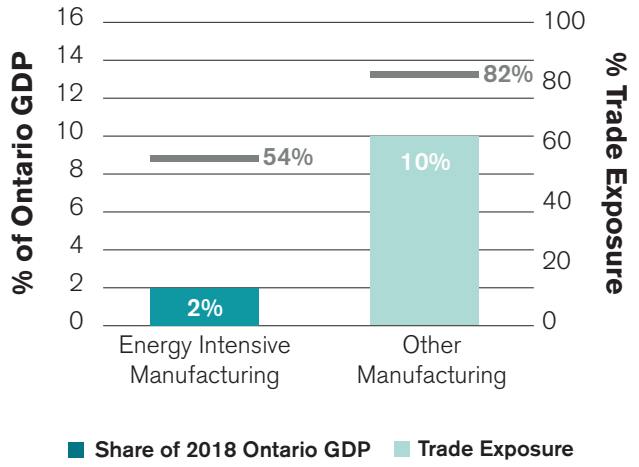
MANUFACTURING COMPETITIVENESS HINGES ON A LOW-COST ADVANTAGE

The Made-in-Ontario, home-grown energy solution could benefit Ontario's manufacturing sector, spur growth in Ontario's vehicle manufacturing industry, and enable a transformation of the transportation sector.

Most manufacturing in Ontario is trade exposed, and manufacturers are currently challenged because of high electricity prices. Traditionally-recognized large energy-intensive manufacturing and industrials represent 2% of Ontario's GDP, and are 54% trade-exposed. [6] Trade exposure for other types of manufacturing is even higher, at over 80%. [7]

Because of this high degree of trade exposure, electricity costs impact Ontario's trade. As shown in Exhibit 4, the price of power paid by manufacturers in Ontario is higher relative to our neighbouring jurisdictions in the Great Lakes region. Cost growth in Ontario has exceeded the recent benefit of exchange rates. Ontario has a manufacturing trade surplus with U.S. states where higher electricity rates are higher, and a trade deficit with states where electricity rates are lower. Lowering electricity costs can help Ontario's manufacturers gain advantage.

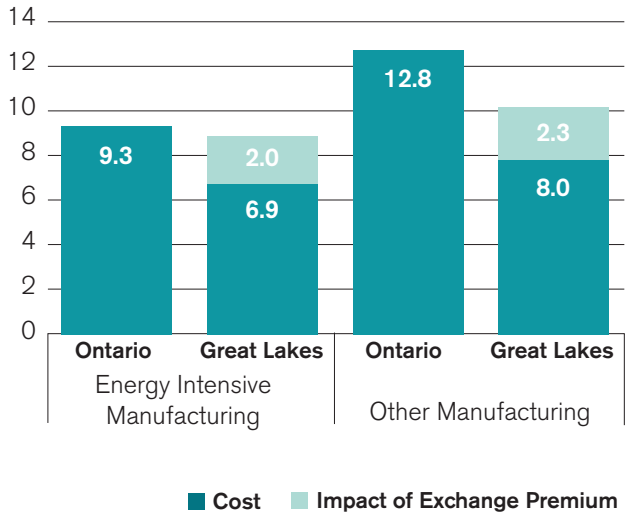
Exhibit 3: Ontario GDP and Trade Exposure
(% of total Ontario GDP, % Trade Exposure)



Sources: Statistics Canada 2020; Ecofiscal Commission, 2016; Strapolec analysis

Ontario's smartly integrated, home-grown energy solution would create a low-cost electricity advantage that could improve the competitiveness of its manufacturing sector. [8] Capitalizing on this could reduce electricity rates for energy-intensive manufacturing by 16% and rates for all other manufacturing by 18%, making both competitive with Ontario's trading partners in the wider Great Lakes region. [9]

Exhibit 4: Manufacturing Electricity Rate Comparison 2018
(CA ¢/kWh)



Sources: Ontario Industrial: OER Q4 2018; EIA, n.d.; Hydro Quebec 2018; Strapolec analysis

[6] *Strapolec Analysis based on: Statistics Canada, 2020 and Canada's Ecofiscal Commission, 2016*
[7] *CME, 2017*
[8] *Green Ribbon Panel, Clean Air Climate Change and Practical, Innovative Solutions, 2020*
[9] *Strapolec Analysis*

OVER 100,000 JOBS COULD BE SUSTAINED IN ONTARIO'S VEHICLE MANUFACTURING SECTOR

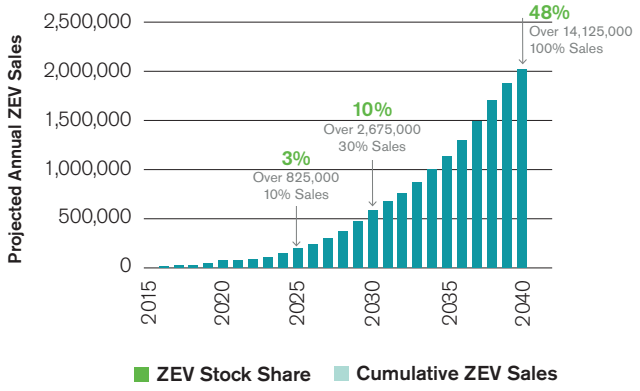
Zero-emissions vehicle adoption is projected to accelerate in the coming decades, putting Ontario's vehicle manufacturing sector at risk.

The vehicle manufacturing sector is a key element of Ontario's economy. Canada is the world's 12th largest car manufacturer and the 5th largest car exporter by value. [10] Much of this is centered in Ontario: in 2017, the province was North America's top vehicle manufacturing region. [11] The sector is also a major source of jobs. It employs 106 thousand people directly, and generates hundreds of thousands of indirect jobs across the economy. [12] Despite these strengths, Ontario's vehicle manufacturing industry is moving slowly to embrace zero-emissions vehicle (ZEV) manufacturing. Electric vehicle (EV) production makes up just 0.4% of the total vehicles produced in Canada, 80% less than other vehicle-producing nations.

Additionally, declining demand for traditional internal combustion engine (ICE) vehicles threatens the sector. Transport Canada has set ambitious new ZEV sales targets, which would translate into 100% of new vehicle sales being ZEVs by 2040. Ontario must help lead this transition.

During discussions with its main union in Canada, Unifor, Ford Motor Co. announced a $2 billion investment to mass-produce EVs and their batteries in Canada, which is a positive first step in the right direction. This momentum would benefit from other leading vehicle manufacturers such as Toyota and Honda following suit.

Exhibit 5: Projected Adoption Rate of ZEVs in Canada
Projected Annual ZEV Sales; 2015-2040)



Source: Transport Canada, 2020

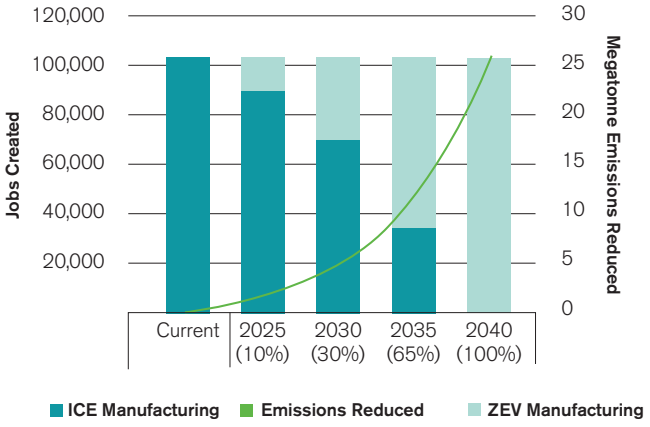
[10] *World's Top Exports, 2020*
[11] *Government of Ontario, 2019*
[12] *Government of Ontario, 2020a*

Consideration could also be given to getting drivers behind the wheels of ZEVs, and ensuring that the necessary infrastructure exists to make these vehicles a viable alternative. ZEVs and ZEV-friendly policies benefit the environment and greatly improve public health.

