Renewable is Doable:

Affordable and flexible options for Ontario's long-term energy plan

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Executive summary

Ontario has experienced an absolute decline in electricity demand in recent years, due in part to the province's successful conservation programs. Grid electricity demand in Ontario is projected to drop back to 1992 levels by 2022. This will effectively eliminate the need for new reactors to replace the aging Pickering nuclear station.

Ontario is in the midst of reviewing its long-term energy plan (LTEP). The most recent iteration of the plan calls for two new reactors to be built at the Darlington nuclear station. A decrease in future demand therefore has significant consequences. The proposed new reactors at Darlington would be providing electricity that will not be needed, while incurring substantial construction and operating costs.

Apart from the Pickering station, Ontario has several other nuclear stations approaching the end of their operational lives. The province's current LTEP, developed in 2010, only allows for this capacity to be replaced with more nuclear — either by building new reactors or refurbishing old ones. This report asks the question that electricity planners are precluded from asking by the current LTEP: as they reach the end of their lives, can Ontario replace nuclear reactors with a cost-effective, low-carbon energy mix?

Ontario's new "Conservation First" initiative provides the opportunity to continue electricity savings. The evidence presented in this report shows that putting conservation first, and supplementing it with a diversified portfolio of green energy sources, can be more cost-effective than renewed investment in nuclear stations whose costs continue to increase.

The electricity generated by new reactors is estimated to cost more than 15 cents per kilowatt hour (kWh). A portfolio of green alternatives could provide the same energy for just over 10 cents per kWh, and at more effective times of the day. The cost of renewable energy technologies, and especially solar power, is dropping dramatically. This is why jurisdictions across the United States and Europe are cancelling planned nuclear projects in favour of renewable alternatives. The continued rapid decline in solar costs makes it increasingly likely that residents and businesses across Ontario will look to produce power themselves.

These are all good reasons for Ontario's next LTEP to keep the province's options open and not lock into nuclear. Previous LTEPs have constrained the growth of both conservation and renewables in order to ensure that enough demand is maintained and grid space is available for nuclear power to make up 50% of the supply mix. By constraining alternatives, this requirement ultimately leads to higher electricity costs in Ontario.

Key steps to ensure clean, affordable electricity

In light of these trends of declining electricity demand, increasing nuclear costs and the increasing affordability of renewables, here are three key steps to ensure that Ontario's next energy plan provides clean, affordable electricity:

1. To support the government's "Conservation First" policy, the Ontario Power Authority (OPA) should pursue all cost-effective conservation and efficiency opportunities before it considers procuring new electricity generation. Ontario's next long-term energy plan should establish ambitious demand reduction targets, with escalating minimums for 2020, 2025 and 2030.

2. The arbitrary requirement that nuclear power must provide 50% of Ontario's electricity should be eliminated. Instead, there should be fair competition among all alternatives based on cost as well as their environmental risks and benefits.

3. Because all past nuclear projects in Canada have significantly exceeded their budgeted cost, the costs and risks of reactor life-extension projects should be subject to open and transparent public review.

1. Introduction: Putting conservation first in the long-term energy plan

To successfully implement the government's new "Conservation First" initiative, structural barriers to conservation and efficiency should be removed from Ontario's long-term energy plan.

Ontario's past long-term energy planning initiatives have all overestimated long-term electricity demand growth, while also underestimating the cost of nuclear power.

These two assumptions — which have consistently proven incorrect — have led past Ontario governments to focus on building large nuclear stations to fill a perceived shortage of electricity decades into the future. As result, the ambition for both conservation and renewable sources is either significantly reduced or capped in the longer term.

Long-term electricity planning processes over the past decade have taken a "nuclear first" approach. They have assumed that nuclear generation needs to be maintained at 50% of supply for 10 to 20 years in the future, despite having no technical justification for such a requirement.[1] As a result, renewables and conservation efforts are used only to meet any remaining anticipated requirements.[2]

Figure 1 shows how the province's conservation targets in the 2011 long-term energy plan (LTEP) are significantly higher for 2010 to 2020 than for the plan's later years — in effect, the plan is restricting conservation efforts. Figure A1 in the appendix also shows how the growth of renewables is arbitrarily capped by 2018.

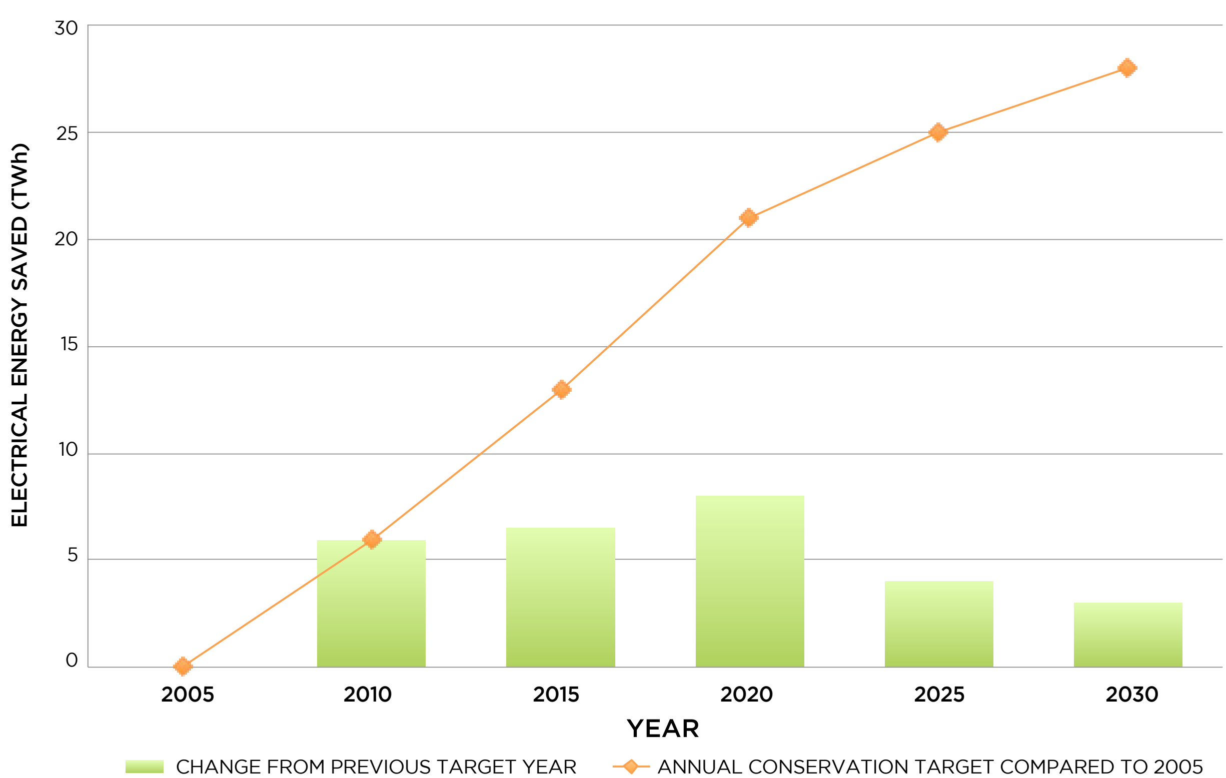

FIGURE 1

DECLINE OF CONSERVATION TARGETS BEYOND 2020

Source: Environmental Commissioner of Ontario and Ontario Ministry of Energy[3]

The Ontario government has announced a new "Conservation First" vision for electricity.[4] A true conservation-first approach would maximize efficiency and conservation efforts before determining what (if any) new nuclear investments are required, rather than the other way around. Such an approach has the potential to displace existing supply, in particular nuclear stations as they reach the end of their operational lives after 2020. It would be a truly different approach to electricity planning.

Prioritizing energy savings, and then incremental clean energy supplies as demand evolves, would heed the lessons learned from past long-term energy plans that have started with the premise of large, centralized supply. These smaller options can be deployed more quickly and incrementally compared to mega-projects, which often require lead times of 10 years or more.

In order to implement a conservation-first approach rather than a nuclear-first one, the government must clearly direct the Ontario Power Authority (OPA) to make conservation and efficiency the first priority. This direction should include ambitious milestones for procurement targets and transparency mechanisms to ensure timely implementation. These procurement targets should be enshrined in the 2013 LTEP directive, with escalating minimum conservation targets between now and 2030. This would ensure that the government's commitment to put conservation first is realized in practice, and would prevent the decline of conservation targets after 2020.

2. No need for new reactors: Falling electricity demand

With electricity demand set to return to 1992 levels by 2022, there is no need for new nuclear reactors. The government's renewed commitment to conservation could further reduce Ontario's reliance on existing nuclear and gas generation.

In 2006, the Ontario government directed Ontario Power Generation (OPG) to begin the planning and secure the approvals needed to build up to four additional reactors at the Darlington nuclear station. This was done to address a significant increase in demand predicted by the OPA and the possible closure of the Pickering nuclear station.[5]

By 2010, the significant increase in electricity demand predicted by the OPA had failed to materialize. However, this reality was not reflected in the government's 2011 LTEP directive. It called for the construction of up to 2,000 megawatts (MW) of new nuclear generation to replace the Pickering nuclear station after its closure. There are six reactors at the Pickering nuclear station and OPG plans to operate the station until 2020, although it has yet to gain full approval from the Canadian Nuclear Safety Commission (CNSC).[6]

A new 2,000 MW nuclear station would produce approximately 15 terrawatt-hours (TWh) of electricity per year.[7] Electricity demand in Ontario has already dropped by 10 TWh since 2006. Data recently obtained from the Independent Electricity System Operator (IESO) through a Freedom of Information request[8] shows that the IESO expects demand to fall by an additional 7 TWh between 2013 and 2022 (see Table A1 in the appendix). Combined, these reductions in demand more than offset the energy a new nuclear plant would produce.

The IESO data, illustrated in Figure 2, shows that annual electricity demand is set to drop from 143 TWh currently to a low of 130 TWh in 2020. It will rebound slightly to 136 TWh in 2022, when grid demand would equal 1992 levels. This forecast is significantly lower than the medium growth scenarios used for planning in both the 2011 LTEP and the 2013 LTEP review, as well as the low growth scenarios in both.

