Nuclear Industry Views on Meeting Ontario's GHG Targets

Ontario's opportunity is to have a power system in 2050-2100 that supports a thriving 21st century economy, including a holistically decarbonized energy system.

Ontario's challenge is to make choices now that build toward this power system. These choices must be cautious in assumptions about future technology. A reliable strategy to meet emission targets within 35 years or less should rest on technologies, such as nuclear energy, that are already proven to be minimal- or zero-emitting, and that have passed the necessary hurdles of demonstration, verification, standardization and safety.

Policy context

Ontario has a sound Long Term Energy Plan (LTEP). The province also has greenhouse gas (GHG) reduction targets. The nuclear industry endorses both the LTEP and the targets. We encourage appropriate research and planning so that the right actions can be taken to reach them.

Decarbonizing today's energy system is a transformative policy effort -- comparable to a deep national economic reform. Such policy efforts are best preceded by a program of research and planning that includes academic studies, scrutiny of other jurisdictions' experiences, thorough economic modelling, and expert consultations. A program of this kind may take years and outlive any one government.

We see a need for further modelling efforts as a planning tool for GHG action in Ontario.[1] Existing work is useful, but could be improved with more focus on specific policy responses (such as cap and trade), and by scrupulous efforts to avoid technology bias.[2]

[1] For relevant modelling exercises on decarbonization in a Canadian context, see National Roundtable on the Environment and the Economy, "Getting to 2050" (2007) and Navius Research/Carbon Management Canada, "The Deep Decarbonization Pathways Project" (2014). For an international view of the challenge, see World Business Council for Sustainable Development, "Mitigation of Climate Change" (2014).

[2] The Canada chapter of the SDSN-IDDRI "Pathways to Deep Decarbonization" report, which is based on Navius' work, assumes that nuclear energy output in Canada will "remain constant [to 2050] due to facility siting and political challenges," but also assumes spectacular expansion of wind farms and biofuels with no mention of siting or political challenges for those technologies. Such arbitrary technology bias, which is very common in energy path studies, must be avoided if sound policy is the goal.

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Some certainties

Whatever their differences, modelling exercises point toward agreement on the following general conclusions.

- The longer action is delayed, the greater become the difficulty and cost become of meeting a given target.
- All paths to deep decarbonization are very expensive. Policy choices are likely to involve how to contain these very large costs, how much sunk capital investment will be "stranded" (made uneconomic), and who bears the cost of those losses.
- Policymakers must think holistically about the energy system, the economy and the environment. Over-focusing on one program (for example, promoting wind and solar) may well produce unintended consequences that undermine ability to reach the overall goal.[3]

Out-of-province wealth transfers

Linking Ontario's market-based mitigation program to other jurisdictions (Quebec, California) will give emitters valuable access to a larger pool of reduction opportunities.

At the same time, if Ontario found it more difficult than expected to make its GHG reductions, there could be large-scale, one-sided purchase of allowances/offsets by Ontario emitters from other jurisdictions. Over extended periods, this would likely prove to be politically unsustainable. The wealth transfers out of the province would eventually be unacceptable to governments, business and/or the public, and steps would be taken to end them.[4]

For this reason, longer-term models might realistically set bounds on net purchases by Ontarians of allowances and offsets from other jurisdictions.

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[3] For example, intermittent wind and solar generation may be backed up by natural gas generation, inadvertently raising GHG emissions from a generating mix that was previously very low-carbon (see Hatch, "Lifecycle Assessment Literature Review of Nuclear, Wind and Natural Gas Power Generation," 2014). Or the cost of power may rise more than anticipated, discouraging the replacement of fossil fuels with electricity.

[4] It is worth noting that the same would likely be true of large-scale, long-term electric power purchases by Ontario from other provinces, at least in the absence of some compensating export revenue for Ontario or unless the price of the power were very favourable for Ontario. Governments and others would have reservations about transferring wealth out of the province if there were reasonable alternatives that would create jobs and economic activity in-province.

A safe bet: Ontario will need much more electricity

Industry, transportation and buildings together account for about 80% of Ontario's GHG emissions.[5] Apart from cleaning up the large industrial emitters (30%), which appears to be targeted through proposed regulations, decarbonization of the transport and building sectors must be addressed if targets are to be met. These have huge implications for the electric power grid of the future.