ZEV manufacturing and ZEV adoption could benefit from Ontario supporting and developing the infrastructure necessary to make these vehicles commercially competitive. Doing so would rejuvenate the vehicle manufacturing sector, while failure to adapt could result in the complete loss of the sector by 2040. With its low-cost, low-GHG emission electricity grid, strong local demand, and skilled workforce, Ontario is well placed to make the shift to ZEV manufacturing and protect this vital part of its economy.

INVESTMENT IN DOMESTIC ENERGY AND VEHICLE MANUFACTURING IS AN OPPORTUNITY TO BE A VENDOR NOT A BUYER IN THE NEW ECONOMY

Exhibit 6: Manufacturing Jobs Implications of ZEV Adoption in Canada
(*Jobs created; Megatonnes GHG emissions reduced*)



Source: Strapolec Analysis

Notes: Assumes Federal EV sales targets from Transport Canada, 2020. Assuming equivalent jobs/car for ZEV manufacturing as ICE manufacturing, and that converting to manufacturing ZEVs stops ICE job erosion. Includes trucks.

SHIFTING HEAVY DUTY VEHICLES AND TRUCKS TO HYDROGEN COULD REDUCE GHG EMISSIONS AND CLEAN OUR AIR

Efficient trucking can reduce GHG emissions for many sectors in Ontario. By enabling a hydrogen economy, the smartly integrated solution could transform Ontario's transportation sector.

The trucking sector is a necessary catalyst for the economy, and efficient trucking is critical for many sectors. It allowed Canada to export $234 billion in goods in 2019, serving almost every sector of the export economy. [13] It is also concentrated in Ontario, which accounts for approximately half of Canada's trucking jobs.[14]

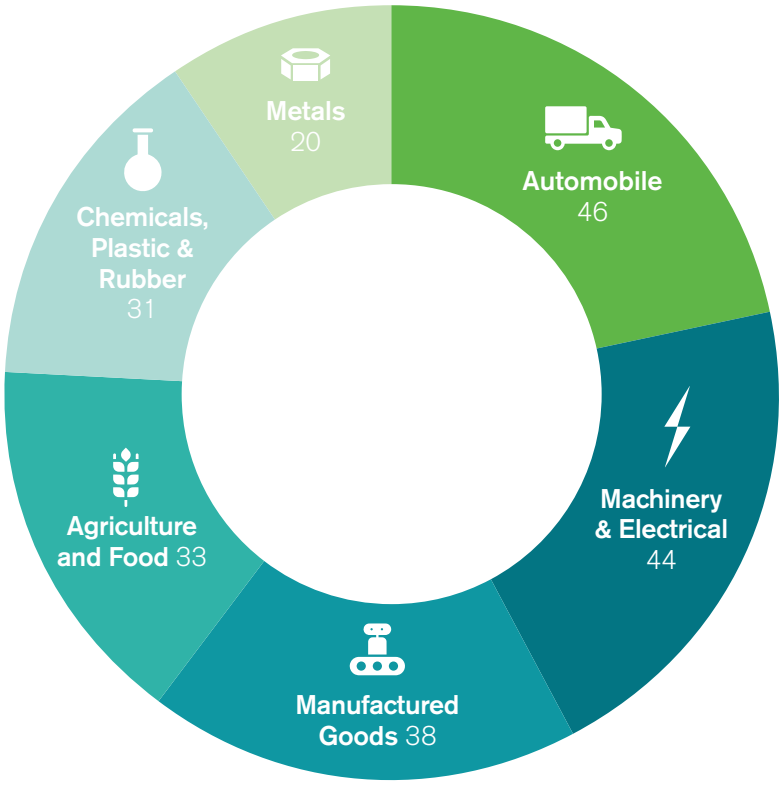
However, trucking is energy and GHG emissions intensive, and is a source of other air pollutants. Across Canada, on-road freight produced 60 Mt of GHG emissions in 2017, accounting for 34% of all GHG emissions from transportation.[15] It was also a major emitter of NOx's, which have adverse effects on air quality. [16]

Ontario can decarbonize its trucking fleet by converting to hydrogen-powered fuel cell electric vehicles (FCEVs). Trucks powered by fuel cells have lower weight penalties and better cold temperature performance compared to battery-powered equivalents. Lowering GHG emissions from trucking would reduce supply chain GHG emissions for other sectors, and conversion to FCEVs would reduce the need for imported fossil fuels.

Further, converting to FCEVs would create additional demand for Made-in-Ontario electrolysers. In a new fuel distribution model, these could be built at gas stations to generate fuel on-site. Ontario would need 5.5 GW of electrolyser capacity if it converted 80% of its heavy trucks to FCEVs, complementing the domestic hydrogen economy.

TRUCKS ARE HEAVY GHG AND NOX EMITTERS. BY MOVING TO HYDROGEN, THEY WILL EMIT ONLY WATER.

Exhibit 7: Ontario's Exports through Trucking
(*In billions of CAD*)



Source: Statistics Canada, 2019

[13] *Statistics Canada, 2019*
[14] *Government of Canada, 2019c*
[15] *NRCan, 2019c*
[16] *Statistics Canada, 2019*

INVESTMENTS IN MADE-IN-ONTARIO TECHNOLOGIES FOR THE NEW ECONOMY WOULD NURTURE AN INNOVATION ECOSYSTEM IN ONTARIO.

An *innovation ecosystem* would create a sustainable competitive advantage in strategic industries and allow *Ontario to become a global leader for years to come.*

A STRONG DOMESTIC INNOVATION ECOSYSTEM IS KEY TO SUSTAINABLE PROSPERITY IN THE NEW ECONOMY

Investments in strategic industries would develop a skilled workforce, facilitate new products and enable growth, catalyzing a lasting competitive advantage for Ontario.

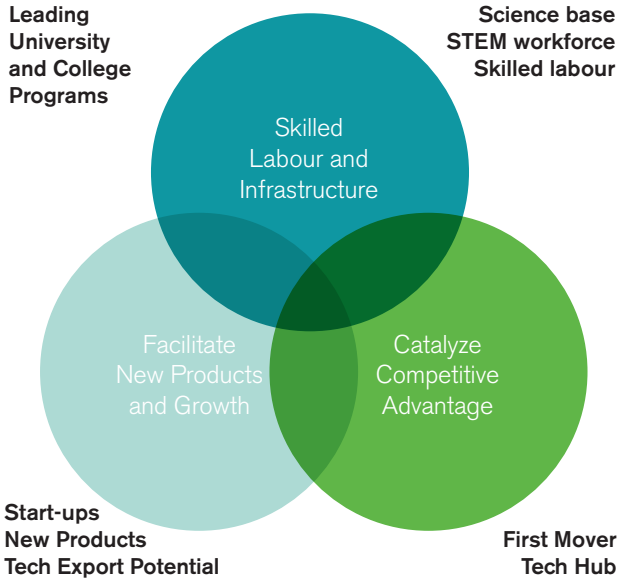
Enable skilled labour and infrastructure

Investments in nuclear, hydrogen, biomass and manufacturing capabilities would incent jobs in both STEM fields and skilled labour. University and College programs in these sectors would give rise to new fields of study, new innovations, and world-leading experts. Aspiring for leadership positions in these cutting-edge fields could create a science and research platform, encouraging the exchange of ideas, new basic research and technical R&D.

