# CLEAN AIR, CLIMATE CHANGE AND PRACTICAL, INNOVATIVE SOLUTIONS

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

GROWING ECONOMY.
SUSTAINABLE ENVIRONMENT.
REAL SOLUTIONS.


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.
17
Rainy
Lake
Rainy
Fort
Frances
Thunder
Bay
11
Lake Superior
Lake Michigan

# CONTENTS

# 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.

# EXECUTIVE SUMMARY

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 is the first report in a series to provide a roadmap for Ontario to maintain its climate leadership and continue to improve its energy system for the health and prosperity of the province.

### 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 and other renewables, 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 from 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 Canadian surveyed*)


*Sources: Ipsos, Three Quarters (75%) Say Canada Needs to Do More to Address Climate Change, 28 December 2018*

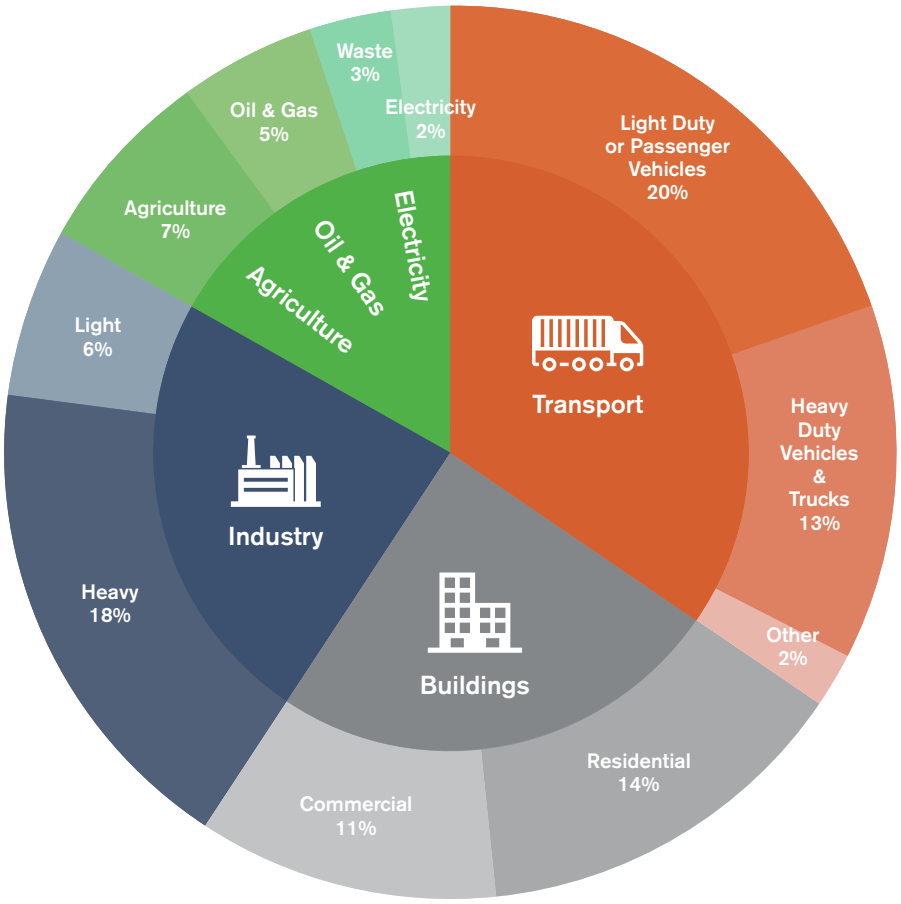
*1 WHO, Climate Change and Health, 2018. Retrieved from https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health*