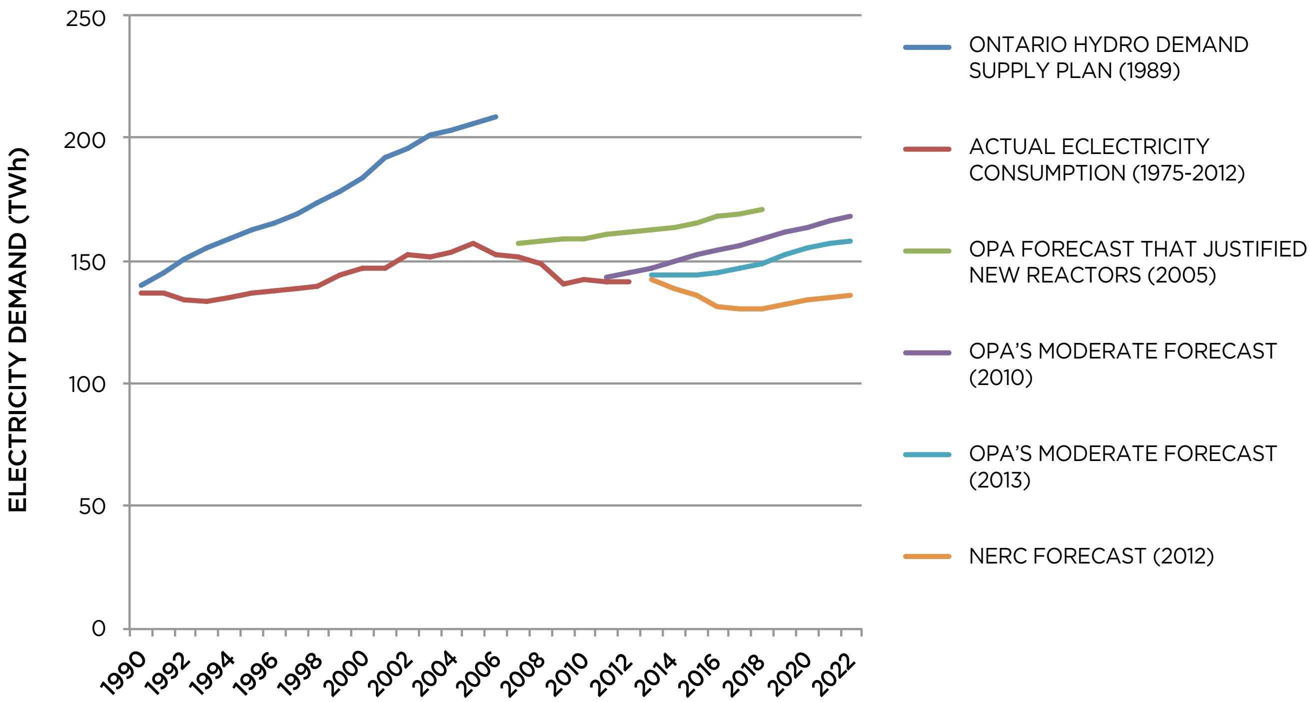

FIGURE 2

ONTARIO HISTORIC ELECTRICITY DEMAND COMPARED TO RECENT FORECASTS

Calculated using data from the Independent Electricity System Operator, Ontario Power Authority and Ontario Hydro [9]

The new nuclear capacity set out in the 2011 LTEP was based on the government's instruction to the OPA to guarantee nuclear power generators 50% of the electricity market. Based on the IESO's 2012 projection, 50% of supply in 2022 would be approximately 67 TWh. This is slightly less than the combined output of the existing Darlington nuclear generating station (henceforth referred to simply as Darlington) and the Bruce A and B stations (henceforth referred to as Bruce A and Bruce B).

Based on the IESO demand projections and existing conservation targets and programs, the 2010 directive to maintain nuclear at 50% of supply could be achieved without building new reactors, by simply closing Pickering at the end of its design life. Furthermore, if the government follows through on its renewed commitment to conservation, the need to refurbish and extend the life of the eight reactors at Bruce B and Darlington would be called into question.

However, the OPA released new demand forecasts in the summer of 2013 as part of the LTEP review, which anticipate higher growth than the IESO data. As with their previous forecasts, the OPA is predicting significant growth in all but one scenario.[10] The difference between the OPA's low and high forecasts is very large: approximately 70 TWh, or close to 50% of current demand.[11] This difference is approximately equal to the amount of electricity generated by both Darlington as well as Bruce A and B (see Table A2 in the appendix). This significant uncertainty underlines the need for caution in electricity system planning, especially when considering procuring such large-scale increments of generation.

Compared to the OPA forecasts, the IESO data is more consistent with recent history in Ontario, where demand has dropped annually since 2005. This drop is in part a consequence of changes in the industrial structure, successful conservation programs, and the replacement of old capital with new, more efficient equipment. According to the IESO, electricity demand in Ontario is expected to decline further in 2013 "due to the rise of conservation and embedded generation capacity over the past three years."[12]

Embedded generation refers to decentralized generation options, such as rooftop solar, community wind projects or combined heat and power (CHP) facilities.[13] These facilities are "embedded" within local distribution networks and supply local electrical loads. They reduce demand and strain on the provincial transmission grid because they are not connected to it, and they reduce the need to transmit electricity from other parts of Ontario to meet local demand. The majority of embedded generation is solar power, and its output will increase to 1,700 MW by the end of 2014.[14] The decline in electricity demand and increase in embedded generation eliminates the need for nuclear generation to replace the soon-to-be decommissioned reactors at Pickering.

This report proposes an adaptive, incremental approach to dealing with possible future changes in electricity demand based first on conservation, and second on the deployment of clean energy options.

3. Nuclear costs keep going up

Over the past decade, the cost of building new nuclear reactors has been consistently underestimated in Ontario. New reactors are not cost-effective.

The OPA's cost estimates for new reactors have steadily risen, but Figure 3 shows that the agency is still underestimating costs compared to independent financial analysts and other regulatory agencies.

In 2006, based on the advice of the OPA, the Ontario government committed to building new reactors. At the time, the OPA advised the government that new reactors would cost approximately $2,600 per kilowatt (kW) and cost the electricity consumer between five and seven cents per kWh.[15] In 2007, the OPA told the government that new reactors would be cost-effective at up to $2,900 per kW, or about $6 billion for 2,000 MW. This would cost the consumer from 6.5 to 11 cents per kWh.[16]

At the time, the OPA argued this was a conservative estimate, and that it was higher than the estimated cost of next-generation reactors such as the Advanced CANDU Reactor (ACR) and Westinghouse's AP-1000 design.[17] Reactor vendors claimed these new reactors would be significantly cheaper than existing designs. That turned out not to be the case.

In 2007, environmental think tanks and organizations, including the Pembina Institute and Greenpeace, provided expert analysis to the Ontario Energy Board (OEB). They argued that a cost of $5,000 per kW for new reactors would be more accurate.[18] Under cross-examination the OPA admitted that, at an overnight capital cost of approximately $3,600 per kW, building new reactors would no longer be economical.[19]

In 2008, then-Energy Minister George Smitherman initiated the first competitive bidding process for new reactors. This bidding process required full risk transfer to reactor vendors, meaning that vendors would be responsible for delays and cost overruns.[20] The reported results of this process indicate that even the environmental organizations underestimated the full price of new reactors. The bidding process was suspended in 2009, and afterward it was reported that Atomic Energy of Canada Limited (AECL) had quoted a cost of more than $10,000 per kW, or $26 billion for a 2,400 MW station.[21] That is four times more than OPA's 2005 cost estimate.

In 2011, the federal government sold the CANDU reactor division of AECL to SNC-Lavalin. The newly formed CANDU Energy decided to abandon the marketing of its ACR design in favour of a repackaged version of its 1970s-designed CANDU-6 reactor. CANDU Energy claimed that the cost of building two "enhanced"[22] CANDU-6 reactors at Darlington would be between $5,000 and $7,000 per kW.[23]

This price range is higher than the estimate provided by environmental groups to the OEB in 2008, which the OPA acknowledged was uneconomical.[24] Even the leadership of CANDU Energy seems to acknowledge privately that their reactors are too costly for Ontario: Kevin Wallace, the president of CANDU Energy, told his employees in 2012 that "It's all about [dollars per megawatt] and we're too expensive."[25]

In 2013, the OPA estimated that new reactors would cost between $6,000 and $10,000 per kW to build, and would produce electricity at between 8.5 and 14 cents per kWh.[26] Table A4 in the appendix provides the OPA's most recent levellized unit energy cost (LUEC) for new reactors. Notably, a number of the assumptions used to calculate these costs differ significantly from both market risk assessments and historic nuclear performance.

During the development of the 2011 LETP, the OPA used a similar cost range of between eight and 13 cents per kWh. However, the OPA stated during public consultations that it would not consider non-nuclear options for replacing Pickering.[27] This occurred in spite of the government's 2011 supply mix directive, which instructed the OPA that new reactors should be procured only if they are cost-effective.[28]

Estimates by independent analysts indicate that the OPA continues to underestimate the cost of new reactors. In 2008, Moody's Investors Service estimated the cost of new reactors to be around 15 cents per kWh.[29] In 2011, the California Energy Commission estimated the cost of new reactors to range between 16 and 34 cents per kWh.[30] In 2013, Toronto-based Power Advisory LLC estimated the cost of new reactors in Ontario to be 15 cents per kWh.[31] Figure 3 shows how the cost estimates for building new reactors have increased steadily over the past decade.

In 2012, OPG paid $26 million to Westinghouse and CANDU Energy to develop cost estimates for the construction of new reactors.[32] OPG has not stated publicly whether this procurement process will also require the full transfer of risk for delays and cost overruns to the reactor vendors.

If not, the vendors could dramatically reduce their upfront prices by passing potential cost overruns onto taxpayers or electricity consumers. This represents a real risk, as all past nuclear projects in Ontario have gone over budget by anywhere from 40% to 250% (see Table A3 in the appendix).

While the cost of new reactors has increased significantly over the past decade, the cost of renewables continues to drop.[33] New nuclear is not a cost-effective choice for Ontario's energy future.

All past nuclear projects in Ontario have gone over budget by anywhere from 40% to 250%

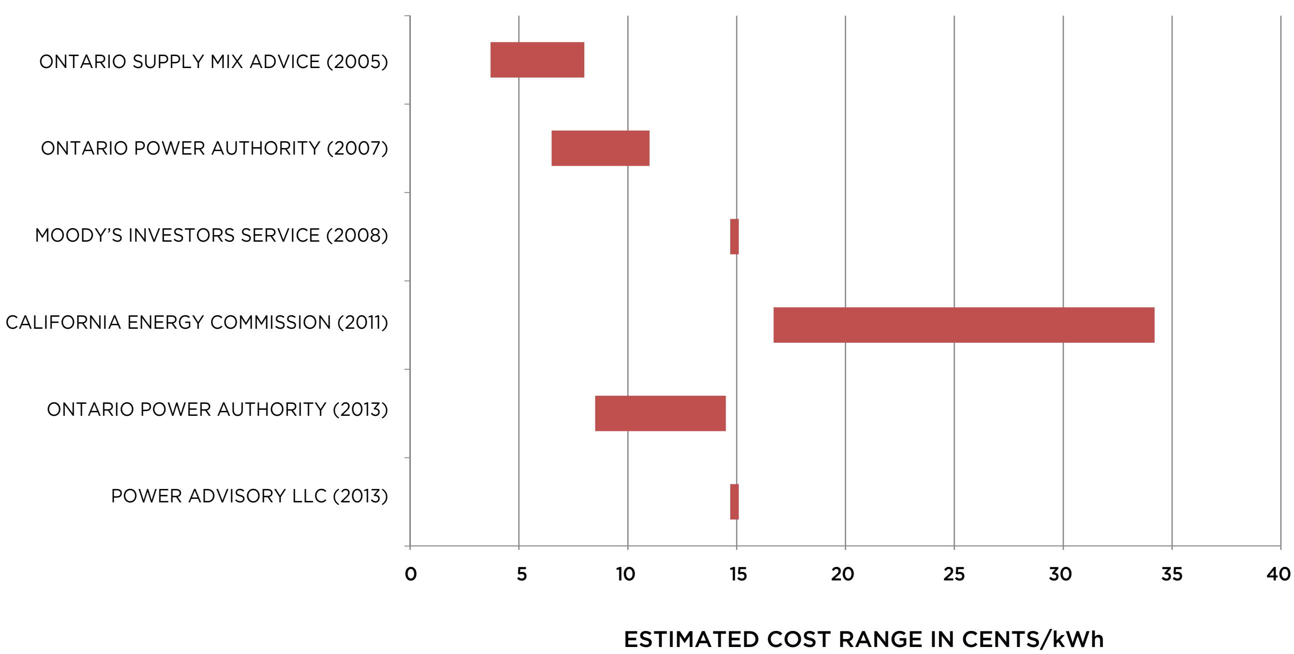

FIGURE 3
COST ESTIMATES FOR NEW NUCLEAR REACTORS
Calculated using data from the Ontario Power Authority, Moody's Investors Service, the California Energy Commission and Power Advisory LLC[34]

4. Surplus nuclear: A barrier to increased conservation

The government's commitment to conservation and efficiency is on a collision course with Ontario's over-reliance on inflexible nuclear generation. To increase conservation targets beyond current levels, the government will need to revisit its arbitrary commitment to maintaining nuclear at historic levels.