- Electrifying transportation (34% of provincial GHG emissions). The only technology readily available that would result in the scale of GHG reductions needed in the transport sector is the electrification of transportation. This requires modelling of various assumptions about the balance of personal vehicles versus transit, market penetration of electric vs. gasoline vehicles, and when (and how quickly) vehicle batteries will be recharged. In scenarios where electric transport is a material help to GHG reduction, large increases in power demand can be expected as these systems come into use.
- Electrifying building heat (17% of provincial GHG emissions). The majority of GHG emissions related to the building sector are due to space heating. While making buildings more thermally efficient (so less fossil fuels are used) and supplementing current heating systems with ground source heat pumps are partial solutions, these measures cannot fully decarbonize this sector. Electric heating has a large contribution to make, and should be targeted in the longer time frame over which buildings are refitted or replaced. Again, in scenarios where electrification of buildings is relied on as a material help in reaching GHG targets, large increases in power demand can be expected as this is done.

This means that decarbonizing our energy system involves using much more electricity, and for a different mix of purposes than we use them for today. The province requires a non-GHG-emitting generation mix and a power system that supports this.

Technology deployment

Currently unproven technology fixes may be available (if very unpredictable) in the distant time frame (post 2050), but their availability even post-2050 is highly uncertain.

Technology fixes in energy, transport and buildings are not like new technology in information technology or telecoms, because hardware in the former sectors is larger, more durable, more costly, and has more health and safety implications. After being invented, energy, transport and building technologies need periods of verification, standardization, safety engineering and

[5] Percentages from Ontario, Ministry of the Environment and Climate Change, "Ontario's Climate Change Discussion Paper 2015," fig. 3.

capital investment before they can make their way into general use. The capital investment phase takes longer in slower-growing economies.

It would be very risky to assume that economic large-scale electricity storage technologies (other than hydro) will become available in time to help meet 2020 or 2030 targets – much less be widely installed.

At Ontario's foreseeable rates of economic growth and investment, we will need all the time we have (5 to 35 years) to start transitioning our capital stock toward lower-carbon systems. Time spent waiting for new technologies means less time to accomplish this replacement. Rather, reliable decarbonizing strategies in these circumstances should rest on the use of already-proven technologies.

Mid-century electric load scenarios for Ontario

The Canadian Nuclear Association asked a team within one of its members[6] to develop several illustrative scenarios of what electrification of vehicles and building heat could contribute to meeting Ontario's ambitious 2050 emission reduction goal, if the power were generated without GHG emissions.

Two electric vehicle (EV) cases and two electric heat (EH) cases were developed. While various EV charging profiles were considered, for this purpose it was assumed that smart grid technology would allow charging to occur at the least cost times for the system to supply the power.

Table: Annual loads for base case, and medium & high penetration scenarios in 2050

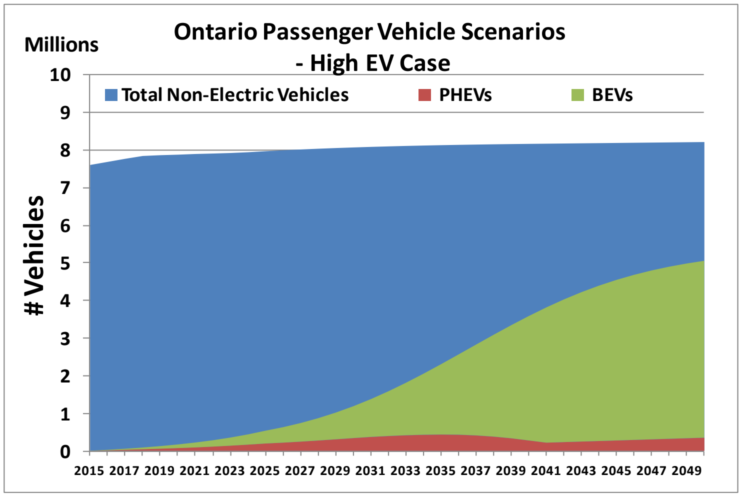
	Base case	Medium penetration	High penetration
Annual EV charging load	8 TWh	14 TWh (+6 TWh)	21 TWh (+13 TWh)
Annual building heating load	21 TWh	31 TWh (+ 10 TWh)	42 TWh (+21 TWh)
Annual Ontario provincial load	168 TWh	184 TWh (+16 TWh)	202 TWh (+34 TWh)

[6] Model Development & Analytics, Commercial Operations & Environment, Ontario Power Generation

Electric vehicle scenarios and assumptions

The Medium EV case assumes that half of passenger vehicles sold in 2050 are EV and that the total number of EVs on the road in 2050 is 3.2 million, which would be 40% of the total fleet. It also assumes that EV charging is centrally controllable, with the majority of charging occurring overnight.