# 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: Canada's Official GHG Inventory, 2019*

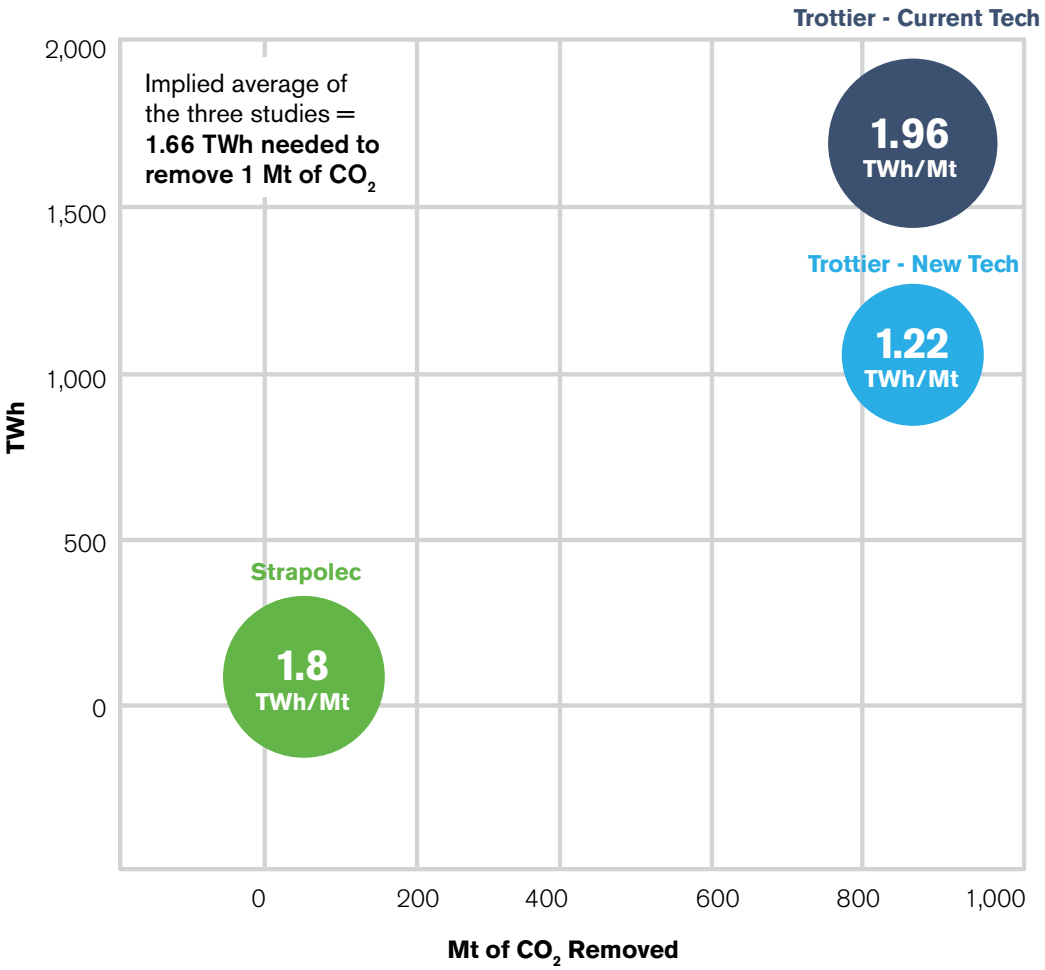
*2 Plug'N Drive. Electric Vehicles Available in Canada. 2020.*

# 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: Ontario's GHG emissions and the Long-Term Energy Plan, 2016; Trottier Energy Futures Project, Canada's Challenge & Opportunity, 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, OPO 2016 Outlook F; Environmental Commissioner of Ontario, 2016; Trottier Energy Futures Project, 2016; Strapolec: Emissions and the LTEP, 2016.*

