



Powerful Options

A review of Ontario's options for replacing aging nuclear plants

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Ontario Clean Air Alliance Research Inc.

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Executive Summary

Over the next 12 years, Ontario will need to replace 60.4 billion kWh of electricity produced by nuclear generators that will have reached the end of their productive lives by 2021. This report reviews the following replacement options: a) conservation and efficiency to reduce demand for electricity; b) wind power; c) natural gas-fired combined heat and power (CHP); d) renewable electricity imports from Quebec; e) hydro-electricity imports from Labrador; and f) the construction of new nuclear reactors in Ontario.

Of all these options, nuclear power is the highest cost and highest risk.

This report finds that decreased electricity demand, thanks to increased conservation efforts, could eliminate the need to replace 47% of the nuclear power generation that will have reached the end of its service life by 2021. According to the Ontario Power Authority (OPA), the cost of reducing demand by investing in energy efficiency is approximately 2.7 cents per kWh.

Wind power when integrated with Hydro Quebec's hydro-electric generation resources has the potential to provide Ontario with sufficient firm, reliable renewable electricity to replace 100% of end-of-service-life nuclear power generation by 2021. The cost of electricity from large-scale land-based wind farms in southern Ontario is 9.6 to 13.5 cents per kWh.

Natural gas-fired combined heat and power plants could also provide 100% of our required replacement power by 2021. According to the OPA, CHP can supply electricity at a cost of approximately 6 cents per kWh.

The electricity transfer capacity between Ontario and Quebec will increase by 1,250 MW in 2010. Assuming no further increases in interconnection capacity, electricity imports from Quebec would be able to provide 40% of our required replacement power. In 2008, Hydro Quebec's average revenue from its electricity export sales was 9 cents per kWh. Most of these export sales were to the U.S. Pursuant to the *National Energy Board Act*, Hydro Quebec must give Ontario an opportunity to purchase electricity on terms and condition (including price) as favourable as the terms and conditions of its U.S. export sales.

Hydro-electricity from the Lower Churchill Falls Project in Labrador has the potential to fill 28% of Ontario's 2021 electricity supply gap at a cost of approximately 6 cents per kWh plus transmission costs. The total market cost for Ontario consumers could be approximately 9 cents per kWh.

According to Moody's Investors Service, the cost of electricity from new nuclear power plants is likely to be at least 15.1 cents per kWh U.S.\$ (approximately 18 cents Canadian as of May 2009). In addition, a history of cost overruns, late delivery, premature aging and unexpected breakdowns suggests that new nuclear reactors may be the least reliable option to meet Ontario's future electricity needs.

Ontario has numerous options to replace the electricity produced by its aging nuclear power fleet. Furthermore, it appears that many of these replacement options can meet the province's electricity needs at a much lower cost than new nuclear reactors.

In conclusion, Ontario has numerous options to replace the electricity produced by its aging nuclear power fleet. Furthermore, it appears that many of these replacement options can meet the province's electricity needs at a much lower cost than new nuclear reactors.

Approximate Costs of Ontario's Electricity Resource Options

Energy Efficiency	Land-Based Wind Power in Southern Ontario	Natural Gas-Fired Combined Heat and Power	Renewable Electricity Imports from Quebec	Hydro-Electricity Imports from Labrador	New Nuclear Reactors
2.7 cents per kWh	9.6 – 13.5 cents per kWh	5.7 – 6.0 cents per kWh	9 cents per kWh	9 cents per kWh	15.1 cents per kWh (US\$)

Nevertheless, the Government of Ontario is planning to sign, in the Spring of 2009, a contract for the construction of two new nuclear reactors at the Darlington Nuclear Station east of Oshawa.