For several years now, Ontario's electricity system has been faced with the problem of surplus baseload generation (SBG). This occurs when there is more electricity being produced by non-flexible power plants than is needed or can be readily sold to neighbouring electricity markets. Because electricity supply and demand must always be balanced to maintain grid stability, this excess electricity supply poses a problem for system operators tasked with maintaining the reliability of Ontario's power system.[35]

Two remedies exist for SBG: exporting electricity to neighbouring jurisdictions, or turning off supply. Exporting has proven costly, forcing Ontario's grid operator to pay neighbouring jurisdictions to import the province's excess power. Turning off supply is also costly because generators that are curtailed (i.e. told to stop sending electricity to the grid) must be compensated for the resulting loss of revenue. Ontario has historically used nuclear stations to provide baseload generation, but reactors cannot be turned on and off rapidly in response to changes in demand.[36]

The province's surplus exists because in 2005 the government committed to increase nuclear supply, based on a forecasted growth in demand that failed to materialize. With electricity demand expected to continue falling, and with the government committed to reducing demand further through energy conservation, SBG conditions will persist for decades unless the government reduces its commitment to nuclear generation.

In 2005, the OPA produced its Supply Mix Advice Report with recommendations to the Ontario government on the future direction of the province's electricity system. The OPA told the government that "Ontario's most critical need in the long term is for base-load supply"[37] and that electricity demand was expected to increase dramatically over the next 20 years. To meet this forecasted growth in baseload demand, the OPA recommended that the government maintain nuclear's 50% share of supply.

Because the OPA expected significant increases in electricity demand, maintaining nuclear at 50% of supply would require building new reactors in addition to refurbishing all of Ontario's 20 existing reactors. The government accepted the OPA's advice, and its first supply mix directive in June 2006 called for nuclear capacity to potentially increase to 14,000 MW.[38]

Instead of growing as predicted by the OPA, electricity demand has fallen by 6% or 10 TWh since 2006.[39] According to the IESO, electricity demand will fall to 1992 levels by 2022. The failure of the OPA's 2005 demand forecast to materialize, combined with the increased commitment to inflexible baseload supply, is the root cause of the SBG situation the province has been experiencing.

The predicted return of electricity demand to 1992 levels should be taken as a warning: if it wants to avoid a situation of continued SBG, Ontario should reduce its installed nuclear capacity while continuing to prioritize energy conservation. This same challenge has arisen before. When Darlington went online in 1992, the result was a significant surplus of electricity. This forced the government of the day to scale back on its commitments to green energy and conservation.[40]

Indeed, with declining demand, Ontario will have to contend with significant SBG until the end of the decade.

Some renewable energy opponents have alleged that current SBG is due to the approximately 2,000 MW of wind generation that has been added to the grid. In fact, this surplus has two causes: the return to service of an additional 1,500 MW of nuclear generation at Bruce A, and OPG's plan to keep running Pickering until new reactors can come online.

As seen when Darlington went online in 1992, a surplus of electricity is a barrier to conservation. The OPA's preference will be to guarantee a market for the electricity once capital has been invested, especially for generation with high upfront capital costs like nuclear reactors, rather than to reduce demand. Any policy seeking to prioritize conservation must address how the costs and inflexibility of nuclear generation could be a barrier to the continued long-term advancement of conservation.

With demand dropping, conservation and green energy options are a more flexible way to address Ontario's changing electricity needs. Unlike large, centralized nuclear stations, renewable energy and conservation can be ramped up gradually — and switched on and off safely — in response to changes in demand.

As proposed in this report, a diverse mix of conservation, demand-side management and renewable energy, combined with smart grid technology, can replace the traditional base and peak loads model.

5. The unasked question: How should we replace aging reactors?

Ontario's current LTEP doesn't allow us to ask an important question: How should Ontario replace its aging nuclear stations when they reach the end of their operational lives?

Unlike other reactor designs, CANDU reactors require extensive repairs after approximately 25 years in order to continue operating. These repairs involve the removal and replacement of the hundreds of highly radioactive pressure tubes from the reactor core, as well as the replacement of other life-limiting components such as steam generators. The plant systems also have to be upgraded to meet modern regulatory requirements. This process is referred to as reactor "refurbishment" by the industry, although "reconstruction" may be a more appropriate term given the work, cost and timelines required to extend the life of a CANDU reactor.

A decade ago, CANDU operators argued that these extensive repairs were nonetheless economical compared to other generation options. The CANDU industry also argued that its history of cost overruns and delays would not be repeated. In 2005 Duncan Hawthorne, the chief executive officer of Bruce Power, said that his company's ability to refurbish two of the Bruce A reactors on time and on budget would be a "test case" for future nuclear projects in Ontario, and that "If we can't do this, don't talk nuclear again in this province."[41]

Those refurbishments — and every reactor life-extension project in Canada since then — were delayed and went significantly over budget. Nine of Canada's 22 CANDU reactors will be closed by 2020 due to the high cost of refurbishment. The estimated cost of refurbishing a CANDU reactor has tripled over the past decade. In 2002, the cost of refurbishing a CANDU reactor was estimated at approximately $840 million.[42] It has now increased to over $3 billion.[43]

In 2006, the OPA estimated that electricity from a refurbished CANDU reactor would cost between 6.3 and 8.0 cents per kWh;[44] by 2007, that estimate ranged between 6.4 and 8.5 cents per kWh.[45] In 2013, however, the OPA inexplicably reduced the lower bound of its cost estimate for refurbishment, and its upper bound is lower than Gentilly-2 or Pickering B refurbishment costs (see Figure 4). The OPA now estimates the cost of refurbishment to range between 5.5 and 9.0 cents per kWh.[46] The assumptions used to make these estimates differ remarkably from past experience refurbishing nuclear reactors (see Table A4 in the appendix).

According to documents acquired through Freedom of Information requests, in 2009 OPG decided against refurbishing the four Pickering B reactors when the cost reached approximately 10 cents kWh.[47] In 2012, Hydro-Québec decided to close the Gentilly-2 reactor based on the experience of other refurbishment projects at Point Lepreau, N.B. and in South Korea. It estimated that refurbishing Gentilly-2 would result in an electricity cost of 10.8 cents per kWh.[48]

Despite these significant cost increases, the Ontario government's 2011 LTEP directive does not require the OPA to ensure that reactor life-extension projects are cost-effective. In other words, the OPA has been directed to proceed with refurbishing the province's remaining reactors even if conservation and renewables are more affordable.

Because there is no obligation to demonstrate that future refurbishment projects are cost-effective, the OPA and OPG appear to have decided to withhold information on refurbishment estimates from the public. In 2009, OPG estimated the cost of refurbishing Darlington to be between six and eight cents per kWh. OPG, however, has refused to release its detailed cost estimates in response to Freedom of Information requests.[49] The OPA has also refused to release its internal 2010 review of alternatives to the Darlington refurbishment.[50]

Analysis conducted by the OPA in 2012 shows that it is cheaper to build new gas plants at current prices than to refurbish the Darlington or Bruce nuclear stations.[51] The analysis in this report also shows that at 10 cents per kWh, a portfolio of conservation and green energy is also competitive with nuclear refurbishment. Unfortunately, however, the current LTEP puts nuclear first and doesn't require nuclear to compete with or outperform other energy supply options.

To protect electricity consumers and Ontario's burgeoning renewable energy industry, the government should require the full risks and costs of reactor refurbishment projects be released and publicly reviewed before such projects are approved.

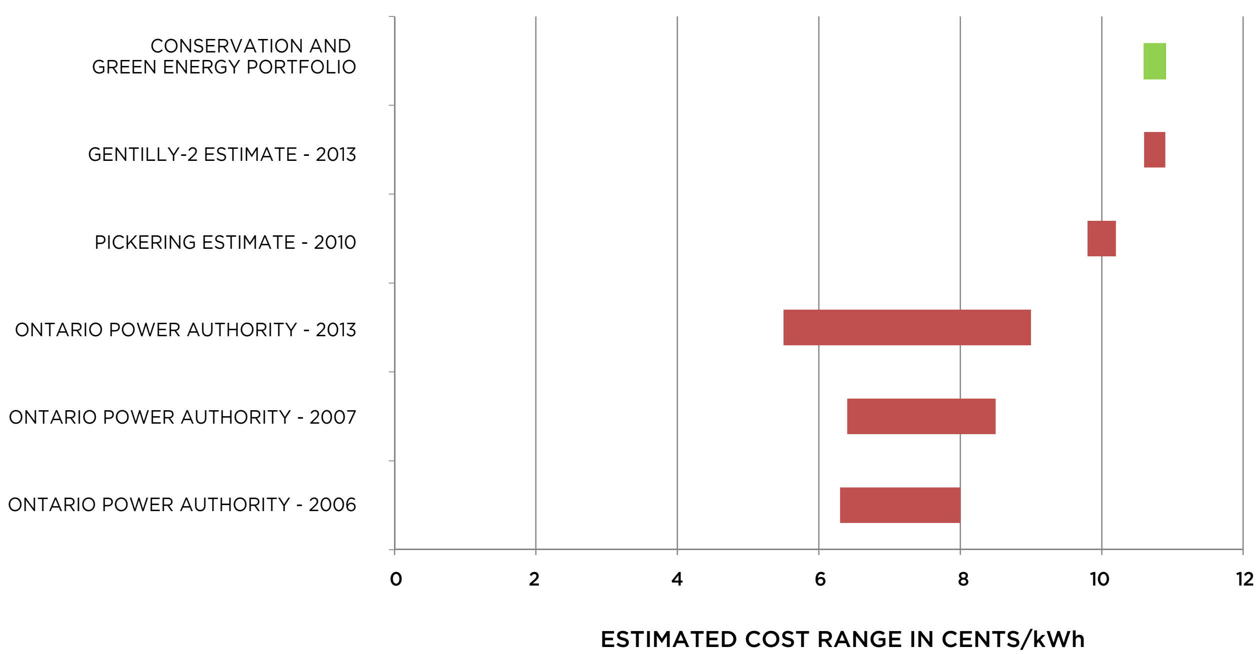

FIGURE 4
COST ESTIMATES FOR ELECTRICITY FROM REFURBISHED REACTORS COMPARED TO A GREEN ENERGY PORTFOLIO
Calculated using data from Ontario Power Generation, Hydro-Québec, and Ontario Power Authority[52]

6. Green energy's future: Even more affordable

If new generation is needed, it is more affordable to invest in a portfolio of renewable energy options than new reactors.