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

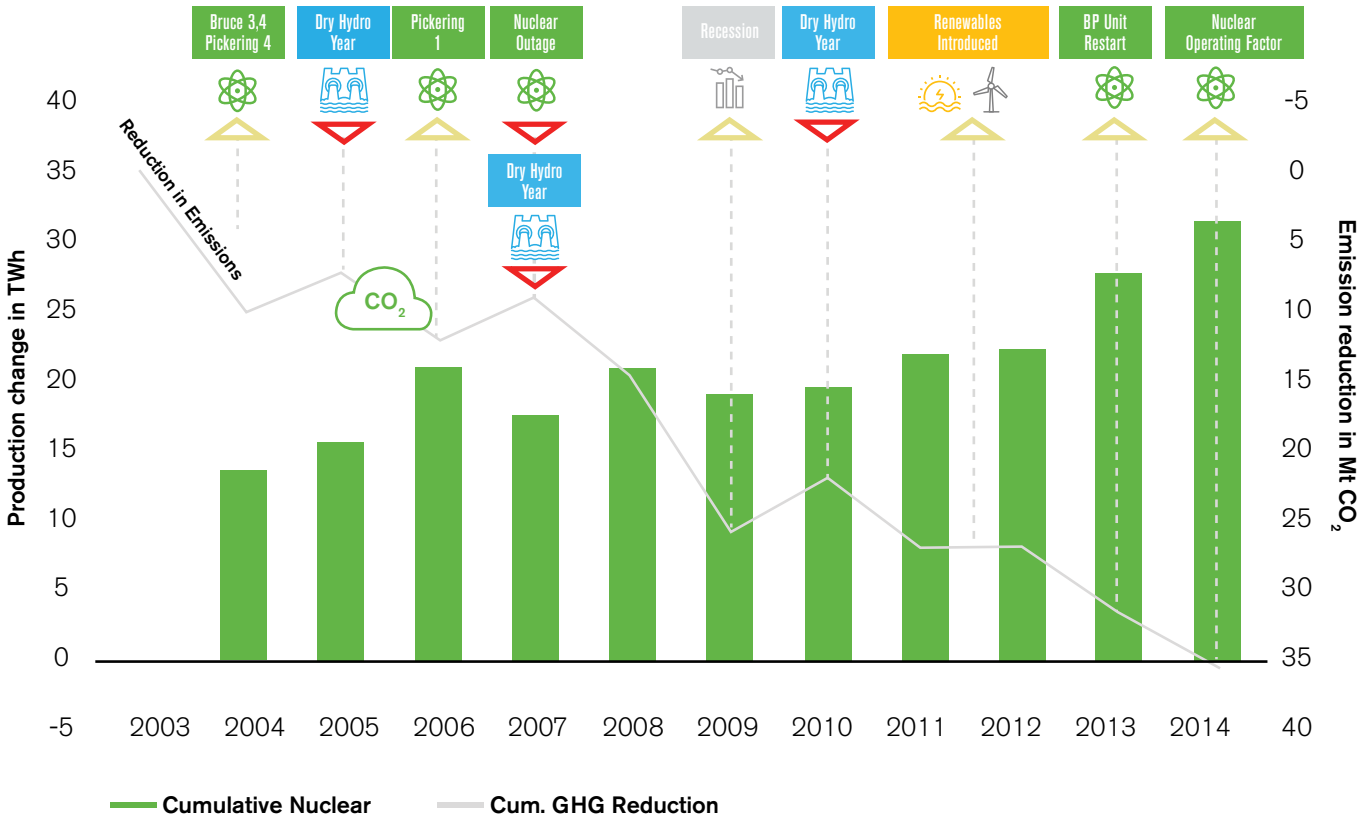
*Nuclear was responsible for 89 per cent* of the GHG-emissions reduction achieved by displacing coal in Ontario, and has successfully reduced the number of smog days in the province from 53 in 2005 to zero in 2015.

# 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 the restart of the Bruce Power Units 1 and 2 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, Extending Pickering Nuclear Generating Station Operations, 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