Before committing to sign a contract for new nuclear reactors, it would be highly prudent for the Government of Ontario to take the following actions:

1. Direct the OPA to significantly increase its funding for our electric utilities' (e.g., Hydro One, Toronto Hydro) energy efficiency programs. As of December 31, 2008 for every dollar that the OPA has spent on conservation and demand management it has contracted for \$60 of new electricity supply.
2. Direct the OPA to establish a natural gas-fired CHP feed-in-tariff or standard offer program — a program that would pay a fixed price for each kWh of electricity produced by CHP. On June 14, 2007 Ontario's then Minister of Energy, Dwight Duncan, directed the OPA to establish a natural gas-fired CHP standard offer program. According to Minister Duncan's directive, the goal was to have the standard offer program in place by December 2007. Unfortunately, the standard offer program has still not been implemented.
3. Direct the OPA to make negotiating long-term electricity supply agreements with Hydro Quebec and Nalcor Energy a top priority.

Introduction

Thanks to the leadership of Premier Dalton McGuinty, Ontario will be able to achieve a virtually complete coal phase-out by January 1, 2010. Ontario's coal phase-out is the single largest greenhouse gas reduction initiative in North America – equivalent to taking almost seven million cars off the road.¹

Ontario's next major electric power challenge is to replace its existing nuclear generation capacity when it comes to the end of its productive life.

In 2008 Ontario's Bruce A and B, Pickering and Darlington nuclear reactors produced 84.4 billion kWh.²

Virtually all of the Bruce B, Pickering and Darlington nuclear generators will be out of service by 2021.³ However, all of the Bruce A reactors are forecast to be in service until at least 2034.⁴

According to the Ontario Power Authority's forecast, the Bruce A nuclear reactors will produce 21 billion kWh and all of our other existing nuclear reactors will produce 3 billion kWh in 2021.⁵ Therefore, Ontario needs to replace 60.4 billion kWh of nuclear generation (84.4 billion today – 24 billion remaining in 2021) within the next 12 years.

Currently, the government plans to replace these aging nuclear reactors with new reactors. In fact, its 20 year electricity plan would actually raise the amount of installed capacity of nuclear units from the current 11,426 MW⁶ to approximately 14,000 MW.⁷

This report looks at other options for replacing our aging nuclear fleets. It finds that all of these options are financially cheaper without even beginning to factor in the many additional costs of nuclear power, from safety and security risks to waste disposal.

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Falling Demand for Electricity

According to Ontario's Independent Electricity System Operator (IESO), on a weather-normalized basis Ontario's demand for electricity fell from 152.3 billion kWh in 2006 to 148.9 billion kWh in 2008. Furthermore, the IESO is forecasting that demand will fall to 143.6 billion kWh in 2011 (see Table 1).⁸

Table 1: Ontario's Falling Electricity Demand

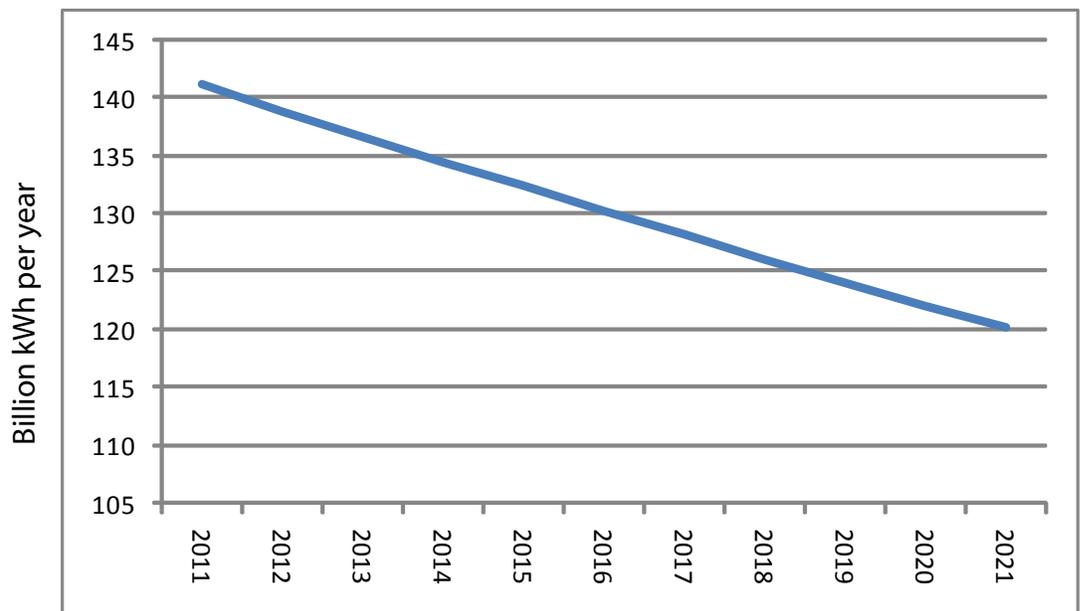
Year	Normal Weather Energy (Billion kWh)	% Growth in Energy
2006	152.3	-1.9%
2007	151.6	-0.5%
2008	148.9	-1.8%
2009 (forecast)	146.6	-1.6%
2010 (forecast)	143.6	-2.0%