Ontario's 2011 LTEP put new supply options ahead of conservation and efficiency. The province's current conservation targets are initially high, but they drop significantly after 2020, when the new nuclear plant and refurbishment projects are scheduled to come online.

If Ontario were to truly put conservation first, the province's next LTEP would have escalating annual minimum conservation targets, until all economically feasible efficiency has been achieved. Such an approach could prevent future increases in electricity demand or even accelerate the current trend of declining demand.

Putting conservation first and reducing future electricity demand allows for a slower, more incremental approach to building new generation when it is needed. Green energy projects tend to be built in smaller and more diverse increments than large nuclear facilities. Such an approach is not only more sustainable, but also more flexible. New generation can be built out in a manner that better reflects changes in demand.

An example of a potential green energy portfolio that could replace nuclear generation is illustrated in Table 1. This portfolio includes a combination of conservation and green energy (see Table A5 in the appendix) and is capable of meeting Ontario's energy needs at a lower cost than new nuclear stations.

GREEN ENERGY PORTFOLIO	Total capacity additions 2015-2022 (MW)
Hydro	600
On-shore wind	1,000
Off-shore wind	200
Rooftop solar	500
Ground-mount solar	500
Biomass, biogas and landfill	300
Combined heat and power	325
Additional efficiency and conservation	450
Green portfolio total	3,875

TABLE 1
GREEN ENERGY PORTFOLIO BY TECHNOLOGY AND CAPACITY (MW)
Source: Pembina Institute

Unlike building a large nuclear plant, green energy capacity can be added in increments beginning in 2015 and ending in 2022. The full green energy portfolio would therefore be installed and feeding power into the grid well before the earliest proposed new reactors at Darlington could go online.[53] Green energy can also be commissioned and built in much shorter timeframes than nuclear projects. This incremental approach can be sped up or slowed down depending on how demand in Ontario changes in the coming years.

Although there is more variability in output from a green energy mix than from nuclear, this can be beneficial. The combined output of a diversified green energy portfolio actually follows typical changes in hourly demand better than nuclear generation, which runs at a constant output day and night (see Figure A3 in the appendix for details).

The costs for this portfolio were calculated based on 2013 feed-in tariff (FIT) prices,[54] as well as previous 2012 FIT prices for larger projects. The prices of both solar and wind energy are incrementally adjusted with annual declination rates of 8% and 1% respectively. These rates are based on historic price declines since the inception of Ontario's FIT program, as well as international precedents and published renewable price forecasts.[55]

A weighted cost for the total portfolio was then developed based on the percentage of the total 15 TWh produced by each of technology used. The result was a weighted 2023 cost of 10.35 cents per kWh. As is shown in Figure 5, this is lower than the cost of electricity from new reactors as estimated by independent analysts. Moody's Investors Service estimates that new nuclear costs close to 15 cents per kWh,[56] while the California Energy Commission puts the cost as high as 34 cents per kWh.[57] These numbers illustrate both the variability of nuclear cost estimates and the degree to which costs are increasing.

The green energy portfolio is also diversified in terms of technologies. This helps to ensure that any increases in the cost of a specific technology or its associated fuel (such as in the case of CHP and biomass) have minimal impact on the portfolio. That said, the costs of renewable energy technologies have actually been continually declining. For instance, between 2011 and 2012 the costs of utility-scale solar systems fell by 40%, and those of residential systems fell by nearly 30%. The overall price of solar panel modules has fallen 80% since 2008. The cost of on-shore wind turbines also fell by 2-3% from 2011 to 2012, and prices in wind capacity auctions continue to fall in markets worldwide.[58]

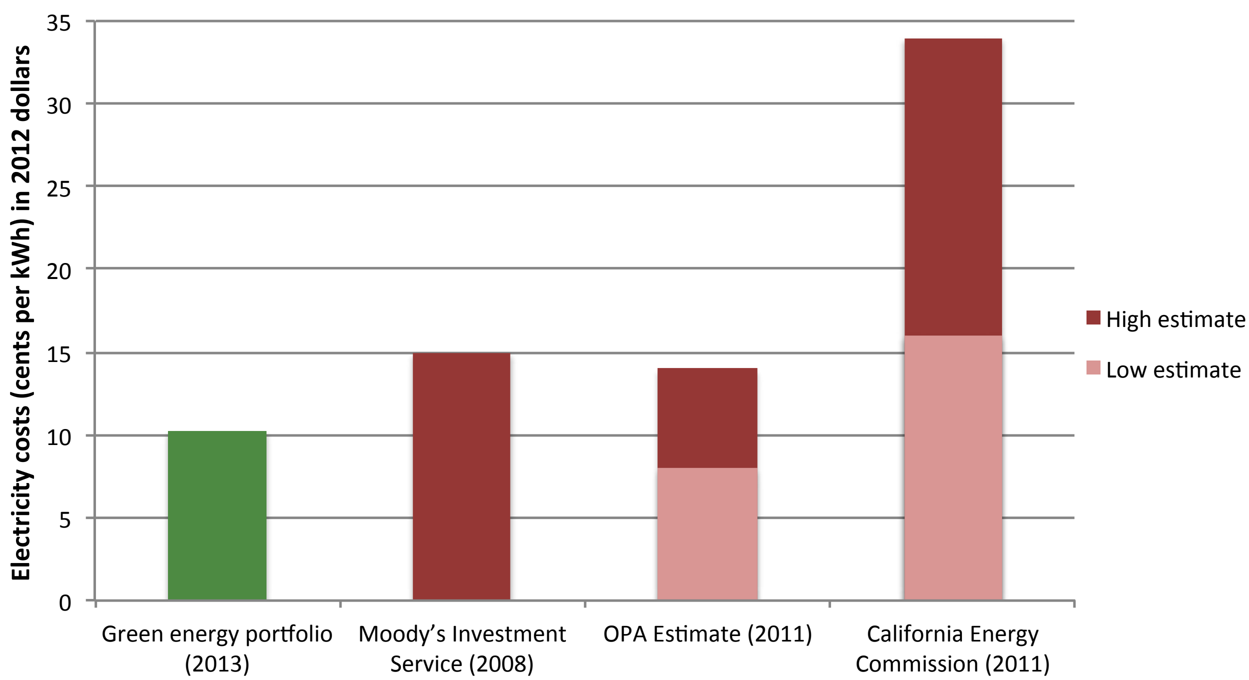

FIGURE 5
COST OF A GREEN ENERGY PORTFOLIO FOR ONTARIO COMPARED TO NEW NUCLEAR GENERATION
Calculated using data from the Ontario Power Authority, Moody's Investors Service and the California Energy Commission[59]

More information on the breakdown of the green energy portfolio by technology can be found in Table A5 of the Appendix.

7. A sustainable, low-carbon mix

Diverse and resilient, green energy is a sustainable, low-carbon way to meet Ontario's energy needs at a more affordable cost.

Renewable energy opponents often emphasize that variable renewable generators are dependent on fossil fuel backups. However, these sceptics fail to acknowledge that large, centralized nuclear stations also need fossil-fuel-powered stations for backup in the case of planned or unplanned outages.

Ontario was forced to shut down seven reactors in 1997 due to safety concerns. To compensate for the loss of approximately 5,000 MW of supply, the government was forced to increase reliance on its coal stations, thus increasing Ontario's greenhouse gas (GHG) emissions by 120%.[60]

The proposed solution was to return the Pickering and Bruce A nuclear stations to service as quickly as possible. This solution was undermined by the same problems that often afflict nuclear projects: cost overruns and delays. OPG initially claimed that it could restart all four of the Pickering reactors by the end of 2001,[61] but abandoned the restart of the last two Pickering A reactors in 2005 because of the prohibitive cost.[62] Similar delays and cost overruns were also experienced while restarting the Bruce A reactors.

With the phase-out of coal-fired generation, Ontario now relies on large gas plants to back up the province's nuclear stations in the event of unforeseen or planned outages (output variation of the Pickering station can be seen in Figure A2 in the appendix), including the multi-year refurbishments scheduled for most of the existing reactors. In 2011, the OPA estimated that GHG emissions would increase by approximately six megatonnes between 2015 and 2020, as gas generation is used to back up reactors at Darlington while they are refurbished.[63]

Judging from past experience, large gas plants will have to be relied on for longer than anticipated as refurbishment projects experience delays. Given this context, reducing electricity demand and shifting to a more decentralized renewables-based system looks even more appealing — it is a lower-risk and more cost-effective approach to achieving a low-carbon electricity system.

The green energy portfolio described in this report is an affordable, low-carbon alternative to building new reactors. This green energy portfolio reduces electricity demand through additional efficiency and conservation, and provides reliable electricity when Ontarians need it using green energy technologies.

The portfolio was modelled using actual IESO historic output data for each supply source.[64] The hydro data was weighted to reflect the relative shares of run-of-river projects and large storage reservoirs in Ontario. When the overall output of this portfolio is aggregated, we see that it averages more output during higher-demand (and higher-value) hours both in the summer and in the winter, as illustrated in Figure 6 and Figure 7 respectively. As well, Figure A4 and Figure A5 in the appendix illustrate how the average outputs of wind and solar systems complement each other to help create this overall profile.

In the absence of explicit electricity storage systems, natural gas[65] and reservoir hydro are required to complement the proposed green energy portfolio, much as they are required for outages and maintenance of a comparably sized nuclear facility.