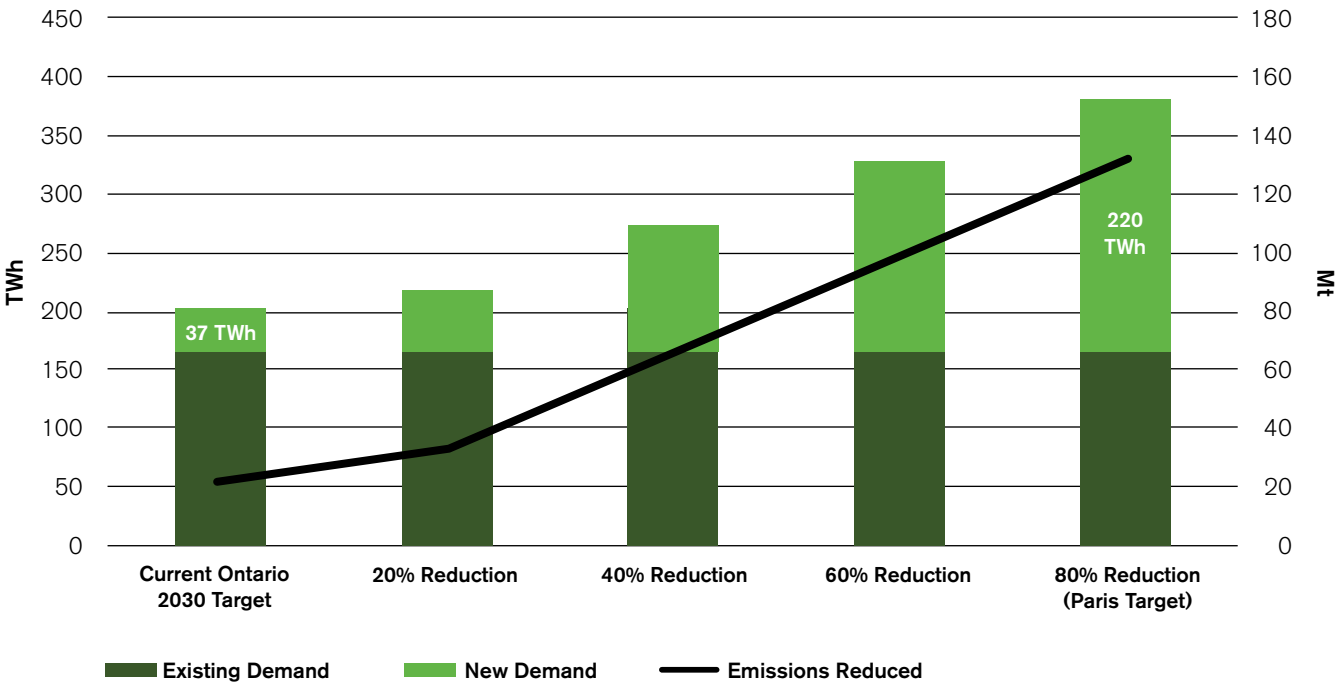
## Ontario must use clean electricity to reduce its emissions again.

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, Annual Planning Outlook, 2020; Government of Ontario, Made in Ontario Environment Plan, 2018; Strapolec Analysis*

[4] *Government of Ontario, Made in Ontario Environment Plan, 2018; IESO, Annual Planning Outlook January 2020, Data Tables, 2020.*

# ONTARIO'S GHG EMISSION REDUCTION ACHIEVEMENTS ARE AT RISK

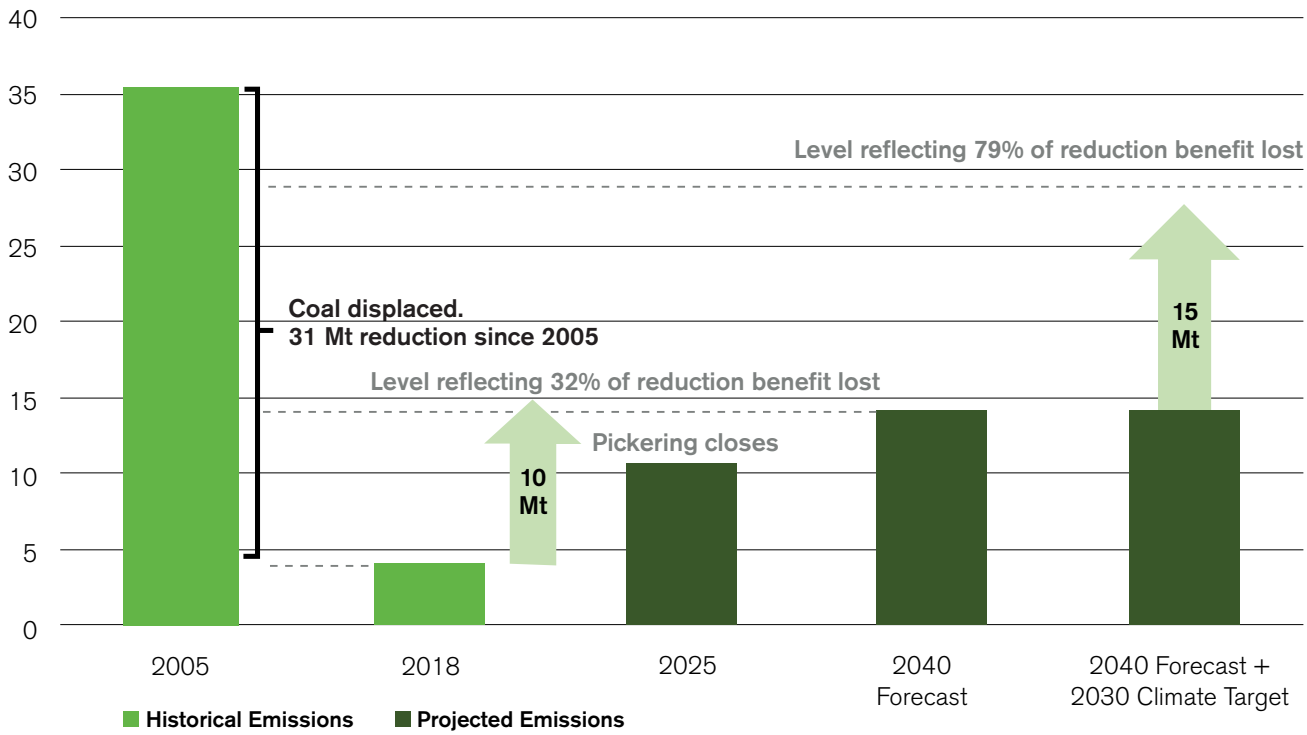
## To realize the benefits of electrification, Ontario will need zero-emission electricity resources, however none are yet planned.