According to the IESO, demand will continue to decline despite the eventual economic recovery:

“Despite the eventual economic recovery, demand will continue to decline as the impact of greater levels of conservation combined with the growth in embedded generation take effect.”⁹

In percentage terms, the IESO is forecasting that the average annual decline in demand will be -1.6% per year between 2006 and 2010. Figure 1 shows Ontario's demand for electricity for each year from 2011 to 2021 if electricity demand continues to decline at a rate of -1.6% per year.

Fig. 1: Ontario's Electricity Demand if demand continues to fall by 1.6% per year



Therefore, if electricity demand continues to decline by 1.6% per year, Ontario's total annual demand for electricity will fall by 28.6 billion kWh or 19.2% between 2008 and 2021. If this occurs, falling electricity demand will eliminate the need for replacement generation to address close to half (47%) of the gap left by nuclear plants going offline by 2021.

While a continuous 15-year decline in our electricity consumption would be inconsistent with historical trends in Ontario, it would be consistent with our continuing transformation towards an increasingly knowledge-based economy. As the Martin Prosperity Institute has noted, Ontario is currently undergoing a profound economic transformation which is unlikely to be reversed:

“The current economic transformation is as big and as challenging as the transformation from agriculture to industry. Our economy is shifting away from jobs based largely on physical skills or repetitive tasks to ones that require analytical skills and judgment. This shift is also evident in the long-term trend away from employment in goods-producing to service industries, from occupations that depended on physical work to produce goods to ones that provide service and rely on creativity. The change is inexorable. We cannot turn away from it; nor can we slow it. The clock of history is ticking. Competitive advantage and prosperity will go to those jurisdictions that can best prepare themselves and adapt to this long-run trend.”¹⁰

As a further reality test, it is important to note that in 2007 New York State's electricity productivity (GDP per kWh) was 2.4 times greater than Ontario's.¹¹ To achieve electricity productivity parity with New York in 2007, Ontario would have needed to reduce its overall electricity consumption by 58%, which indicates that there is lots of potential for ongoing efficiency improvements in Ontario.

According to the Ontario Power Authority (OPA), the cost of reducing demand by investing in energy efficiency is approximately 2.7 cents per kWh.¹²

Falling electricity demand could eliminate the need for replacement generation to address close to half (47%) of the gap left by nuclear plants going offline by 2021.

Wind Power

According to a report prepared for the OPA by Helimax Energy Inc., Ontario's total on-shore (land based) wind power potential equals 1,711 billion kWh per year. That is our total on-shore wind power potential is more than 11 times greater than Ontario's total annual electricity consumption.

Table 2: Ontario's On-Shore Wind Power Potential¹³

	Megawatts (MW)	Billion kWh Per Year
Entire Province	628,067	1,711
North of 50 th Parallel	598,884	1,632
South of 50 th Parallel	29,183	79

Combined with land-based wind power south of the 50th parallel, this could essentially provide Ontario with its needed replacement power three times over or six times over if we factor in reduced demand from efficiency improvements.

In another report for the OPA, Helimax identified and assessed 64 potential off-shore wind power sites in the Great Lakes. According to Helimax, these sites could support 34,500 MW of wind power capacity which would produce 111.5 billion kWh of electricity per year.¹⁴ Combined with land-based wind power south of the 50th parallel, this could essentially provide Ontario with its needed replacement power three times over or six times over if we factor in reduced demand from efficiency improvements.