Facilitate new products and growth

An enabling environment nurtures the rise of start-ups that advance and commercialize these technologies and create innovative business models to spur growth for Ontario. With available factors of production and a supportive environment, new types of products can be built for Ontario's strategic industries. From a rich history in innovation and R&D for the CANDU nuclear industry, Ontario has a proud legacy as a technology exporter. New technologies such as hydrogen can build on these capabilities and increase value-added exports.

Exhibit 8: Smart integration & domestic investments can facilitate an ecosystem of innovation



Catalyze competitive advantage

With investment, Ontario's existing advantages in nuclear, hydrogen, and vehicle manufacturing can be turned into leadership positions in cutting edge fields like next generation reactors, SMRs, fusion, storage, electrolyzers, biomass, and ZEV manufacturing. Innovating and moving first can mean long-term competitive advantages in export markets, and can give rise to tech hubs that foster ongoing innovation, providing platforms for business networking, skilled immigration, and innovative financing. Spillover benefits can be created that would be felt by other industries.

ONTARIO CAN BE A WORLD LEADER IN THESE STRATEGIC INDUSTRIES

FOCUSING ON DOMESTIC ENERGY SOLUTIONS AND STRATEGIC INDUSTRIES WOULD GENERATE WIDESPREAD BENEFITS ACROSS ALL REGIONS OF ONTARIO.

Ontarians would *benefit from improved* public health, energy security, and job creation.

MADE-IN-ONTARIO CLIMATE SOLUTIONS BENEFIT ALL REGIONS OF ONTARIO

The health, GHG emissions, and economic benefits of investments in Made-In-Ontario solutions would be felt across the province.

Large Scale Air Quality and GHG Emissions Benefits

Air quality can have serious effects on public health. The WHO estimates that around 7 million people die every year from exposure to fine particles in polluted air that lead to diseases such as stroke, heart disease, and lung cancer. [17] Studies have also shown that reductions in average particulate matter exposure can increase life expectancy. [18]

Made-in-Ontario solutions discussed above would cut pollution from many sectors of Ontario's economy. By fuel-switching from ICE vehicles to ZEVs, less gasoline and diesel fuel would be burned by cars, trucks and buses, cleaning the air and reducing the incidence of asthma, cancer, and cardiovascular diseases.

Nuclear

A robust nuclear supply chain exists in southern Ontario, and would benefit from further investments in nuclear generation. While the jobs benefits would be localized, the effects of low-cost baseload electricity generated by nuclear in southern Ontario would benefit the entire province.

SMR Development and Usage

The benefits of SMR innovation and manufacturing would emerge in the heartland of Ontario's industrial complex, where those activities would take place. On the other hand, SMR usage would also substantially benefit northern communities that experience fuel insecurity and rely on imported diesel for electricity. SMRs have mining applications that can benefit northern communities.

Biomass

Biomass can form a forestry and mining solution for northern Ontario. It can provide a low-carbon alternative in northern communities, while providing innovations and high-quality jobs. Biomass pellets and electricity could also be exported to Manitoba, providing further growth for the industry.

ALL COMMUNITIES CAN GAIN ECONOMIC PROSPERITY, ENERGY SECURITY AND CLEANER AIR

[17] *WHO, 2018*
[18] *Pope et. al., 2009*

Hydrogen

The hydrogen economy's applications in energy-intensive industries could allow it to play a role across the province, providing cross-cutting GHG emissions reduction benefits. Innovation and export benefits would arise in southern Ontario, while northern communities would benefit from increased energy security. Hydrogen production and distribution would be needed across the province. At the federal level, the ongoing development of a Hydrogen Strategy for Canada presents another area where the decisions and actions taken by Ontario in helping to establish the hydrogen economy will have amplified effects across the country.

Exhibit 9: Distributed benefits of Made-In Ontario Solutions

		SOUTHERN ONTARIO	NORTHERN ONTARIO
PUBLIC HEALTH	CLEANER AIR	✓	✓
	REDUCES HEALTH CARE COSTS	✓	✓
INTEGRATED SOLUTION	NUCLEAR POWER INDUSTRY	✓	
	SMR DEVELOPMENT AND USAGE	✓	✓
	BIOMASS		✓
	HYDROGEN ECONOMY	✓	
STRATEGIC INDUSTRIES	NUCLEAR, BIOMASS AND HYDROGEN - ENERGY SECURITY IN THE NORTH		✓
	VEHICLE MANUFACTURING AND SUPPLY CHAIN	✓	
	TRUCKING BENEFITS TO INDUSTRIES	✓	

Vehicle Manufacturing Sector

Ontario's vehicle manufacturing sector is a large employer for southern Ontario, and anchors a deeply integrated supply chain within the province. Transitioning this industry to ZEV manufacturing would prevent its decline, and maintain its benefits for decades to come.

Trucking

Transitioning the trucking sector to hydrogen fuel would create GHG emissions benefits for all industries and sectors, and improve air quality across the province. It would also require new depots and charging stations to be built across the province, generating jobs and local spending.

ONTARIO IS HIGHLY INTEGRATED WITH THE ENTIRE GREAT LAKES REGION, THE 3RD LARGEST ECONOMY IN THE WORLD.

Ontario's GHG reduction strategies are also relevant to the Great Lakes region. An *integrated approach will allow Ontario to maximize the benefits* of its leadership.

BENEFITS WOULD BE SHARED ACROSS THE GREAT LAKES REGION

By integrating its approach with the Great Lakes, Ontario can maximize the ensuing benefits.

The Great Lakes region is a major global centre of industry and trade. With its population, GDP and employment rates, it would be the world's 3rd largest economy if it were a country. More than half of U.S.-Canada border trade happens here, accounting for more bilateral trade than the U.S. has with Mexico, China, the U.K., or Japan. [19]

Ontario is deeply integrated into the Great Lakes region. 42% of its exports are to the Great Lakes states, including 54% of its manufacturing exports, [20] and as a result, the impacts of Ontario's strategies for GHG emissions reduction extend to the Great Lakes.

Nuclear energy is produced across the Great Lakes region and the sector would benefit further from Ontario's investments. The region has its own large and deeply integrated nuclear supply chain. Ontario's friendly nuclear environment is conducive to growing nuclear generation, and a Great Lakes regional approach could accelerate the development of new leading nuclear technologies.

The hydrogen economy may best be developed on a regional basis. The Great Lakes region has a large industrial base that requires GHG emission reduction solutions. The regional economy provides large-scale hydrogen opportunities, with potential supply chain benefits that could be shared across Canada and the U.S.