The High EV case (shown in the figure below) increases the EV sales penetration rate in 2050 from half to 75%, resulting in a fleet penetration of 60%, which is 4.9 million EVs. Battery electrics (BEVs), as opposed to plug in hybrids (PHEVs), represent 90% of the electric vehicle market by 2050.

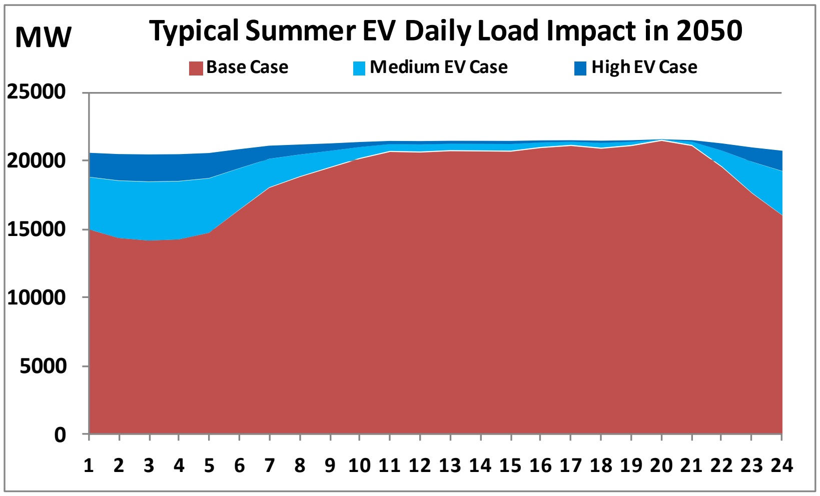


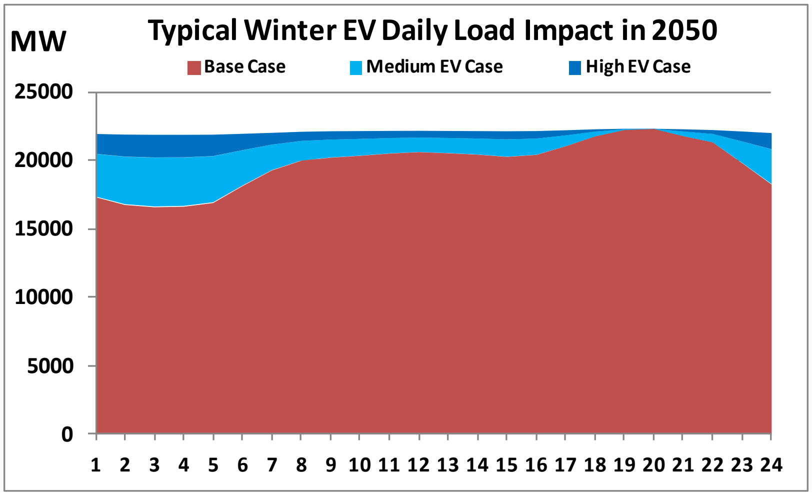
With mass adoption of electric vehicles, there would be considerable incentive to be able to control when EV charging occurs, with the intention of avoiding spikes in demand. This is particularly important when considering high levels of solar and wind generation on the system, as their variability could potentially result in net load (ie. demand minus wind and solar production) peaking in any hour of the day. The system operator's capability to dispatch (turn on and off) EV charging load would be a natural evolution of the electrification of transportation.

Electric vehicles' impact on the power system[7]

If the majority of EV charging occurs at night, the additional EV load on the power system serves to flatten the total daily load shape.

This flattening effect has benefits: it increases the efficiency of the power system, by utilizing spare off-peak resources, which in Ontario tend to be carbon-free (notably nuclear and hydro). Furthermore, this flattening effect requires no significant additional investment in peaking capacity. Rather, electric vehicles increase the need for affordable base load power.





[7] Electrification Coalition, "Electrification Roadmap – Revolutionizing Transportation and Achieving Energy Security" [Online]. Available at: http://www.electrificationcoalition.org. (2009, Nov)
Axsen et al, "Electrifying Vehicles – Insights from the Canadian Plug-in Electric Vehicle Study" [Online]. Available at: http://rem-main.rem.sfu.ca/papers/jaxsen/Electrifying_Vehicles_%28FINAL%29_V2.8_%28July10%29.pdf. (2015)
Electric Power Research Institute, "Environmental Assessment of Plug-In Hybrid Electric Vehicles, Volume 1: Nationwide Greenhouse Gas Emissions," Report #1015325 [Online]. Available at: http://www.epri.com/abstracts/pages/ProductAbstract.aspx?productId=000000000001015325