Nevertheless, wind power is intermittent and therefore, by itself, cannot provide a constant firm supply of base-load electricity. However, by integrating Ontario's wind generation with Quebec's hydro-electric resources, wind power can be converted into a constant 24/7 source of electricity supply. For example, when our wind generation is above average, we can export our excess generation to Quebec. As a result, Hydro Quebec could reduce its hydro-electric generation and store more water behind its hydro-electric dams. Conversely, when our wind output is below average, Hydro Quebec could increase the output of its hydro-electric generation stations and export electricity to Ontario. On an annual basis, Ontario's net wind exports to/imports from Quebec would be zero.

And, since the output of Ontario's wind farms is greater during the winter than the summer, Ontario's net wind exports to Quebec during the winter would help Hydro Quebec meet its annual peak day demands. Quebec, on the other hand, has surplus power during Ontario's peak summer period.

In short, by integrating Ontario's wind generation with Quebec's hydro-electric capacity, Ontario's intermittent (variable) wind generation can be converted into a firm (non-variable) renewable electricity source for Ontario consumers while also assisting Quebec to meet its peak day demands. This means wind power has the potential to replace 100% of our end-of-service-life nuclear power generation.

According to the OPA, the cost of producing electricity from large-scale, on-shore wind farms in southern Ontario is between 9.6 and 13.5 cents per kWh.¹⁵

Natural Gas-Fired Combined Heat and Power

Most buildings and factories in Ontario use natural gas to produce just one service, namely heat. It is much more efficient to use these same molecules of natural gas to simultaneously produce heat and electricity. Combined heat and power (CHP) plants can have energy efficiencies of 80 to 90%; compared to the energy efficiency of a nuclear reactor of only 33%.¹⁶

CHP plants can be installed in apartment buildings, condominiums, shopping centres, hospitals, schools, airports and factories.

According to the OPA, CHP plants can supply electricity at a total cost of 5.7 to 6.0 cents per kWh assuming natural gas costs of \$8 per MMBTU.¹⁷ (On April 29, 2009 the spot price of natural gas was less than \$4 per MMBTU.)

In addition, as a result of its very high efficiency, the greenhouse gas emission rate of a CHP plant is 80% lower than that of a coal-fired power plant.¹⁸

While nuclear power plants can have even lower greenhouse gas emission rates than CHP plants, the cost of achieving the incremental greenhouse gas emission reductions, by building a new nuclear power plant instead of CHP plants, would exceed \$430 per tonne.¹⁹

Ontario's existing CHP capacity is 1,281 MW.²⁰ There are three available estimates of Ontario's total CHP potential capacity:

1. According to industry expert Tom Casten, it is 11,400 MW.²¹
2. According to a report prepared for Natural Resources Canada, it is 13,735 MW.²²
3. According to a report prepared for the Ontario Ministry of Energy, it is 16,514 MW.²³

Therefore Ontario's incremental CHP supply potential is at least 70.9 billion kWh per year.²⁴ As a consequence, CHP has the potential to provide 100% of our needed replacement power generation by 2021.

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Renewable Electricity Imports from Quebec

With the completion of the new 1,250 MW interconnection between Quebec and Ontario in 2010, the total transfer capacity between the two provinces will rise to 2,788 MW.²⁵ As a consequence, starting in 2010, Ontario will have the potential to import up to 24.4 billion kWh per year from Quebec. At this interconnection level, renewable electricity imports from Quebec can provide 40% of our needed replacement power generation.

In 2008 Hydro Quebec exported 21.3 billion kWh of electricity at an average price of 9 cents per kWh.²⁶

Hydro Quebec has numerous profitable options to meet Ontario's electricity needs.

Re-Directing Electricity Exports to Ontario

In 2008, Hydro Quebec exported 18.8 billion kWh pursuant to short-term contracts.²⁷ Most of these exports were to the U.S. In the future, they could be to Ontario.