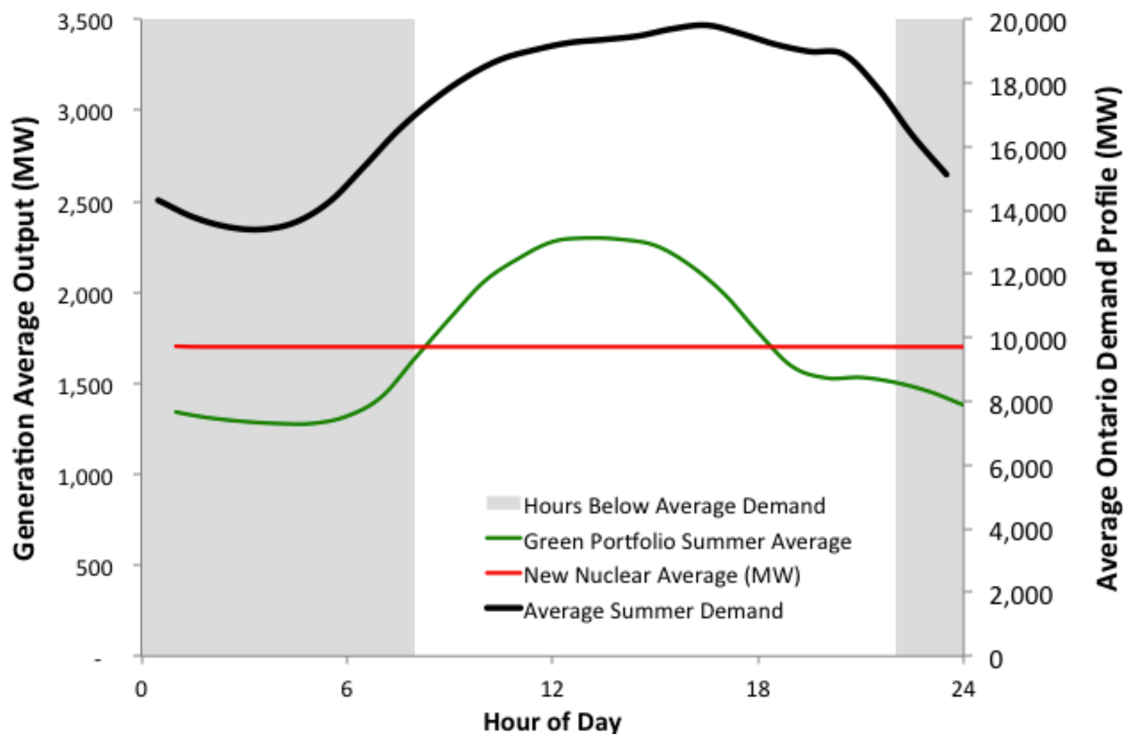

FIGURE 6

AVERAGE SUMMER GENERATION OUTPUT COMPARED TO SUMMER DEMAND

Calculated using data from the Independent Electricity System Operator[66]

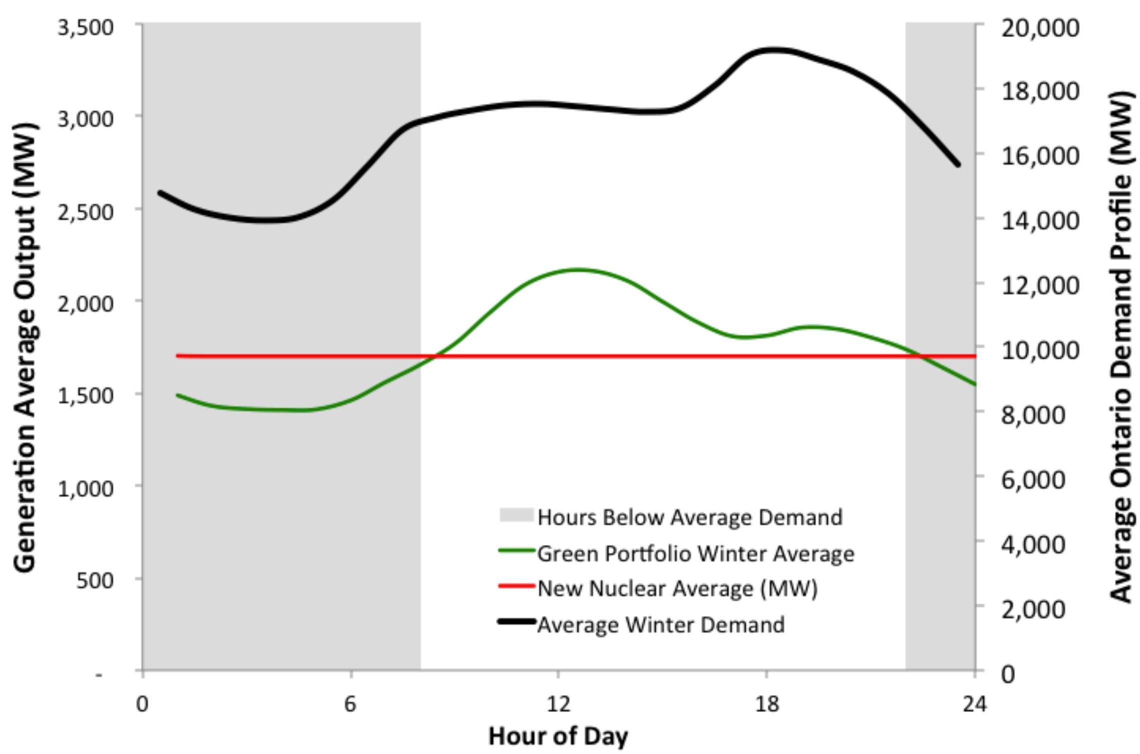

FIGURE 7

AVERAGE WINTER GENERATION OUTPUT COMPARED TO WINTER DEMAND

Calculated using data from the Independent Electricity System Operator[67]

8. Keep the door open: The renewable revolution

The cost of renewable energy is falling and the Fukushima nuclear accident has accelerated deployment of renewables, as some of the world's largest economies abandon nuclear power while redoubling their efforts to fight climate change.

With major nuclear accidents having occurred approximately once per decade somewhere in the world, the risk of future accidents is significant.[68] Such accidents, even when they occur overseas, invariably call into question the safety of currently operating reactors. Addressing future safety concerns could lead to the shutdown of nuclear stations in Ontario, resulting in billions of dollars in stranded investment.

Germany, Belgium and Switzerland have all committed to ending their reliance on nuclear power following the 2011 Fukushima accident in Japan. In the wake of the accident, the Japanese government passed legislation similar to Ontario's Green Energy Act, which has lead to a 73% surge in renewable energy investment in 2012 and a total of US$16 billion invested in renewables.[69]

Japan and Germany are the world's third- and fourth-largest economies. Their decision to abandon nuclear power and fight climate change will spur significant investments in renewable technology over the next decade. The International Energy Agency predicts that global power generation from renewable sources will be twice that of nuclear by 2016, and it will also exceed power generation from gas.[70]

The collective power of small, decentralized renewable generation is already out-producing centralized coal, gas and nuclear stations. Germany's solar panels, for example, produced more electricity than the four reactors at Darlington in 2012.[71] In China, wind produced more electricity than nuclear for the first time in 2012, and also grew at a faster rate than coal generation.[72]

In Ontario, the preferential treatment given to nuclear generation in the government's current supply mix directive effectively limits the growth of renewable energy and local electricity generation. Figure A1 in the appendix illustrates how wind is constrained under the current directive. As mentioned earlier, the directive also provides a disincentive to conserving electricity, as this would aggravate the SBG problem that Ontario faces.

Figure 8 shows an international selection of non-hydro[73] renewable energy targets for 2020, as a percentage of electricity supply compared to their current contribution. Ontario is shown for the purpose of comparison. Clearly, Ontario's initial leadership developing diverse supplies of renewable energy (see Table A7) will be lost without increased targets in the next LTEP directive."

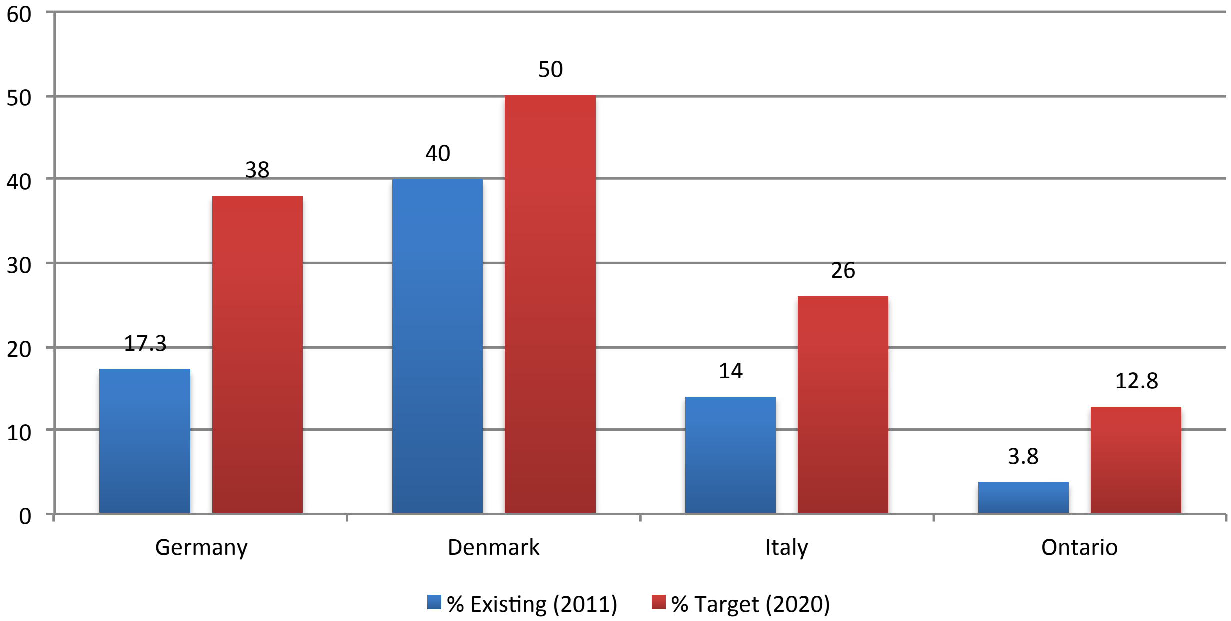

FIGURE 8

ELECTRICITY PRODUCED FROM NON-HYDRO RENEWABLES

Source: Calculated using data from the Government of Germany, REN 21, Independent Electricity System Operator and the Ministry of Energy Ontario[74]

By constraining renewables in its LTEP, Ontario risks more than simply losing its current position as a leader in the development of renewable energy. The province also risks putting itself at a competitive disadvantage, by being stranded with expensive and unneeded electricity supply from nuclear that hampers the growth of renewables.

The cost of renewable energy technologies, especially solar power, is dropping dramatically (see Figure 9). Academic observers predict the ongoing decline in solar costs will make it hit grid parity — the price at which solar becomes competitive with traditional supply without any subsidies — in both North America and Europe within the next five to 10 years.[75] In fact, a July 2013 report from Deutsche Bank[76] notes that residential-scale solar photovoltaic (PV) systems have already reached grid parity in 11 jurisdictions internationally, including Italy, South Africa and South Korea. Ontario is closer to solar grid parity than Germany (see Table A8 in the appendix).

Solar power's rapid progression toward grid parity disrupts the business model of traditional electrical utilities.[77] As solar prices drop, consumers may increasingly decide to produce electricity themselves. This reduces grid demand and poses a significant threat to the bottom line of traditional electrical utilities. Cost-competitive solar power means that electricity consumers could simply remove themselves from the market on most days.

The rapid decline in solar prices, and its potential financial impact on maintaining nuclear at historic levels, is not even acknowledged by the OPA in its LTEP planning documents. The OPA assumes a static price for solar power between 35 and 55 cents per kWh based on current feed-in tariff prices.[78]

Despite their continually increasing affordability, renewables are constrained in the current LTEP. Table A6 in the appendix shows that most of the renewable energy capacity that has been procured by the Ontario government will be built by the end of 2014, with much smaller amounts coming online from 2015 to 2018. Of the government's 10,700 MW target for renewables, nearly 2,000 MW has yet to be procured, raising questions about the government's commitment to continued renewable energy development.

The global trend in the renewable energy sector can be either an opportunity for building a more sustainable electricity system in Ontario, or a threat to the province's long-term competitiveness. If the government continues with its nuclear-first approach to energy planning, Ontario could be saddled with unneeded and expensive nuclear supply for decades to come.