The potential for GHG emission savings from switching from gasoline to electric vehicles is large: these scenarios suggest reductions of roughly 8 Tg of CO_2 in the Medium EV case, and up to 16 Tg in the High EV case in 2050, representing reductions about 4.5% and 9%, respectively, below 1990 levels (compared to Ontario's overall target of 80% below 1990 levels).[8]

Building heat scenarios and assumptions

The medium scenario for electrification of building heat used the following assumptions:

- Energy conservation results in a 50% reduction in residential and commercial heat requirements relative to 2015 levels.
- By 2050, that 50% of homes whose gas furnace has reached its end of life replace it with electrified heating. This results in 40% of all residential homes converting to electric heat by 2050. In these scenarios, two electric heating technologies are considered: 20% of homes that are converting adopt heat pumps, while 80% adopt resistance furnaces or baseboards.
- Commercial building electrification is assumed to be 50% of total commercial building stock in 2050.

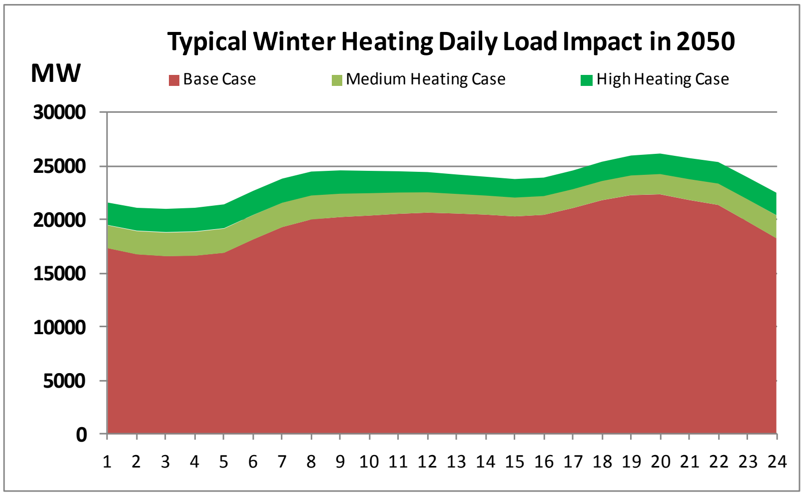
The high version of this scenario increases the electrification adoption rate from 50% to 100%.

Building heat electrification's impact on the power system

In 2050, the building heating load goes up 10 TWh in the Medium scenario and 21 TWh in the High scenario.

Heating load is less flexible in nature than vehicle charging. The impact of electrification of heating on the load shape is relatively even across the day, and could result in an increase in the power system's winter peak demand of roughly 5 GW in the High scenario.

[8] See also Plug N' Drive, "Electric Vehicles: Reducing Ontario's Greenhouse Gas Emissions." (2015, May)

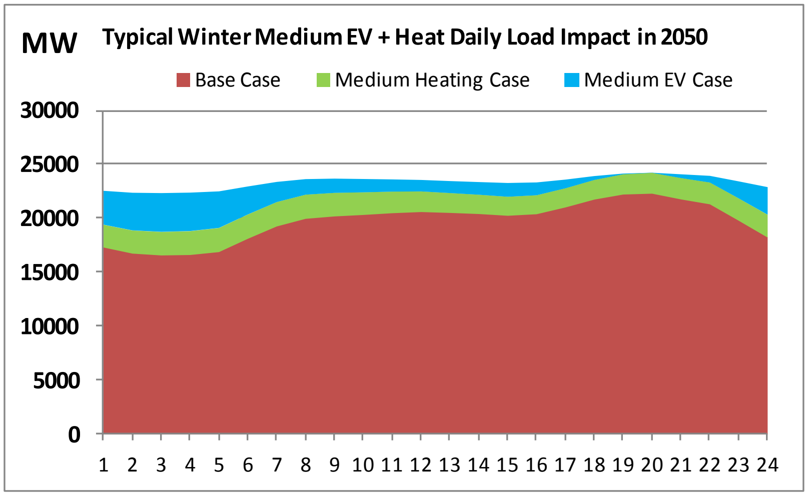


Alternatively, utilization of thermal storage technologies in buildings could shift some heating load off the highest demand periods, again increasing the need for non-GHG emitting baseload power.

Electrification of space and water heating in the Medium and High Electric Heating scenarios makes a major reduction in GHG emissions. Up to 14 Tg of CO2 equivalent emissions could potentially be avoided due to a shift from natural gas heating to resistance electric heating and heat pumps. This represents reductions almost 8% below 1990 levels (compared to Ontario's overall target of 80% below 1990 levels).