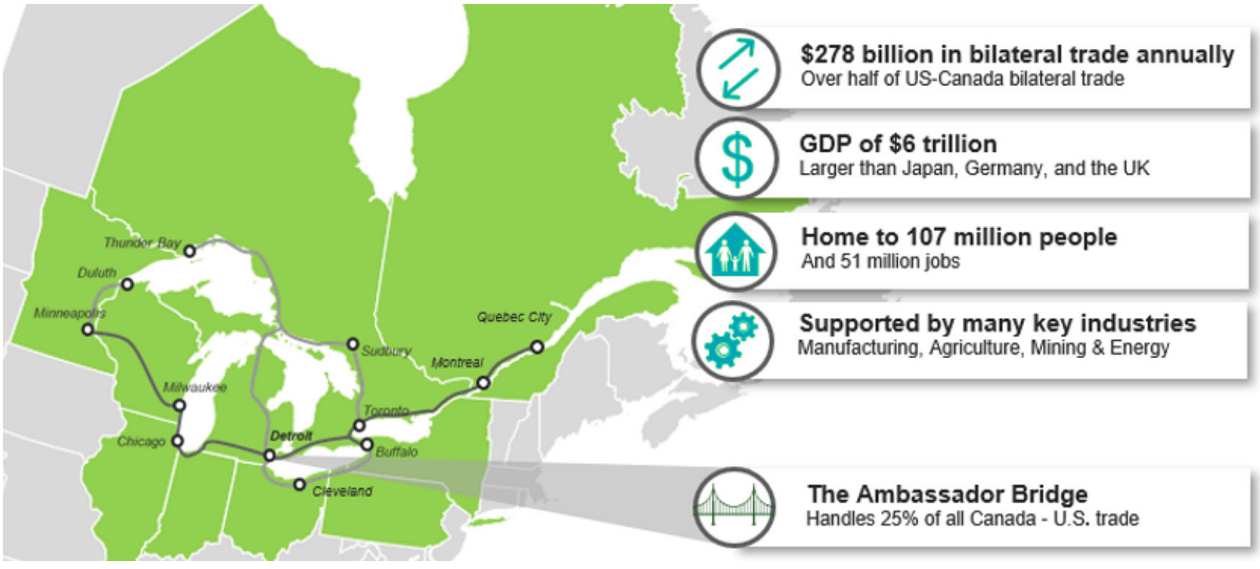
The Great Lakes region is known for its vehicle manufacturing capabilities, and is effectively the world's 4th largest vehicle manufacturer behind China, the U.S. (of which it is a large part), and Japan. [21] The vehicle manufacturing sector is significant for both Ontario and the Great Lakes region's economies. A Great Lakes regional approach could benefit the development of ZEVs in the region.

EMISSION REDUCTIONS, JOBS, AND GROWTH WOULD BOOST THE ENTIRE GREAT LAKES REGION

Trucking underpins U.S.-Canada trade, and much of this occurs in the Great Lakes region: over half of all Canada-U.S. road trade goes through border crossings between the U.S. and Ontario. [22] Supporting a zero-emissions trucking corridor along just 3 bridges on Ontario's border could have an outsized impact on the economy and GHG emissions, and could create demand for large amounts of hydrogen in the region.

Regional synergies could grow trade and Ontario's exports within the world's third largest economic region, but will require integrated planning across the region.

Exhibit 10: Overview of the Great Lakes Economy



Sources: The Visual Capitalist, 2017; Statistics Canada, 2019

[19] *The Visual Capitalist, 2017*
[20] *Government of Canada, 2020f*
[21] *Government of Ontario, 2020b; OICA, 2020*
[22] *Statistics Canada, 2019*

SUCCESSFUL POLICY ACTION REQUIRES COLLABORATION BETWEEN BUSINESS AND GOVERNMENT.

Proactive policy *engagement is needed* among all levels of government and the private sector.

CLIMATE POLICY IS A COMPLEX CHALLENGE FOR GOVERNMENTS REQUIRING PRIVATE SECTOR SUPPORT IN POLICY DEVELOPMENT AND EXECUTION

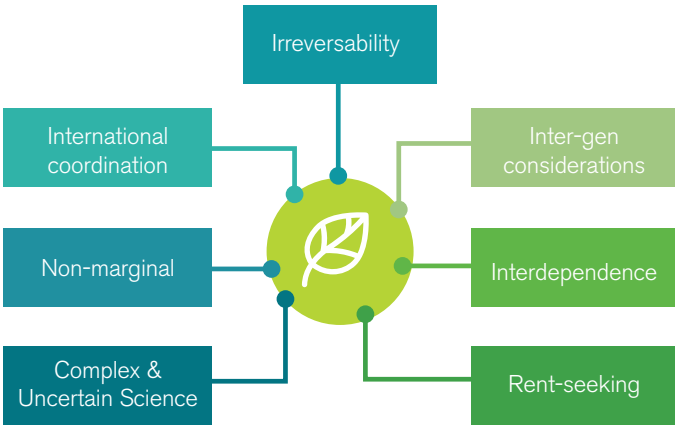
Like many other areas of state intervention, climate policy requires internalizing externalities and providing public goods. However, additional complexity arises from the irreversibility of climate change, its intergenerational impacts, complex inter-dependencies, non-marginal nature, and other complications. These factors create the need for a nuanced and sophisticated approach to climate-related intervention.

Success in climate policy entails government and corporate leadership playing complementary roles. Societies cannot rely entirely on governments or on businesses. An appropriate model for climate intervention lies in the middle, with a collaborative approach between governments and corporations.

Government intervention in climate policy is required as investments are too long-term and non-marginal, and carry international political considerations. Systematic interventions such as setting rules and targets, ensuring fair implementation and providing appropriate signals in the form of regulations are needed. Targeted actions can complement rule-setting and implementation, by providing support for specific strategic pursuits, such as research and development in FCEVs.

Businesses see that reducing environmental impact can be beneficial for consumers and investors. Business leaders can take responsibility with an integrated, strategic approach to climate change and embedding relevant incentives, structures and disclosure requirements. Organizations have recognized the importance of enabling long-term business resilience through climate change tools.

Exhibit 11: Complexity Considerations for Climate Policy



Source: Oxford Review of Economic Policy, 2010a

Exhibit 12: Climate Change – Role of Government and Business

Government Mandate	Business Responsibilties
• Set out overarching vision and objectives • Develop 'rules of the game' • Ensure fair and impartial implementation of rules • Build stability in the rules • Take targeted actions -Support R&D -Price externalities -Make substantial investments -Targeted funding for public infrastructure -Develop public finance mechanism -Provide access to clean energy	• Ensure accountability and incentives • Embed structure • Incorporate climate risks and opportunities • Report and disclose • Measure to further climate objectives -Utilize existing opportunities (eg ESG) -Innovate to create new opportunities

ONTARIO HAS A SOUND FOUNDATION WITHIN CANADA TO INNOVATE ON PROACTIVE, IMPACTFUL CLIMATE POLICIES.

Several policy options are available for climate-related interventions.

WELL FOUNDED POLICY INITIATIVES ARE CRITICAL TO A ROADMAP FOR SUCCESS

Supportive policies take several forms, and together can enable a cohesive response.