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, Annual Planning Outlook January 2020, Data Tables, 2020.*

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

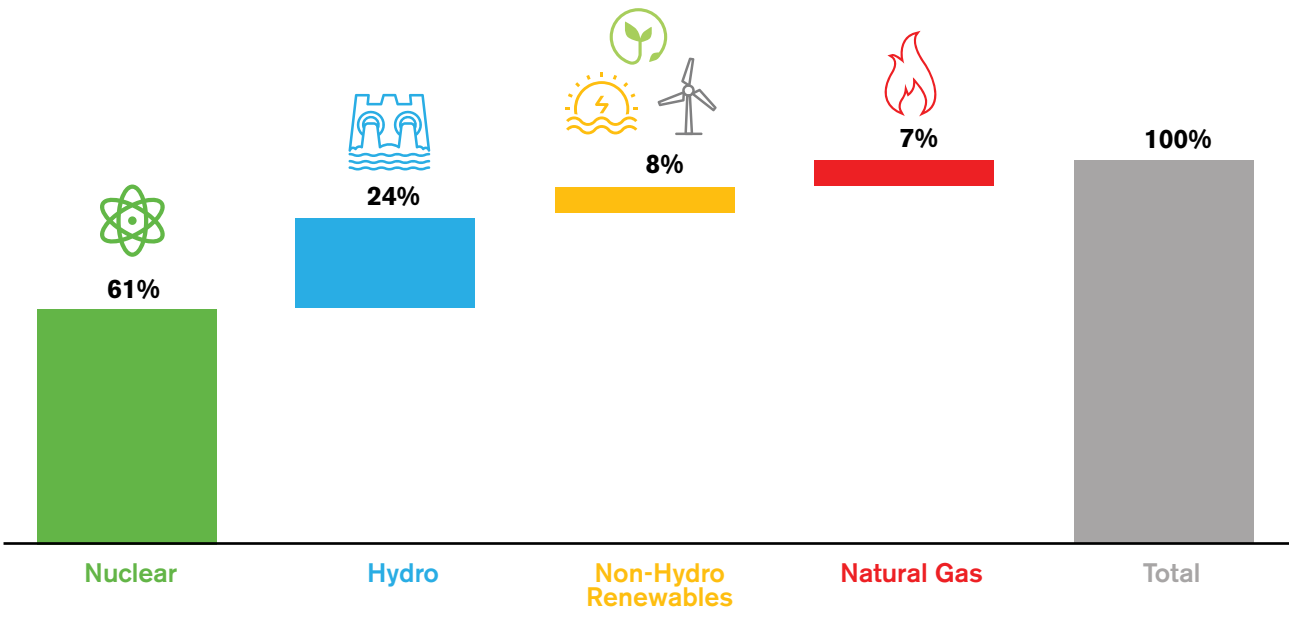
[6] *Strapolec Analysis*

# 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)*



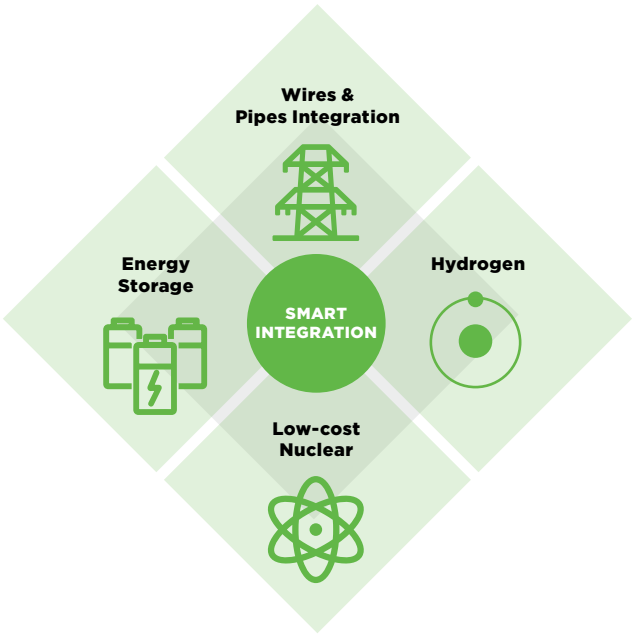

*Source: IESO. Generator Output and Capability, 2018. 2019.*

# 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]

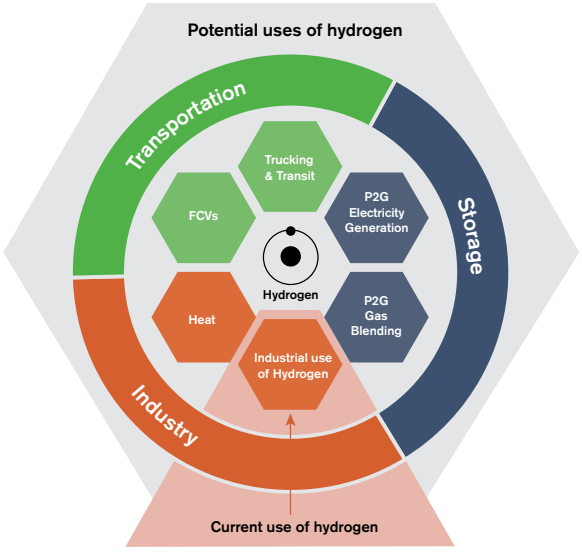