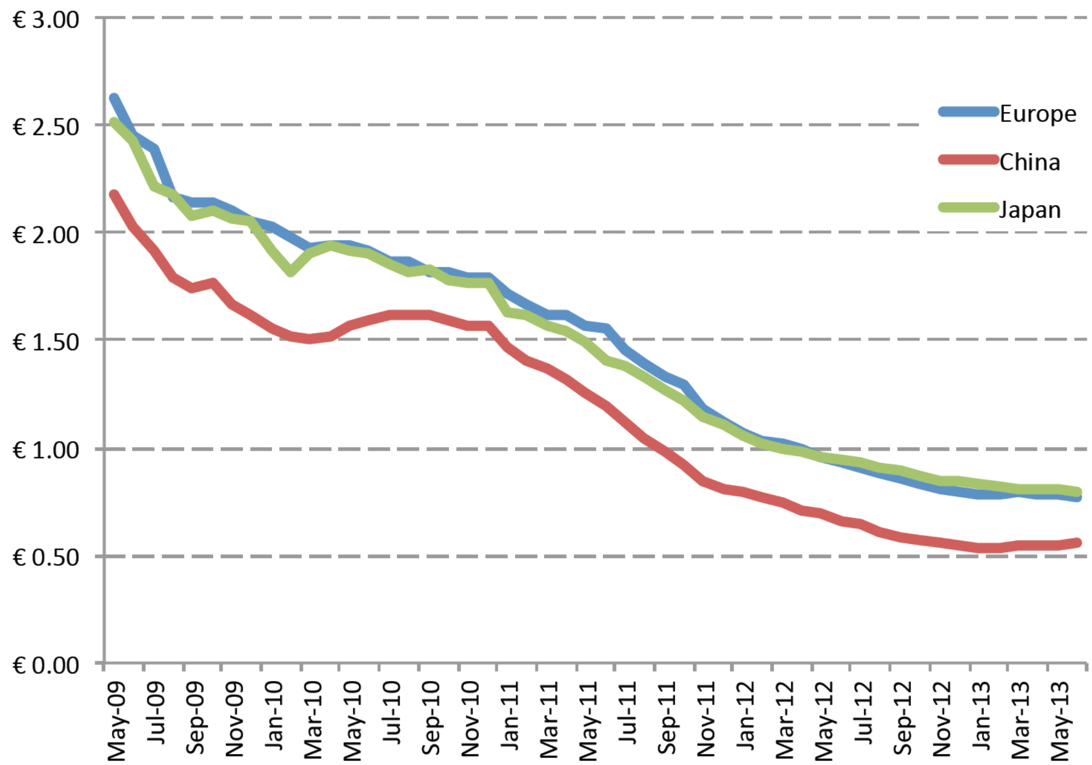

FIGURE 9
PRICE PER WATT OF SOLAR PHOTOVOLTAIC MODULES
Caluclated using data from pvXchange and SolarServer[79]

9. Conclusion: Avoid locking into a nuclear future

Why risk tens of billions of dollars on building or refurbishing reactors when conservation and green energy solutions can keep the lights on at a lower cost?

History has repeated itself since 2006, when the Ontario government committed to building new reactors and refurbishing all of its aging ones. The estimated cost of building new reactors has skyrocketed, all reactor life-extension projects in Canada have gone significantly over-budget, and the projected increase in electricity demand has failed to materialize.

Meanwhile, the ongoing Fukushima nuclear accident in Japan has accelerated the global deployment of renewable energy, as some of the world's largest industrial economies seek to eliminate nuclear risks.

Based on the evidence, there is a clear need to end Ontario's commitment to maintain nuclear generation at the historic level of 50% of electricity supply. This is especially true if the government wants to continue to follow through with its "Conservation First" energy initiative and maintain a viable renewable energy industry.

With declining electricity demand, new reactors are no longer needed to replace the Pickering generation station. But even if there was a residual need to replace this lost capacity with new generation, the high cost of new nuclear plants and the declining cost of green energy options would make new reactors a more costly choice.

With electricity demand forecasted to fall over the next decade, the debate about Ontario's electricity future should focus on whether renewable energy and conservation should be considered to replace the aging Darlington and Bruce B stations.

Given the cost overruns of all Canadian CANDU life-extension projects, there is good reason to question the prudence of the government's life-extension plans for Darlington and Bruce B. The government's current energy policy does not require these projects to be cost-effective or even publicly reviewed. This leaves Ontario's electricity consumers in the dark, and potentially on the hook for billions of dollars, while also putting the province's renewable energy industry at risk.

With the continually increasing affordability of green energy options, the government should avoid locking itself into refurbishment projects until operators have declared the full costs and risks, and then subjected their numbers to an open and transparent public review.

Key steps to ensure clean, affordable electricity

1. To support the government's "Conservation First" policy, the Ontario Power Authority should pursue all cost-effective conservation and efficiency opportunities before it considers procuring new generation. Ontario's next long term energy plan should establish ambitious demand reduction targets, with escalating minimums for 2020, 2025 and 2030.

2. The arbitrary requirement that nuclear power must provide 50% of Ontario's electricity should be eliminated. Instead, there should be fair competition among all alternatives based on cost as well as their environmental risks and benefits.

3. Because all past nuclear projects in Canada have significantly exceeded their budgeted cost, the costs and risks of reactor life-extension projects should be subject to open and transparent public review.

Appendix

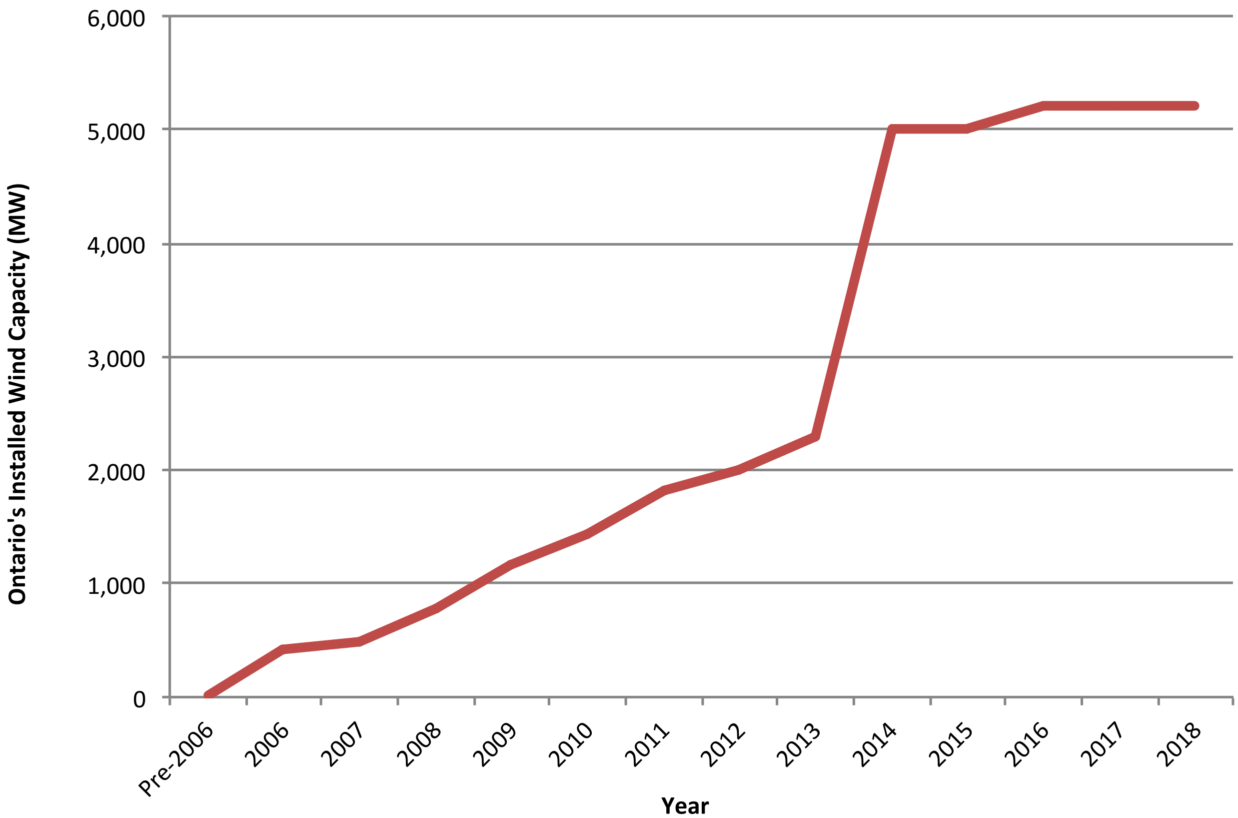

FIGURE A1
WIND ENERGY GROWTH IN ONTARIO
Calculated using data from the Ministry of Energy, Ontario Power Authority, Independent Electricity System Operator and Samsung[80]

The currently procured and expected (i.e. revised Korean Consortium/Samsung wind projects) wind power capacity will fully meet government targets by 2016.

<table>
<tr><th></th><th>Actual</th><th>Current</th><th colspan="10">Projected</th></tr>
<tr><td>Unit</td><td>2011</td><td>2012</td><td>2013</td><td>2014</td><td>2015</td><td>2016</td><td>2017</td><td>2018</td><td>2019</td><td>2020</td><td>2021</td><td>2022</td></tr>
<tr><td>Peak (MW)</td><td>25,450</td><td>23,298</td><td>23,301</td><td>23,080</td><td>22,859</td><td>22,638</td><td>22,471</td><td>22,583</td><td>22,891</td><td>23,010</td><td>23,390</td><td>23,442</td></tr>
<tr><td>GWh</td><td>141,474</td><td>140,106</td><td>142,792</td><td>139,139</td><td>135,487</td><td>131,834</td><td>129,965</td><td>130,369</td><td>132,556</td><td>134,163</td><td>135,339</td><td>135,879</td></tr>
</table>

TABLE A1
IESO 10-YEAR DEMAND FORECAST
Source: Independent Electricity System Operator[81]

This demand forecast was acquired through a Freedom of Information request to the Independent Electricity System Operator dated July 19, 2012. This forecast differs significantly from the "Medium Growth Demand" scenario used as the basis for the government's 2010 LTEP. The forecast used in 2010 LTEP predicted that demand would be approximately 23.5% higher in 2022 than the IESO forecast. The above forecast is also lower than even the "Low Growth Scenario" presented in the 2013 LTEP review.

Status	Commitment	Station	Installed (MW)	Annual Production (TWh)
Committed	Refurbishment	Bruce A	3,000	21.8
Directed	Refurbishment	Darlington	3,524	25.6
Directed	Refurbishment	Bruce B	3,287	23.9
Directed if economical	New Reactors	Darlington	2,000	14.5
TOTAL			11,811	85.8

TABLE A2
NUCLEAR PRODUCTION IN THE 2011 LONG-TERM ENERGY PLAN
Source: Adapted from Ontario Power Authority[82]

This table shows the status and potential production of Ontario's nuclear stations under the 2011 LTEP directive. At present, only the refurbishment of the four Bruce A reactors has been fully committed to by the government. According to the 2011 directive, the construction of two new reactors may only proceed if it is economical, but the refurbishment of the eight Darlington and Bruce B reactors could proceed even if not economical. The chart provides estimates of annual generation in TWh assuming an 83% capacity factor.