Policies to support climate action usually fall into one of four categories: mandates, subsidies, incentives, or strategic focuses. Governments around the world use climate policies to focus on reducing GHG emissions in specific areas of the economy, or apply them more broadly across sectors. Sector-specific policies are usually directed at the transportation, electricity, buildings, and industrial sectors, given that these are the main sources of GHG emissions.

On the other hand, "cross-sector" climate policies can encourage behavioral changes. Potential strategies include many variations of carbon pricing, government support for R&D, and financing measures.

Exhibit 13: Domestic Sector-Specific Policies - Samples

	MANDATES	SUBSIDES	INCENTIVES	STRATEGIC FOCUS
Transport	ZEV Sales targets, Clean Fuel standard, HDV emission standards, EV rebates, Hydrogen infrastructure funding			
Electricity	Part of Powering Past Coal Alliance, will phase out coal by 2030			
Buildings & Appliances	Updated building codes, energy saving rebates for appliance and support for building retrofits			
Industry	Availability of output based pricing system for industrial customers to reduce carbon tax			
Targeted Investments	SMR Roadmap, Low Carbon Economy Fund, Federal Hydrogen Roadmap			

Sources: Transport Canada, 2020; Environment and Climate Change Canada, 2018; Government of Canada, 2019a; NRCan, 2020a; Government of Canada, 2019c; Government of Canada, 2020a; Government of Canada, 2020d; Government of Canada, 2020c.

Ontario and Canada have implemented several sector-specific and cross-sector policies, which are helping to reduce GHG emissions. These policies include a range of sector-specific policy tools that apply across the economy, such as phasing-out coal, updating building codes, and setting ZEV sales targets.

The federal and provincial governments have also implemented cross-sector policies to influence broader behavior change, such as R&D investment and extending support through the Canadian Infrastructure Bank.

This existing experience in climate policymaking provides Canada and Ontario with a solid foundation from which to innovate on further proactive, impactful climate policy initiatives in collaboration with the private sector.

Exhibit 14: Domestic Cross-Sector Policies - Samples

Carbon Pricing

Federal government implemented a carbon tax with option for other measures such as Quebec's Cap and Trade

R&D

Climate and clean growth programs, strategic innovation fund with clean tech as one of the focus areas.

Financing

Sustainable finance panel, international climate finance commitments, Canadian infrastructure bank.

Sources: Government of Canada, 2020e; Ministry of the Environment, Conservation and Parks, 2018; NRCan, 2019a; Innovation, Science and Economic Development Canada, 2020; Environment and Climate Change Canada, 2019; Government of Canada, 2020b; Evergreen and Coalition for Green Capital, 2017.

IMPACTFUL CLIMATE POLICIES INTEGRATE PROVEN POLICY DESIGN PRINCIPLES.

Available design principles encompassing economic signals, R&D support, and performance standards can enable strategic industries.

PROVEN PRINCIPLES UNDERPIN EFFECTIVE POLICIES

Effective design and adherence to principles are key ingredients for successful policies.

Impactful climate policies consider the best practices for, and synergies between economic signals, R&D support, and performance standards. [23]

Economic Signals

To support desirable products and solutions in gaining traction in the market, policies can provide economic signals to reflect long-term goals and provide business certainty. These signals must price-in the value of any foreseeable negative externalities that may arise.

R&D Support

Supporting R&D through the early stages of innovation can allow domestic industries to bring cutting edge products and services to market. R&D policy support should be founded on clear long-term commitments to provide investors with greater certainty and increase the success rate of conducted research. Policy design should be agile by incorporating stage-gating to remove underperforming projects, and allocating resources to projects with higher likelihood of success. Governments can support research by making high-quality public sector facilities accessible to the private sector. Finally, intellectual property protection is critical, but with a carefully designed regime that does not unintentionally stymie innovation.

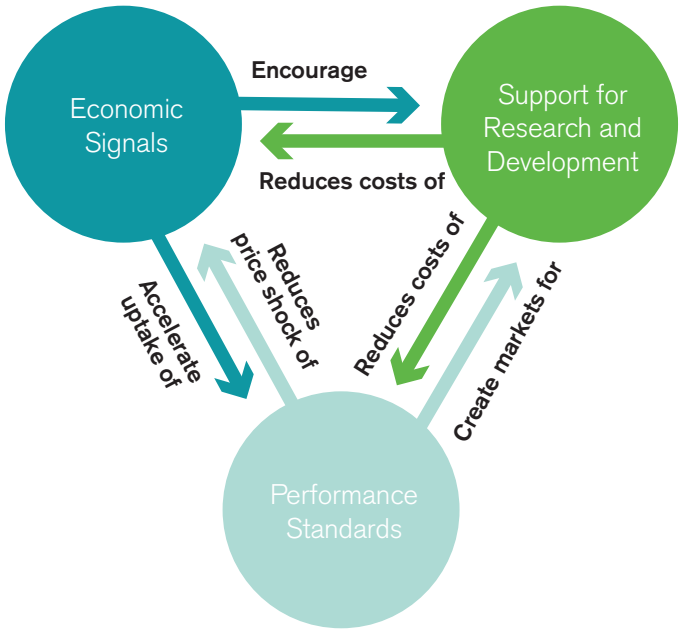
Supporting R&D should also include support for scale-up and commercialization of IP. Canada has had some success in helping companies develop early IP for their products, but has been less successful at helping these companies scale up and grow within the country. By supporting commercialization and scale up, Canada can further attract talent and investment, helping to grow the economy.

Performance Standards

Policymakers should incorporate performance standards that focus on outcomes, not technologies. These standards should have long-term certainty, with little perceived risk by stakeholders that the standards may change unpredictably. Standards development should incorporate continuous improvement, and prevent gaming through simplicity and lack of loopholes.

In applying design principles, policymakers should consider the product lifecycle, maturity, importance to goals and market penetration. These principles should be applied in a considered and nuanced manner to best meet transparent objectives.

Exhibit 15: Climate Policy Design Principles & Synergies



Source: Harvey, Orbis, and Rissman, 2018

[23] *Harvey, Orbis, and Rissman, 2018*

AN OPPORTUNITY EXISTS IN ONTARIO TO REDUCE GHG EMISSIONS, IMPROVE COMPETITIVENESS AND GROW THE ECONOMY.

But it requires *collaboration*.

SUMMARY

Ontario can do its part in the necessary effort to curb climate change while growing the economy, cleaning its air and providing its citizens with jobs and opportunities.

Investing in an integrated solution of hydrogen, biomass, and nuclear would bring nearly 50,000 jobs to Ontario, and provide economic benefits in terms of high-quality jobs, strategic investments, trade balance improvements, enhanced innovation, and public health, all while reducing GHG emissions.

Strategic industries like the hydrogen economy, ZEV manufacturing, and zero-emissions trucking would also be enabled, bringing further benefits in terms of economic growth and public health improvements, and sustaining over 100,000 jobs.

These benefits would be felt across the province, enabling manufacturing jobs and innovation in southern Ontario, and energy security and economic growth for northern communities. Replacing fossil fuel combustion with clean energy like nuclear and hydrogen in industry and transportation would deliver public health benefits that would be appreciated across Ontario.

Benefits would also extend into the Great Lakes region, the world's 3rd largest economy. Ontario's actions could deliver emissions reductions, jobs, and growth to the entire region.