## HYDROGEN

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. 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*

[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'

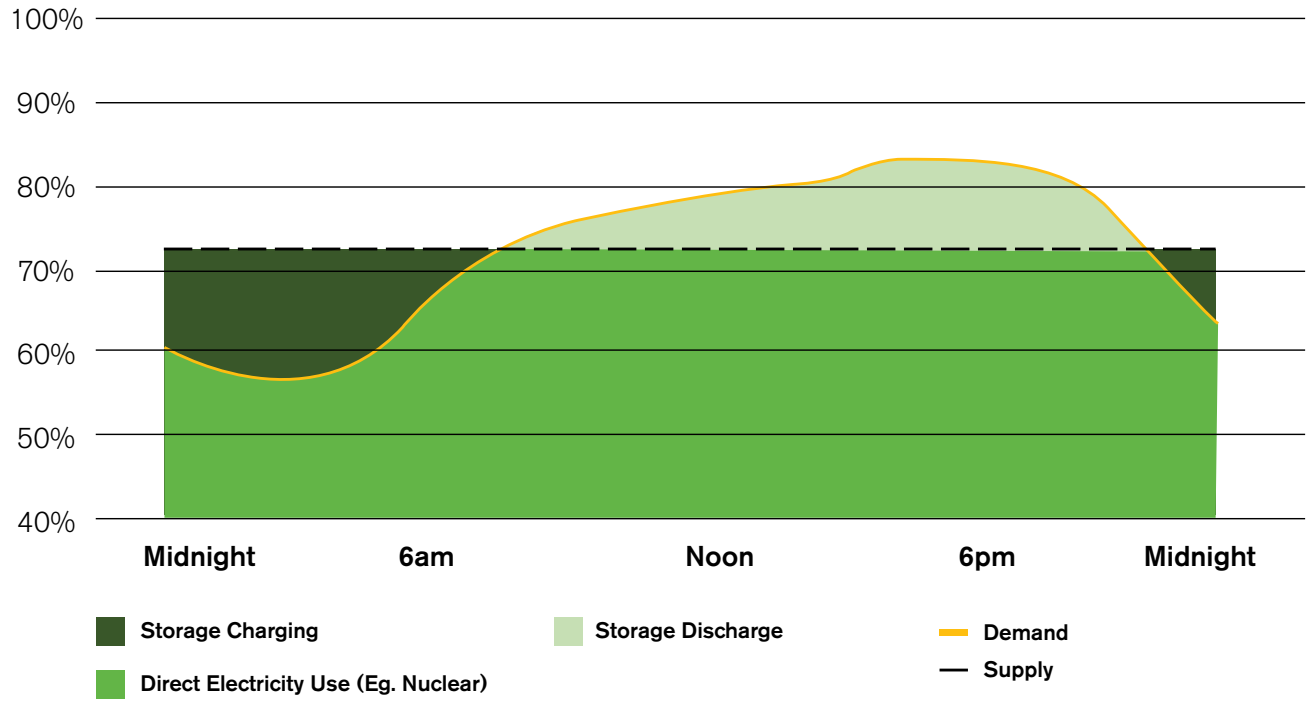
Integration of 'wires and pipes' means integrating the electricity and natural gas systems to make efficient use of natural gas infrastructure during the transition to electrification.