EVs and electric heat: Combined impact on the power system

The figure below shows the resulting winter daily load shape in 2050 when both EV and heating load are added in the Medium case.



The daily load shape in both the medium and high EV + Heat cases is substantially flatter than the base case without electrification. As noted earlier, this flattening effect has benefits in allowing increases in the efficiency of the power system.

When the additional EV and heating loads are combined, there is a demonstrated need for additional energy and capacity, with an incremental demand of 16 TWh of energy. Roughly **3 GW of average peak capacity would be required**.

The combined High case (not shown) contains 34 TWh of additional energy requirement from the base case along with roughly **5 GW additional average peak capacity. These are substantial required additions to the capacity of Ontario's power system**.

The emission reduction benefits are large in both cases: the Medium scenario displaces 17 Tg of GHG emissions in 2050, while the High scenario displaces 30 Tg. This represents GHG emission reductions of almost 11% and 17% below 1990 levels for Medium and High scenarios, respectively, compared to Ontario's overall target of 80% below 1990 levels.

Conclusions

Electrifying transportation and building sectors is the main available pathway to reduce carbon emissions, given that the Ontario electricity supply has already been effectively decarbonized. To facilitate these sectors' shift away from fossil fuels, Ontario's electricity must be available, reliable, affordable, and remain non-GHG-emitting.

The scenarios presented above show that a combination of overnight EV charging and electrified heating could significantly reduce Ontario's GHG emissions (11% to 17% below 1990 levels by 2050), but would create a substantial need for both additional peak capacity (usually measured in gigawatts) and additional electricity generation (usually measured in terawatt hours).

The resultant load shape is flatter, which suggests a technology with a high capacity factor would be the logical choice for supplying this additional load.[9] As the source must also be carbon-free, particularly in the context of a price on carbon, nuclear power would be the best option among existing generation technologies.

Nuclear, even in its currently available forms (that is, disregarding future advances in technology and business models), is not only minimal-emitting but also has high capacity factor (85-90%) and a relatively low levelized energy cost.

Hydroelectricity also meets these criteria, and would be a good option for Ontario to the extent that undeveloped generating sites are available and provided supporting transmission

[9] "High capacity factor" means plants produce a high percentage of the power output of which they are rated to be capable. This is desirable wherever power loads are steady (flat), as it means that large capital investments are used efficiently.

infrastructure can be built. Wind and solar are low emitting when running, but their intermittency requires backup generation, which adds to costs. If that backup is provided by natural gas, as it often is currently, then lifecycle emissions of wind and solar are not dramatically lower than straight natural gas fired generation.[10]

This document relies on scenarios for meeting Ontario's 2050 emission targets that are plausible, and that are conservative in terms of their implications for electric power demand. They assume higher levels of conservation and lower amounts of electrification than recommended by other studies (e.g. Navius). If Ontarians were not successful in achieving the 50% conservation level assumed by these scenarios in 2050, the need for baseload generation would be even higher.

The incremental power demand entailed in these scenarios would call for addition of additional nuclear generating capacity. The amount required in the combined Medium scenario would equal about 2,200 MW of additional capacity, and about twice this amount in the combined High scenario. Additional nuclear units would be the most economic means of supplying the high capacity-factor energy requirement without adding any significant direct CO2 emissions, and without adding emissions associated indirectly with back-up generation (currently usually natural gas fired) for the intermittent power supply that comes from wind and solar.

The energy produced by such plants could displace up to 30Tg of GHG emissions in the highest electrification case studied.

The design and construction of this additional capacity would be largely sourced in Ontario and would support large numbers of durable, highly trained Ontario jobs.[11]

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Ontario's challenge is to make choices now that build toward this power system. These choices must be cautious in assumptions about future technology. A reliable strategy to meet emission targets within 35 years or less should rest on technologies, such as nuclear energy, that are already proven to be minimal- or zero-emitting, and that have passed the necessary hurdles of demonstration, verification, standardization and safety.

[10] Hatch, "Lifecycle Assessment Literature Review of Nuclear, Wind and Natural Gas Power Generation." (2014) The anticipated solution to this intermittency problem is affordable large-scale electricity storage, but this is an example of the problem described earlier in this document under "Technology deployment." Technologies for large-scale power storage are still under development, will take years to be tested and built, will presumably add an element to the cost of renewables, and (if the answer is pumped hydro) may only be available in some localities (i.e. at hydro reservoirs). This is not an argument against investing in these technologies, but it is an argument against strategically relying on them.
[11] See Canadian Manufacturers and Exporters, "Nuclear: A Canadian Strategy for Energy, Jobs and Innovation" (2012)