Proactive policy engagement will be needed among all levels of government and the private sector to achieve these benefits. Thankfully, Ontario has a solid foundation within Canada to innovate on impactful climate policies, and can draw from proven policy design principles to do so.

Ontario has an opportunity to reduce GHG emissions, improve competitiveness, and grow the economy both at home and across the Great Lakes region.

SECTION 4

10 KEY TAKEWAYS FROM THE GREEN RIBBON PANEL

The 2020 Green Ribbon Panel was formed in February of this year by a collection of environmental and economic leaders from across Canada. The primary goal was to advance practical and executable solutions to the challenge of climate change, with a focus on the role that nuclear and Canada's other clean technologies can play while growing our economy.

1. **The world's largest GHG-reduction initiative used nuclear generation to clean Ontario's air.**
   Nuclear was responsible for 89 per cent of the GHG emissions reduction achieved by displacing coal in Ontario and has successfully reduced the number of smog days in the province from 53 in 2005 to zero in 2015.

2. **Emission-reduction policies have implications on electricity demand.**
   37 TWh is needed to achieve the 22 Mt GHG emissions reductions targeted in Ontario's climate plan for 2030.

3. **The cost of a smartly integrated solution could be 28 per cent less than Ontario's current electricity system.**

4. **A Made–in-Ontario, low-emission electricity solution coupled with effective policies can create and sustain 150,000 jobs while achieving climate goals.**
   Leveraging Ontario's economic integration within the Great Lakes region can maximize the benefits of Ontario's leadership.

5. **Smartly integrated nuclear, hydrogen, storage, and wires-and-pipes energy solutions would directly deliver economic benefits to Ontario and Canada.**
   Home grown innovations could enable almost 50,000 jobs and world leading solutions for the new economy.

6. **Low-cost, low-emission electricity enables strategic domestic manufacturing and infrastructure solutions.**
   Low-cost electricity and a hydrogen economy benefit not only manufacturing, but all of Ontario's goods producing sectors.

7. **Investments in Made-in-Ontario technologies for the new economy would nurture an innovation ecosystem in Ontario.**
   An innovation ecosystem would create a sustainable competitive advantage in strategic industries and allow Ontario to become a global leader for years to come.

8. **Focusing on domestic energy solutions and strategic industries would generate widespread benefits across all regions of Ontario.**
   Ontarians would benefit from improved public health, energy security, and job creation.

9. **Ontario is highly integrated with the entire Great Lakes Region, the 3rd largest economy in the world.**
   Ontario's GHG reduction strategies are also relevant to the Great Lakes region. An integrated approach will allow Ontario to maximize the benefits of its leadership.

10. **Ontario has a sound foundation within Canada to innovate on proactive, impactful climate policies.**
    Several policy options are available for climate related interventions.

RECOMMENDATIONS

Ontario has done much to reduce GHG emissions from its electricity sector, but much more must be done to eliminate emissions from our economy and improve air quality.

New efforts must take place in the context of population growth, economic recovery post-COVID-19, and a changing climate. Together, these factors present a range of challenges and opportunities that governments and businesses must collaborate on to address.

The Panel has identified ten immediate recommendations to be pursued within this dynamic environment. These could begin implementation over the next 18-months and serve as short-term steps for the enablement of longer-term objectives.

Recommendations

1. **Leverage Ontario's unique clean energy technologies and existing assets to reduce GHG emissions and lower energy costs.**
    - Recognizing that one of the most significant reductions in GHG emissions in Canada over the last 15 years has come as a result of decarbonizing Ontario's electricity system, it is critical to leverage this success as an urgent priority. To achieve this, Ontario should pursue a smartly integrated electricity system that leverages Ontario's unique suite of technologies to reduce GHG emissions and lower energy costs.
    - As the critically enabling foundation, operators of existing large nuclear and hydroelectric facilities should be requested by the provincial government to determine incremental investment and innovation opportunities for additional generation from existing assets. This should include optimizing existing assets from the perspective of output, performance, capabilities/ applications and long-term asset life management. Such an approach would place a priority on existing assets and their optimization given the long lead-time for new infrastructure projects.

2. **Focus policy objectives on clear, short-term, tangible actions that prioritize targeted, proven, executable solutions and that embrace the diversity of regions across Canada.**
    - There is consensus that policies at all levels of government should embrace the urgent need to tackle climate change as an element to a sustainable economic recovery from the pandemic. This, however, needs to focus on viable solutions that are proven and relevant to our economic needs in a post-COVID world. Additionally, there is also recognition that a focus on practical solutions and immediate steps can reduce regional polarization which can put long-term execution at risk.
    - Public policy objectives should be focused on clear, short-term, tangible actions and activities with priority given to targeted, executable solutions with proven results. The scope of these actions should be within a 3-5-year period, as the reality of pandemic recovery is likely to be on a similar timeline. This will also allow subsequent policy actions to be built upon in sequence and adjusted as required.

3. **Develop a pan-Canadian Hydrogen solution that includes integration with Canada's oil and gas sector, further deployment of hydrogen as a transportation fuel, and leveraging of Canada's clean electricity assets.**
    - As the federal government is currently developing its National Hydrogen Strategy, this presents an opportunity to develop a pan-Canadian solution that would create benefits across the country. Growing the use of hydrogen as a form of clean energy has the unique potential to offer every province the opportunity to reduce GHG emissions in a range of areas in a way that further underpins existing energy or electricity systems.

- For a National Hydrogen Strategy to be successful it will be critical for each province to develop its priority deployment areas for this technology. This wide-ranging opportunity can include integration with Canada's oil and gas sector, further deployment of hydrogen as a transportation fuel and leveraging Canada's clean electricity assets.

4. **Pursue electrification of the economy supplemented by the application of hydrogen technologies to incrementally and reliably achieve the necessary GHG emission reductions.**
   - Electrification of the transportation, building and industry sectors and other parts of the economy continues to provide significant benefits to GHG emissions reduction and air quality. When combined with hydrogen, this electrification forms the core elements to reduce GHG emissions incrementally and reliably. Strategies that include promoting emission reduction applications through Ontario-led manufacturing for hydrogen and battery electric vehicles along with further expansion of charging/fueling infrastructure are important first steps.

5. **Develop a Green Collar Jobs Strategy to build upon Ontario's major strength in its skilled, diverse labour force to underpin and develop, innovate and execute critical activities and projects**
   - Ontario's skilled, diverse labour force is a major strength that can be built upon to develop, innovate and execute the activities and projects critical to achieving our climate objectives.
   - The entire labour force including skilled trades, engineering, project management and a range of other disciplines should be the foundation of a "Green Collar Jobs Strategy" established to shape education and workforce development in these critical areas. This strength could create a skills pool that can be leveraged internationally.
   - The Green Collar Jobs Strategy should also provide explicit attention to the opportunities for Indigenous reconciliation and economic development by enabling strategies that promote Indigenous job creation and economic growth in their communities. This should include working with communities to break down specific barriers to access these jobs and providing incentives to support the establishment of Indigenous-owned businesses and the integration of those businesses into the supply chain.
   - The Green Collar Jobs Strategy should also reduce barriers and create the constructs to ensure greater participation among women and visible minorities. This will not only ensure more appropriate representation but new perspectives, thinking and passion.