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 analysis based on IESO, Hourly Ontario and Market Demand 2018, 2019.*

# 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

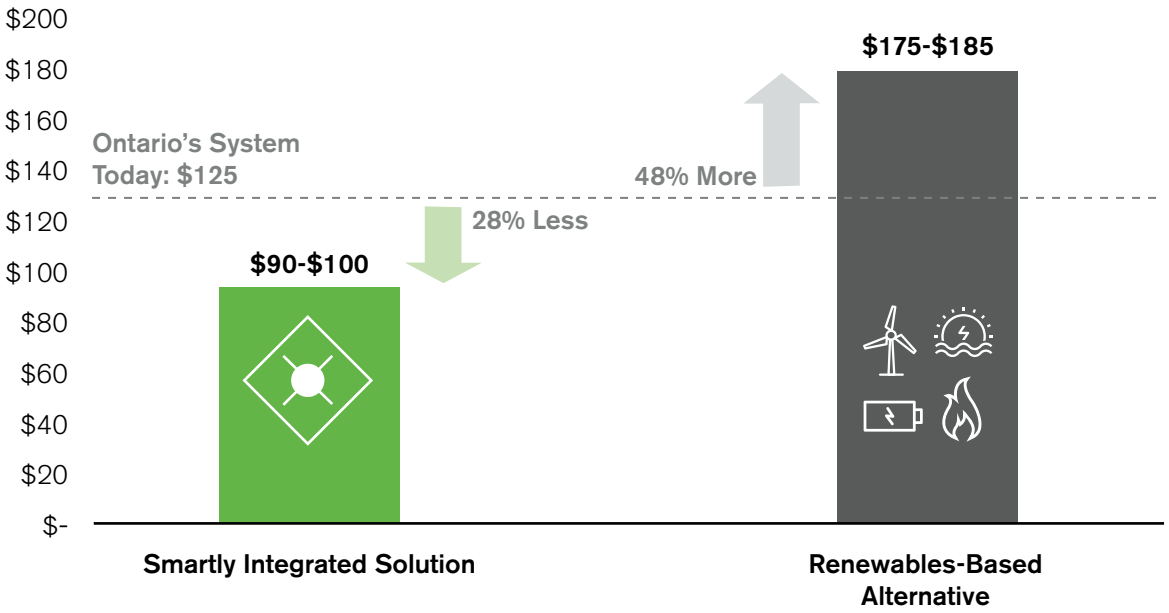
Ontario will need to make informed choices about how to meet the electricity demand implied by its emissions reduction targets.

## 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: Ontario's Emissions and the Long-Term Energy Plan: Phase 2 – Meeting the Challenge, 2016; IESO. Progress Report Contracted Supply-Q3 2019. Note: Both options assume the existing nuclear and hydro baseload are available.*

[9] *Strapolec: Ontario's Emissions and the Long-Term Energy Plan: Phase 2 – Meeting the Challenge, 2016.*

[10] *Renewables based alternative derived from IESO, Ontario Planning Outlook, Option D1 Supply Mix, 2016.*

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

# CONCLUSION

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.

As this report has demonstrated, 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 with hydrogen, storage, and 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.

The Green Ribbon Panel will continue throughout the fall of 2020 to explore options for Ontario to reduce system costs, clean our air, and contribute to economic growth.

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