Project	Estimated cost	Actual cost	Overrun factor
Pickering A (1965-1973)	$508 million (dollars of the year)	$716 million (dollars of the year)	1.4
Pickering B (1974-1986)	$1.585 billion	$3.846 billion	2.4
Bruce A (1969-1978)	$930 million (dollars of the year)	$1.8 billion (dollars of the year)	2
Bruce B (1976-1989)	$3.929 billion	$5.994 billion (dollars of the year)	1.5
Darlington (1977-1993)	$4 billion	$14.3 billion	3.5

TABLE A3
COST OVERRUNS FOR NUCLEAR PLANT CONSTRUCTION IN ONTARIO
Source: Adapted from Ontario Hydro[83]

VARIABLE		Refurbished nuclear		New nuclear	
		Low estimate	High estimate	Low estimate	High estimate
Overnight capital cost, excluding land ($/kW)	Overnight dollars per kW	$1,800	$2,400	$6,000	$10,000
Duration of service	Life (years)	30	30	60	60
Capacity factor, excluding refurbishments	Acf (per cent)	87.1%	87.1%	90.0%	90.0%
Fuel heat rate	MMBtu per MWh	1.00	1.00	1.00	1.00
Fuel price, excluding transport, excluding general rate case	Fuel rate dollars per MMBtu	$5.00	$5.00	$5.00	$5.00
Nominal return on equity after tax	ROE rate per year	9.00%	16.00%	9.66%	9.66%
Nominal interest rate	Interest rate per year	5.48%	5.48%	5.48%	5.48%
Debt ratio (percentage of gross assets at start of service)	Debt ratio (per cent)	53.00%	30.00%	53.00%	53.00%
Levellized unit electricity cost (LUEC)	Real dollars per MWh	$55.00	$90.00	$85.00	$140.00
LUEC Breakdown	Capital	$17.2	$45.0	$61.3	$99.8
	Operating	$32.5	$40.3	$17.7	$31.7
	Fuel	$5.0	$5.0	$5.0	$5.0
	Total	$54.6	$90.3	$84.0	$136.4

TABLE A4

2013 OPA NUCLEAR POWER COST ESTIMATES

Source: Adapted from Ontario Power Authority[84]

GREEN ENERGY PORTFOLIO	Total capacity additions 2015-2022 (MW)	GWh (2023)	Weighted average price cents per kWh (2013-2022)
Hydro	600	2,891	12.65
On-shore wind	1,000	2,453	10.83
Off-shore wind	200	613	17.89
Rooftop solar	500	569	24.11
Ground-mount solar	500	569	21.16
Biomass, biogas and landfill	300	1,577	14.7
Combined heat and power	325	2,278	8.50
Additional efficiency and conservation	450	3,942	3.00
Green portfolio total	**3,875**	**14,892**	**10.35**
Darlington new reactors	2,000	14,892	15.00
Nuclear total	**2,000**	**14,892**	**15.00**

TABLE A5

GREEN ENERGY PORTFOLIO COMPOSITION, OUTPUT AND PRICE COMPARISON WITH NEW NUCLEAR

Note: The nuclear price is based on a 2008 estimate from Moody's Investors Service,[85] which is conservative compared to the 2011 California Energy Commission estimate also presented in this report.[86] Since FIT 3 pricing, which was announced in August 2013, is exclusively for projects with a capacity of 500 kW and less, FIT 2 pricing has been used for the portfolio in instances where the typical project size would be larger than 500 kW (including hydro and biomass).

Table A5 shows that the total average price of the green energy portfolio is already competitive with the price of new nuclear reactors. The price of major new renewable energy technologies, notably wind and solar, is continuing to drop, even beyond major reductions that have occurred over the past several decades.

Ontario's FIT program provides an example of this phenomenon. The result of the two-year FIT review was a price decrease of approximately 15% for wind projects and of more than 20% for solar projects. Additional price decreases were also announced for the FIT program in August 2013. These included a 39% drop in the price for rooftop solar PV projects of 100 kW or larger and a 25.8% decline in the price for non-rooftop (ground-mount) solar PV over 10 kW.

This pricing decline was largely in response to the evolution of the global renewables market, which resulted in both capital and operating cost reductions. This trend of decreasing prices for renewables technology is expected to continue into the foreseeable future, making renewable energy projects even more affordable for Ontario.[87]

The Green Energy Portfolio would deliver the same amount of power as the proposed new reactors at Darlington by using a range of complementary, proven technologies.

First, additional conservation and efficiency would be used to decrease peak and overall demand, as these approaches have been shown to be the most cost-effective.[88] Additional solar power would be added as its maximum output corresponds to the daytime hours in the summer when Ontarians need the power the most (see Figure A4). Additional geographically distributed wind capacity would complement this solar power by producing electricity at a low cost when the sun is not shining (see Figure A4 and Figure A5). Wind also has a higher capacity factor than solar and provides dispatchability, as wind turbines can be turned off much more easily than inflexible nuclear plants if required. Additional small hydro capacity is also included in the portfolio given its high capacity factor (modelled at 55% for the portfolio) and the opportunities that exist in Ontario.

The portfolio would be rounded out by adding biomass, biogas and landfill gas, as well as combined heat and power (CHP) projects. The former have a high capacity factor (modelled at 60% for the portfolio) and use agricultural residues as a feedstock, reducing Ontario's dependence on imported fuels. Investing in additional CHP capacity (modelled at an 80% capacity factor) would ensure that the natural gas that we do burn is used as efficiently as possible, producing both heat and electricity, while reducing the amount of natural gas required and the associated greenhouse gas emissions. This approach has proven effective in Denmark, where decentralized CHP installations — many of which use biomass for fuel — have created a more efficient and resilient power system.[89]

Nuclear plants can take a decade or more to go through the approvals and construction phase. Under the FIT program in Ontario, renewable energy technologies such solar and wind projects (depending on the size) are allowed a maximum of 1.5 years and three years respectively to reach commercial operation.[90]

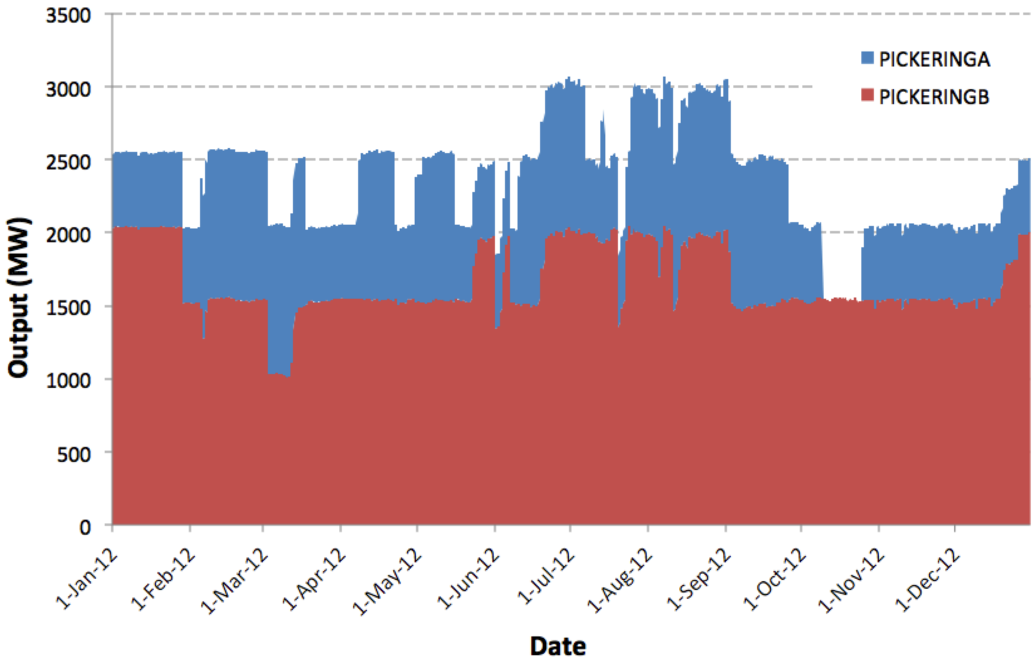

FIGURE A2

PICKERING NUCLEAR STATION 2012 OUTPUT

Source: Independent Electricity System Operator[91]

Figure A3 illustrates sample output comparing typical changes in output from the proposed green energy portfolio and output from a nuclear station. This data was compiled by scaling actual output from the suite of technologies for the 2012 calendar year, and the Pickering nuclear station in 2012. These data should not be interpreted as actual forecasts, but rather samples of variations in output that could be expected and how they compare to the daily patterns in demand from the province. Note that the Ontario demand is on a much larger scale than either of the proposed options.

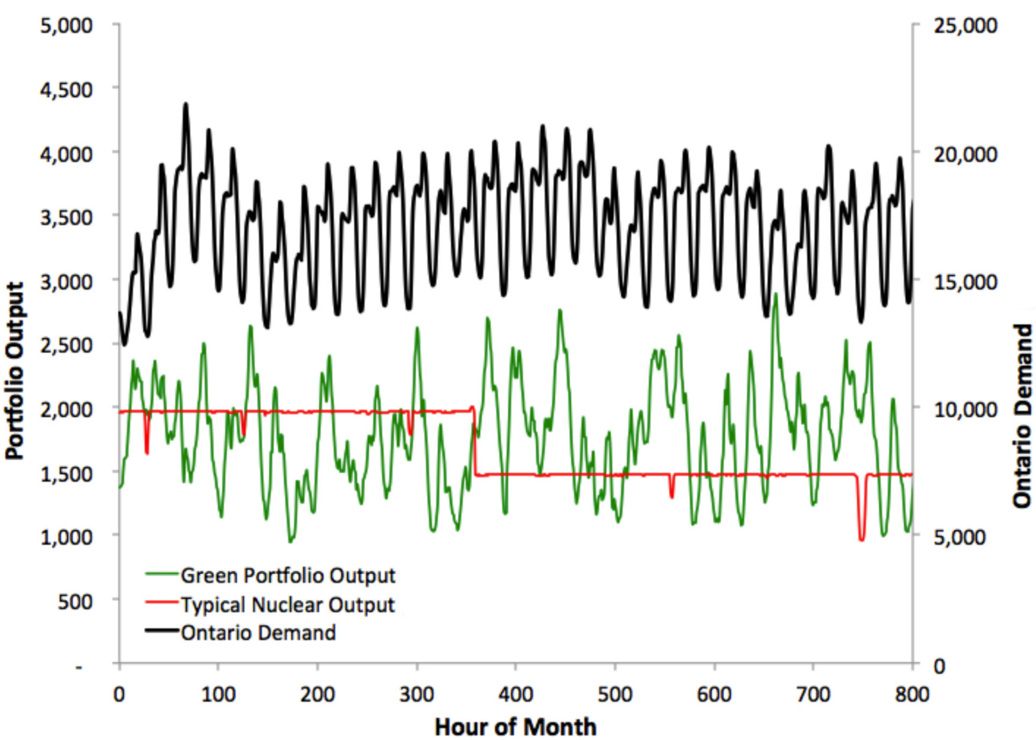

FIGURE A3

COMPARING TYPICAL OUTPUT PROFILES TO ONTARIO DEMAND PATTERNS

Source for Ontario Hourly Demand: Independent Electricity System Operator[92]