6. **Establish Ontario's brand as a clean jurisdiction known for sustainable products.**
   - Brand Ontario as a decarbonized electricity sector so firms based here can declare their operations in the province as 'clean'. It is critical that government work to provide this support and sponsorship to Ontario-based businesses as they seek international markets and capital which is often flowing as a priority to sustainable projects and entities.
   - As nuclear is the primary contributor to enabling the coal plant closures and subsequent elimination of GHG emissions in Ontario, the creation of this brand would include declaring output from nuclear generation as clean. Nuclear is Ontario's unique advantage and ability to generate large volumes of GHG-free electricity.

7. **Leverage Ontario's status within the Great Lakes region to maximize the benefits of sustainability policies**
   - Policymakers should work with those in the Great Lakes region to bring together leaders from government, industry, academia and the non-profit sector to develop the energy priorities, strategies and infrastructure that will make the region, as well as Ontario, more competitive and sustainable. Ontario should work with the Council of the Great Lakes Region to support and maximize the benefits of sustainability policies by supporting clean investment opportunities.

8. **Engage the federal financial institutions, such as the Canadian Infrastructure Bank, to enhance the economic contributions of Ontario's domestic advantages**

- The Green Ribbon Panel applauds the recent action and enhanced focus from the federal government to effectively support investment in new and existing infrastructure through the Canadian Infrastructure Bank, Business Development Canada, and Export Development Canada. We are also encouraged that the federal government continues to make this a priority area for providing capital and creating co-investment opportunities for the private sector. To leverage these great efforts and to capitalize on the mandates of these institutions, policymakers should further enable opportunities to enhance the economic contributions of Ontario's domestic advantages highlighted in this report, including our manufacturing and green tech sectors as well as our low-carbon electricity system.
- To build off this focus, policymakers should look to further leverage these relationships with the private sector and encourage P3 partnerships to create the environment necessary to attract additional capital into Canada and unlock investment opportunities in our domestic energy solutions and manufacturing sector.
- Policymakers should further enable the opportunity to enhance the economic contributions of Ontario's domestic advantages, including our vehicle manufacturing, industrial manufacturing as well as our low-carbon electricity system. These opportunities can be supported by reducing red tape and removing trade barriers for Canadian manufacturers, with a particular focus on inter-provincial elements. Such federal, provincial and business collaboration can provide critical investment that will spur innovation and growth.

9. Create a federal Next Generation Energy Innovation Fund to place focus on the development of demonstration projects for Canada's future clean energy game-changers.

- The federal government should establish a Next Generation Energy Innovation Fund to place focus on the development of national demonstration projects for Canada's future energy game changers and establish clean energy infrastructure zones.
- This fund needs to provide long-term, annual funding to clean energy development such as fusion, hydrogen, small modular reactors, battery and storage along with large, commercial scale reactors by leveraging the federal government's ownership of CANDU technology.
- Identify existing sites for electricity generation across Canada and determine a long-term approval 'envelope' for these sites. This would allow for regulatory certainty and flexibility once future projects are ready to deploy and provide certainty to the investment community to develop globally competitive Canadian made innovations.

10. Consider how future public revenue from carbon pricing policy schemes should be revenue neutral to government and targeted at enhancing the competitiveness of trade-exposed sectors.

- Looking ahead, the extent to which either the federal or provincial governments implement changes on the price of carbon or pollution (which has not been a focus of this report), these revenues should be rebated to electricity consumers at the residential, business and industrial level, therefore being revenue neutral.
- These rebates should include the ability to reduce the cost of clean electricity in the bills for manufacturers and large industrial firms, which would boost their competitive position.

REFERENCES

This publication has relied very heavily upon the findings of Strategic Policy Economics (www.strapolec.ca).

Bruce Power, Meet our People. 2020b. *Retrieved from* https://www.brucepower.com/who-we-are/meet-our-people/

Bruce Power, The Ontario Energy Report. 2020a. *Retrieved from* https://www.brucepower.com/wp-content/uploads/2020/01/2020_OntarioEnergyReport-1.pdf

California Energy Commission, Existing Buildings Energy Efficiency Action Plan. 2015.

Canada's Ecofiscal Commission, Provincial Carbon Pricing and Competitiveness Pressures. 2016. *Retrieved from* https://ecofiscal.ca/reports/provincial-carbon-pricing-competitiveness-pressures/

Canadian Nuclear Safety Commission, Website. n.d.

CBoC, Refurbishment of the Darlington Nuclear Generating Station. 2015. *Retrieved* from https://www.conferenceboard.ca/temp/50180341-61e8-47f0-9b6a-865c98275f6e/Darlington_BR_7529.pdf

CME, CME Remarks at House of Commons Committee on International Trade as Part of E-Commerce Study. 2017. *Retrieved from* https://cme-mec.ca/blog/cme-remarks-at-house-of-commons-committee-on-international-trade-as-part-of-e-commerce-study/

Durham Workforce Authority, Nuclear Sector: 2013 Community Report. 2013.

EIA, Average retail price of electricity to ultimate customers. n.d.

Electric Autonomy Canada, Canada needs stronger EV manufacturing policies to retain its place in evolving automotive sector: report. 2020. *Retrieved from* https://electricautonomy.ca/2020/04/02/icct-power-play-report-canada-ev-manufacturing/

Environment and Climate Change Canada, Final Report of the Expert Panel on Sustainable Finance. 2019.

Environment and Climate Change Canada, Regulations for trucks buses and large vehicles cut pollution, improve air quality, and boost competitiveness. 2018. *Retrieved from* https://www.canada.ca/en/environment-climate-change/news/2018/06/regulations-for-trucks-buses-and-large-vehicles-cut-pollution-improve-air-quality-and-boost-competitiveness.html

Environmental Commissioner of Ontario, Developing the 2017 Long-Term Energy Plan. 2016. *Retrieved from:* https://www.auditor.on.ca/en/content/reporttopics/envreports/env16/LTEP-2016-Special-Report.pdf

Evergreen and Coalition for Green Capital, Green Bank Financing to Accelerate Clean Energy Deployment in Canada through the Canadian Infrastructure Bank. 2017.

Financial Accountability Office. An Assessment of the Financial Risks of the Nuclear Refurbishment Plan, 2017. *Retrieved from* https://www.fao-on.org/en/Blog/Publications/FAO-NR-Report-Nov-2017

Government of Canada, Budget 2019. 2019a. *Retrieved from* https://www.budget.gc.ca/2019/docs/plan/chap-02-en.html

Government of Canada, Canada's actions to reduce emissions. 2020a. *Retrieved from* https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/reduce-emissions.html

Government of Canada, Canada's International Climate Finance. 2020b. *Retrieved from* https://www.international.gc.ca/consultation/climate-finance-financement-climatique/index.aspx?lang=eng

Government of Canada, Canada's Official GHG Inventory, 2019b. *Retrieved from* https://open.canada.ca/data/en/dataset/779c7bcf4982-47eb-af1b-a33618a05e5b

Government of Canada, Canada's Small Nuclear Reactor Action Plan. 2020c.