The Eastmain-1-A/Sarcelle/Rupert Hydro-Electric Project

The Eastmain-1-A/Sarcelle/Rupert hydro-electric project (893 MW) is currently under construction and will be completed in 2012. It will produce 8.5 billion kWh at a cost of 5.1 cents per kWh.²⁸

Wind Power

Hydro Quebec is planning to acquire 3,500 MW of wind generation capacity by 2017. According to Hydro Quebec, this wind generation capacity will produce 10.7 billion kWh per year at a cost of 10.5 cents per kWh.²⁹

Energy Efficiency

By increasing the energy efficiency of its domestic customers, Hydro Quebec can free up some of its existing hydro-electricity generation capacity for export sales. Hydro Quebec has set a target of reducing its domestic customers' electricity consumption by 11 billion kWh per year by 2015.³⁰

Ontario's Cost of Purchasing Electricity from Quebec

Pursuant to the *National Energy Board Act*, Hydro Quebec must give Ontario an opportunity to purchase electricity on terms and conditions (including price) as favourable as the terms and conditions of its export sales. Therefore, the latest market data indicates that Ontario could purchase electricity from Quebec at a cost of approximately 9 cents per kWh.

At this inter-connection level, renewable electricity imports from Quebec can provide 40% of our needed replacement power generation.

Hydro-Electricity Imports from Labrador

The Churchill River in Labrador is a significant source of renewable energy. However, the potential of this river has yet to be fully developed. The existing 5,428 MW Churchill Falls Generating Station, which began producing in 1971, harnesses about 65% of the potential generating capacity of the river. The remaining 35 per cent is located at two sites on the lower Churchill River, known as the Lower Churchill Project.

According to Nalcor Energy, the owner of Newfoundland and Labrador Hydro, the capital cost of this project is approximately \$10 billion.³¹ Its two installations at Gull Island and Muskrat Falls will have a combined capacity of more than 3,000 MW and will provide 16.7 billion kWh of electricity per year.³² That is, this project has the potential to provide 28% of Ontario's needed replacement power by 2021 at a cost of approximately 6 cents per kWh plus transmission charges.³³

Earlier this year, Newfoundland and Labrador Hydro signed a Transmission Service Agreement with Hydro Quebec that requires Hydro Quebec to wheel power from the existing Churchill Falls Generating Station to the Canada/U.S. border.³⁴ This agreement creates a precedent for a future agreement which would facilitate the transmission of hydro-electricity from Labrador to Ontario via Hydro Quebec's transmission system. In 2008 Hydro Quebec's average charge for electricity transmission was 1.5 cents per kWh.³⁵

In February, Nalcor Energy issued an Expression of Interest to six engineering and project management companies in order to determine their interest in bidding for the Lower Churchill Project's detailed engineering design work.³⁶

Ontario's Cost of Purchasing Electricity from Labrador

As noted above, in 2008 the average price of Hydro Quebec's electricity exports was 9 cents per kWh. Since Nalcor's potential U.S. customers are similar to Hydro Quebec's existing U.S. customers, it appears that the market value of electricity from the Lower Churchill Project is approximately 9 cents per kWh. Finally, as noted above, the *National Energy Board Act* requires Nalcor Energy to give Ontario an opportunity to purchase electricity on terms and conditions (including price) as favourable as the terms and conditions of its U.S. export sales. Therefore the most recent market data indicates that Ontario could purchase the output of the Lower Churchill Project at a cost of approximately 9 cents per kWh.

This project has the potential to provide 28% of Ontario's needed replacement power by 2021.

New Nuclear Reactors

According to Moody's Investors Service, the cost of electricity from a new nuclear power plant is likely to be at least 15.1 cents per kWh U.S.\$ (roughly 18 cents Canadian as of May 2009).³⁷ Furthermore, this cost estimate does not include the cost of decommissioning plants and the long-term storage of radioactive nuclear waste.

In 1998 seven of Ontario's nuclear reactors were shutdown for safety reasons. All of these reactors remained out of service for more than five years.

In addition, Ontario's history with nuclear power raises a number of reliability issues with this supply option.