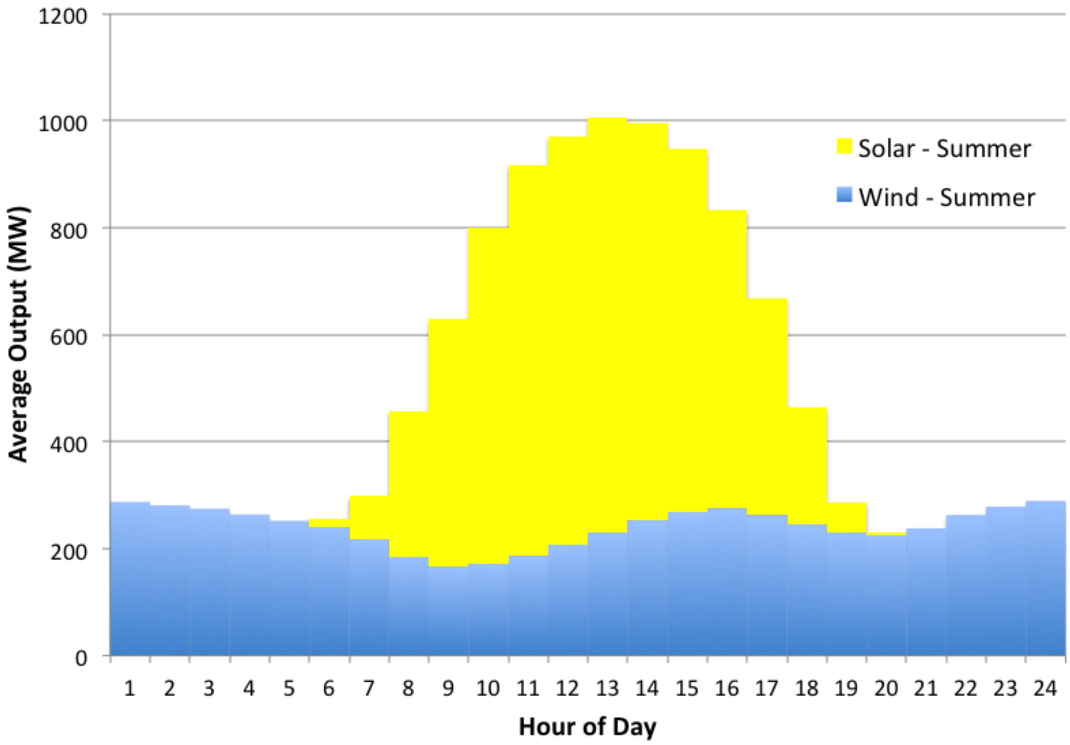

FIGURE A4

AVERAGE SUMMER WIND AND SOLAR PORTFOLIO OUTPUTS

Source: Modelled from historic output data[93]

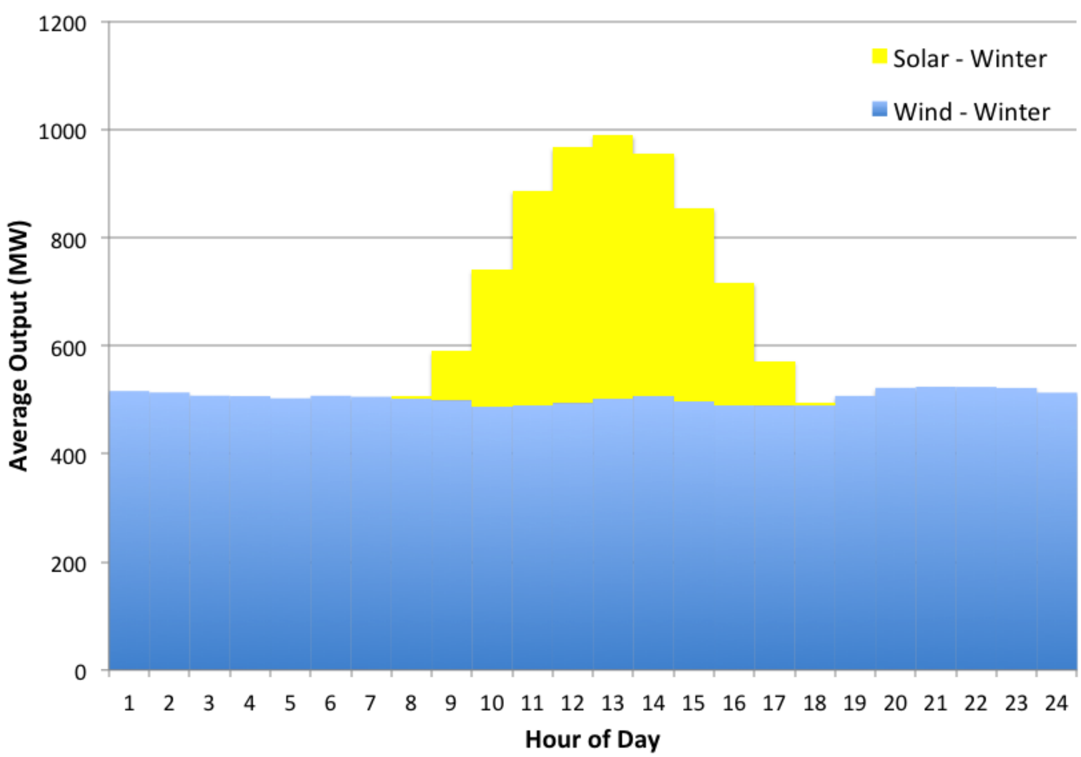

FIGURE A5

AVERAGE WINTER WIND AND SOLAR PORTFOLIO OUTPUTS

Source: Modelled from historic output data[94]

Average wind energy output in Ontario is slightly higher (5-6%) overnight than it is during day. This pattern complements solar output, which peaks during the day. Using historic Ontario electricity generation data for the existing technologies proposed in the green portfolio, we can see that it has an amplitude of variation and ramp rates already within the output of the existing Pickering units.

Although the output of such systems is not constant, increased geographic diversity, combined with demand response and energy storage, can smooth variability. A diverse supply mix ensures reliable and cost-effective supply.

RENEWABLE ENERGY PROCUREMENT CATEGORIES	2013	2014	2015	2016	2017	2018
Existing	2,854	2,854	2,810	2,810	2,805	2,805
Green energy investment agreement	-	1,069	1,069	1,369	1,369	1,369
Contracted and under development	1,084	2,351	3,247	3,477	3,477	3,477
Future small FIT and microFIT procurements	13	268	478	678	878	1,053
Additional future options	-	50	500	1,000	1,500	1,997
Total	**3,951**	**6,591**	**8,103**	**9,333**	**10,028**	**10,700**

TABLE A6

2013-2018 WIND, SOLAR AND BIOENERGY PROCUREMENT FORECAST (MW)

Source: Adapted from Ontario Power Authority[95]

Note: The "additional future options" presents a possible scenario for additional renewable energy deployment between 2014-2018, in order to achieve Ontario's target of 10,700 MW of non-hydro renewable energy capacity by 2018.

PROGRAM	Fuel type	Operational (MW)	Procured (MW)	Uncertain (MW)	Total (MW)	Estimated annual output (TWh)
Pre-FIT	Wind	1,778.80	36.00	0.00	1,814.80	4.45
	Solar PV	455.20	20.00	0.00	475.20	0.50
	Biomass	89.00	22.00	0.00	111.00	0.58
	Sub-total	2,323.00	78.00	0.00	2,401.00	5.53
FIT	Wind	279.80	2,832.76	0.00	3,112.56	7.63
	Solar PV	308.80	1,016.96	953.73	2,279.49	2.40
	Biomass	18.80	44.75	14.77	78.32	0.41
	Sub-total	607.40	3894.47	968.50	5470.37	10.44
Samsung	Wind	0.00	1,069.00	0.00	1,069.00	2.62
	Solar PV	0.00	300.00	0.00	300.00	0.32
	Biomass	0.00	0.00	0.00	0.00	0.00
	Sub-total	0.00	1,369.00	0.00	1,369.00	2.94
Atikokan	Biomass	0.00	205.00	0.00	205.00	0.15
	Sub-total	0.00	205.00	0.00	205.00	0.15
Totals		**2,930.40**	**5,546.47**	**968.50**	**9,445.37**	**19.06**
Total new renewable energy generation by 2018 (TWh per year)			**19.06**			

TABLE A7

ONTARIO'S GROWING RENEWABLE SUPPLY

Source: Adapted from Ontario Power Authority and Ontario Ministry of Energy[96]

Note: The uncertain solar PV data refers to 98% of the remaining 738.5 MW of Small FIT from the June 2013 ministerial directive, as this was the proportion of solar PV awarded in the first Small FIT contracts. The remaining 2% of this figure is assigned to biomass. 230 MW were also added for the microFITs that are to be procured, which will be nearly 100% solar PV.

JURISDICTION	LCOE (per kWh)	Cost of electricity	Type	Solar versus avoided cost
Los Angeles	$0.15	$0.20	Residential	($0.05)
Hawaii	$0.14	$0.37	Residential	($0.23)
New Jersey	$0.21	$0.16	Residential	$0.05
Ontario	**$0.23**	**$0.12**	**Residential**	**$0.10**
Chile	$0.15	$0.25	Residential	($0.10)
Japan	$0.18	$0.29	Residential	($0.11)
China	$0.18	$0.11	Industrial	$0.07
India	$0.14	$0.09	Wholesale	$0.05
South Korea	$0.16	$0.19	Residential	($0.03)
Australia	$0.15	$0.16	Residential	($0.01)
South Africa	$0.15	$0.21	Residential	($0.06)
Israel	$0.14	$0.18	Residential	($0.04)
Germany	$0.26	$0.15	Residential	$0.11
Germany	$0.26	$0.13	Industrial	$0.13
Italy	$0.18	$0.38	Residential	($0.20)
Italy	$0.18	$0.35	Industrial	($0.18)
Spain	$0.18	$0.19	Residential	$0.00
Greece	$0.15	$0.29	Residential	($0.14)
Greece	$0.15	$0.19	Industrial	($0.04)

TABLE A8
INTERNATIONAL JURISDICTIONS AT OR NEARING SOLAR PV GRID PARITY
Source: Adapted from Vishal Shah et al.[97]

Note: The parentheses in the "Solar versus avoided cost" column indicate that using solar power in these jurisdictions is cheaper than purchasing power from the local grid. As indicated, some of the solar and electricity cost numbers presented are for residential consumers, while others are for industrial consumers, and the cost for India reflects the wholesale power price.

Notes and references

1 Ontario Power Authority, *2011 Supply Mix Directive* (2011). http://www.powerauthority.on.ca/sites/default/files/new_files/IPSP%20directive%2020110217.pdf

2 For example, the OPA's 2010 long-term demand forecast declines over the next decade but then suddenly increases dramatically after 2020 to reach 160 TWh of supply by 2030. Coincidently, this is the sudden reverse in electricity demand trends is what would justify maintaining Ontario's existing nuclear fleet at historic levels. See: Ontario Ministry of Energy, "Ontario's Long-Term Energy Plan: Demand." http://www.energy.gov.on.ca/en/ltep/demand/

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