Government of Canada, Canadian Industry Statistics. 2019c. *Retrieved from* https://www.ic.gc.ca/app/scr/app/cis/gdp-pid/48-49#fn1

Government of Canada, Coal phase-out: the Powering Past Coal Alliance. 2019d. *Retrieved from* https://www.canada.ca/en/services/environment/weather/climatechange/canada-international-action/coal-phase-out.html

Government of Canada, Energy Savings Rebate Program. 2020d. *Retrieved from* https://www.canada.ca/en/environment-climate-change/news/2019/08/energy-savings-rebate-program.html

Government of Canada, Pricing pollution: how it will work. 2020e. *Retrieved from* https://www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work/industry/pricing-carbon-pollution.html

Government of Canada, Trade Data Online (accessed July 10 2020). 2020f. *Retrieved from* https://www.ic.gc.ca/eic/site/tdo-dcd.nsf/eng/home

Government of Ontario, Automotive Industry. 2020a. *Retrieved from* https://www.investinontario.com/automotive#auto-intro

Government of Ontario, Driving Prosperity: The Future of Ontario's Automotive Sector. 2019. *Retrieved from* https://files.ontario.ca/auto-strategy-en-final.pdf

Government of Ontario, Invest in Ontario. 2020b.

Government of Ontario, Made in Ontario Environment Plan, 2018 *Retrieved from* https://prod-environmental-registry.s3.amazonaws.com/2018-11/EnvironmentPlan.pdf

Harvey, Orbis, and Rissman, Designing Climate Solutions: A policy guide for low-carbon energy. 2018.

Hydro Quebec, Comparison of Electricity Prices in Major North American Cities. 2018.

Hydrogenics, Annual Financial Statement 2018. 2018a.

Hydrogenics, Renewable Hydrogen Solutions. 2018b. *Retrieved from* http://www.hydrogenics.com/wp-content/uploads/Renewable-Hydrogen-Brochure.pdf

IESO, Annual Planning Outlook January 2020, Data Tables, 2020. *Retrieved from* http://www.ieso.ca/en/Sector-Participants/Planning-and-Forecasting/Annual-Planning-Outlook

IESO, Generator Output and Capability, 2018. 2019a *Retrieved from* http://www.ieso.ca/power-data/data-directory

IESO, Hourly Ontario and Market Demand 2018. 2019b. *Retrieved from* http://www.ieso.ca/power-data/data-directory

IESO, OPO 2016, Outlook F. *Retrieved from* http://www.ieso.ca/en/Learn/About-the-IESO/Publications

IESO, Progress Report Contracted Supply-Q3 2019, 2019c. *Retrieved from* http://www.ieso.ca/-/media/Files/IESO/Document-Library/contracted-electricity-supply/Progress-Report-Contracted-Supply-Q32019.pdf?la=en

Innovation, Science and Economic Development Canada, Strategic Innovation Fund. 2020. *Retrieved from* https://www.ic.gc.ca/eic/site/125.nsf/eng/home

Ipsos, Three Quarters (75%) Say Canada Needs to Do More to Address Climate Change, 28 December 2018. *Retrieved from* https://www.ipsos.com/en-ca/news-polls/three-quarters-75-percent-say-canada-needs-to-do-more-to-address-climate-change

Ministry of the Environment, Conservation and Parks, Made-in-Ontario Environment Plan. 2018.

NEI, Map of US Nuclear Plants. n.d..

NRCan, Clean Growth Program. 2019a. *Retrieved from* https://www.nrcan.gc.ca/climate-change/canadas-green-future/clean-growth-programs/20254

NRCan, Comprehensive Energy Use Database, Transportation Sector, Table 7. 2019b.

NRCan, Electric Vehicle and Alternative Fuel Infrastructure Deployment Initiative. 2020. *Retrieved from* https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-transportation/electric-alternative-fuel-infras/electric-vehicle-alternative-fuels-infrastructure-deployment-initiative/18352

NRCan, The Canadian Nuclear Industry and its Economic Contributions. 2016. *Retrieved from* https://www.nrcan.gc.ca/energy/energy-sources-distribution/uranium-nuclear-energy/nuclear-energy/canadian-nuclear-industry-and-its-economic-contributions/7715

OICA, 2018 Production Statistics. 2020. *Retrieved from* http://www.oica.net/category/production-statistics/2018-statistics/

Ontario Energy Board, Defining Ontario's Electricity Customers, 2016. *Retrieved from* https://www.oeb.ca/sites/default/files/uploads/Report_Defining_Typical_Elec_Customer_20160414.pdf

Ontario Energy Report, Ontario Energy Quarterly Q4 2018. 2018. *Retrieved from* https://www.ontarioenergyreport.ca/pdfs/6389_IESO_Q4OER2018_Electricity_EN.pdf

Oxford Review of Economic Policy, Volume 26, Number 2, Environmental policy, government and the market. 2010.

Pembina Institute, Biomass Sustainability Analysis. 2011.

Plug'N Drive. Electric Vehicles Available in Canada. 2020. *Retrieved from* https://www.plugndrive.ca/electric-cars-available-in-canada/

Pope C. A. III, Ezzati M, Dockery DW, Fine-particulate air pollution and life expectancy in the United States. 2009

Statistics Canada, Table: 36-10-0402-01, Gross Domestic Product (GDP) At Basic Prices, By Industry, Provinces And Territories (X 1,000,000). 2020.

Statistics Canada, Transportation in Canada 2019. 2019.

Strapolec, Extending Pickering Nuclear Generating Station Operations. 2015. *Retrieved from h*ttps://strapolec.ca/wp-content/uploads/2018/09/Impact_of_Extending_PNGS_Operations_Final_Report_November_16_2015.pdf

Strapolec, Ontario's GHG emissions and the Long-Term Energy Plan: Phase 1 – Understanding the Challenge. 2016a. *Retrieved from* https://strapolec.ca/wp-content/uploads/2018/09/Ontario_s_Emissions_and_the_LTEP_-_Phase_1_Final_Report_November_2016.pdf

Strapolec, Ontario's Emissions and the Long-Term Energy Plan: Phase 2 – Meeting the Challenge. 2016b. *Retrieved from* https://strapolec.ca/wp-content/uploads/2018/09/Ontarios_Emissions_and_the_LTEP_-_Ph_2_Report_Final_December_2016.pdf

Strapolec, Renewables-based Distributed Energy Resources in Ontario: Part 3 – Economic Implications of "Made in Ontario". 2019. *Retrieved from* https://www.thinkingpower.ca/PDFs/Commentary/CCRE%20Commentary%20-%20Renewable%20Energy%20for%20Ontario%20-%20Part%203%20-%20Economic%20Implications%20of%20Made%20in%20Ontario%20by%20Marc%20Brouillette%20-%20August%202019.pdf

The Visual Capitalist, The Great Lakes Economy: The Growth Engine of North America. 2017. *Retrieved from* https://www.visualcapitalist.com/great-lakes-economy/

Transport Canada, Zero-emission vehicles. 2020. *Retrieved from* https://www.tc.gc.ca/en/services/road/innovative-technologies/zero-emission-vehicles.html

Trottier Energy Futures Project, Canada's Challenge & Opportunity. 2016 *Retrieved from* https://www.cae-acg.ca/wpcontent/uploads/2016/04/WEB-Trottier-Energy-Futures-ProjectMarch31.pdf

WHO, Climate Change and Health. 2018. *Retrieved from* https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health

World's Top Exports, Car Exports by Country. 2020. *Retrieved from* http://www.worldstopexports.com/car-exports-country/

CS200062C R000 OCT2020