- In 1998 seven of Ontario's nuclear reactors were shutdown for safety reasons. All of these reactors remained out of service for more than five years. Three of these reactors are still shutdown. As a result, of the poor performance of our fleet of nuclear reactors, Ontario Power Generation had to increase the output of its dirty coal-fired power plants by 120% to keep the lights on.³⁸
- As a result of Ontario's heavy dependency on CANDU nuclear reactors, it took Ontario more than 8 days to fully recover from the August 2003 blackout versus less than 2 days for New York State.³⁹
- In May 2008 Atomic Energy of Canada Limited scrapped its two new Maple medical isotope reactors. While the reactors are more or less complete, a design flaw makes it impossible to safely control the nuclear reactions within them.⁴⁰ These failed reactors cost Canadian taxpayers \$600 million.⁴¹

The Government of Ontario is considering bids from three companies (Areva, Atomic Energy of Canada Limited and Westinghouse) to build two new nuclear reactors at the Darlington Nuclear Station.

Atomic Energy of Canada Limited has not yet completed the design work for its proposed Advanced CANDU Reactor, which it hopes to sell to the Government of Ontario.⁴²

There is no operating experience anywhere in the world with respect to Westinghouse's proposed AP1000 reactor.⁴³

There is no operating experience with respect to Areva's proposed EPR reactor. Areva's EPR reactor construction project in Finland is badly behind schedule and massively over budget.⁴⁴

Conclusions

Ontario has numerous options to replace the electricity produced each year by its aging nuclear power generators. Furthermore, as Table 3 indicates, it appears that many of these replacement options can meet the province's electricity needs at a much lower cost than new nuclear reactors.

Table 3: Approximate Costs of Ontario's Electricity Resource Options

Energy Efficiency	Land-Based Wind Power in Southern Ontario	Natural Gas-Fired Combined Heat and Power	Renewable Electricity Imports from Quebec	Hydro-Electricity Imports from Labrador	New Nuclear Reactors
2.7 cents per kWh	9.6 – 13.5 cents per kWh	5.7 – 6.0 cents per kWh	9 cents per kWh	9 cents per kWh	15.1 cents per kWh (US\$)

Our conclusions are consistent with recent statements by Jon Wellinghoff, Chairman of the U.S. Federal Energy Regulatory Commission. On April 22, 2009 Mr. Wellinghoff told reporters at a U.S. Energy Association forum that no new nuclear or coal plants may ever be needed in the United States. According to Mr. Wellinghof, renewables like wind, solar and biomass will provide enough energy to meet base-load capacity and future energy demands. Nuclear and coal plants are too expensive, he added.

Unlike coal and nuclear, natural gas will continue to play a role in generating electricity, Wellinghof added. "Natural gas is going to be there for a while, because it's going to be there to get us through this transition that's going to take 30 or more years."⁴⁷

Nevertheless, the Government of Ontario is planning to sign, by June 20, 2009, a contract for the construction of two new nuclear reactors at the Darlington Nuclear Station east of Oshawa.⁴⁸

Given the plentiful alternatives available, it would be imprudent for the Government of Ontario to proceed with its nuclear plans before fully exploring – and exploiting – our lower cost and lower risk options.

Recommendations

1. Direct the OPA to significantly increase its funding for our electric utilities' (e.g., Hydro One, Toronto Hydro) energy efficiency programs. As of December 31, 2008 for every dollar that the OPA has spent on conservation and demand management it has contracted for \$60 of new electricity supply.⁴⁵

Given the plentiful alternatives available, it would be imprudent for the Government of Ontario to proceed with its nuclear plans before fully exploring – and exploiting – our lower cost and lower risk options.

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2. Direct the OPA to establish a natural gas-fired CHP feed-in-tariff or standard offer program – a program that would pay a fixed price for each kWh of electricity produced by CHP. On June 14, 2007 Ontario’s then Minister of Energy, Dwight Duncan, directed the OPA to establish a natural gas-fired CHP standard offer program. According to Minister Duncan’s directive the goal was to have the standard offer program in place by December 2007.⁴⁶ Unfortunately, the standard offer program has still not been implemented.
 3. Direct the OPA to make negotiating long-term electricity supply agreements with Hydro Quebec and Nalcor Energy a high priority.

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