ONTARIO'S ELECTRICITY FUTURE

QUESTION 14

What are the consequences of the Long-Term Energy Plan's commitment to nuclear power?

If everything goes as planned, nuclear refurbishment of Bruce and Darlington will provide a large amount of low-carbon electricity at a reasonable cost, compared to current alternatives.

Nuclear power has risks that Ontario must balance against Ontario's share of the grave consequences of climate change. In a future where much of our energy use will need to come from electricity, Ontario needs to consider all low-carbon electricity sources, including nuclear.

Nuclear refurbishment appears to be in Ontario's best interests today. However, the commitment period is almost 50 years. During that time, renewables and storage are expected to become much cheaper, and conservation must also play a larger role. Ontario's large, long-term commitment to nuclear may restrict Ontario from taking full advantage of conservation and renewables.

To some degree, economies of scale lock in the province to completing the refurbishment process that it has launched, but Ontario can re-evaluate its need for future refurbishments before giving the final go-ahead, particularly the Bruce units that are scheduled for the late 2020s.

It is not clear whether the plan to extend operations at the Pickering station from 2020 to 2024 still makes sense.

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The details...

The Ontario government is making a huge bet on nuclear electricity. The commitment (restated in the Long-Term Energy Plan) to refurbish the Bruce and Darlington nuclear stations will dominate Ontario's electricity future – all the way to 2064.

The Bruce and Darlington nuclear plants require expensive, time-consuming refurbishment in order to continue to operate. The units scheduled for refurbishment supply more than 40% of the electricity that Ontario currently uses, approximately 60 terawatt-hours (TWh) a year, as shown in Figure 14.1.[1]

If the nuclear plants were closed, instead of refurbished, all this electricity would need to come from somewhere else, and Ontario's challenge of maintaining a low-carbon electricity system would be much greater. Are there alternatives that should be considered? Is it too late?

> The Ontario government is making a huge bet on nuclear electricity.

The government is also proposing to keep the Pickering nuclear plant open for up to four additional years (through 2024) past its planned end of life. Does this choice make sense?

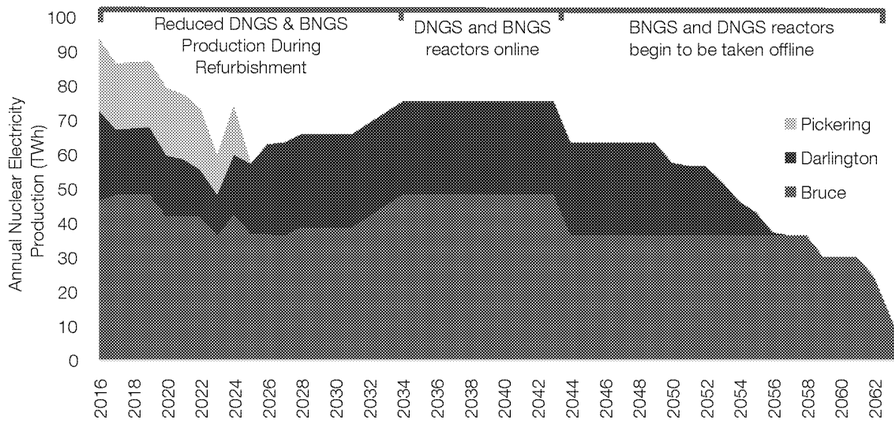

Figure 14.1. Projected electricity production from nuclear power, assuming current refurbishment and life extension plans.

Note: Assumes extended operation of Pickering to 2022/2024. Acronyms: BNGS (Bruce Nuclear Generating Station), DNGS (Darlington Nuclear Generating Station), PNGS (Pickering Nuclear Generating Station).

Source: Financial Accountability Office of Ontario, Nuclear Refurbishment: An Assessment of the Fiscal Impact of the Province's Fair Hydro Plan (Toronto: FAO, Fall 2017) at 8.

Environmental concerns with nuclear power

As discussed in Q10, every source of electricity (except conservation) has some environmental downside. The major environmental concerns with nuclear power are very different than other electricity sources, and are difficult to weigh against those of other sources.

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The most significant environmental concerns with nuclear power relate to:

- the radioactive waste that is produced on an ongoing basis, and which will have to be managed indefinitely to prevent radioactive exposure to humans and the environment
- how to safely and permanently decommission the nuclear plants after use, and
- the risk of accidental releases of radiation.

While the environmental aspects of Ontario's other electricity sources are regulated by the province, regulation of nuclear power to protect human health and the environment is primarily a federal responsibility, carried out by the Canadian Nuclear Safety Commission (CNSC). A brief summary of these issues is provided below.

Nuclear waste and decommissioning

Ontario's nuclear plants generate high-level nuclear wastes (the used nuclear fuel from reactors) that will be dangerous for hundreds of thousands of years, far longer than any human society has survived. High-level waste is extremely radioactive. Currently, used nuclear fuel is stored onsite at nuclear power plants, initially through wet storage with water providing shielding. The spent fuel is then transferred to dry storage using steel and concrete to provide shielding from radioactivity.

> Nuclear wastes will be dangerous for hundreds of thousands of years, far longer than any human society has survived.

Used nuclear fuel in dry storage container.

Source: Ontario Power Generation.

The federally mandated Nuclear Waste Management Organization (NWMO) is responsible for and has developed a plan to deal with used fuel. The plan is storage underground in a "deep geological repository", in a willing host community with suitable stable geology. No long-term repository for used nuclear reactor fuel yet exists anywhere in the world, although the first is now under construction deep underground in Finland.[2]

All five municipalities currently under consideration as host communities for the Canadian repository are located in Ontario.[3] Safe transportation of waste from reactor sites to the final repository by road or rail (estimated at 1 – 2 truckloads per day of high-level waste from all Canadian reactors) will also need to be ensured. The NWMO expects that a site will be selected for the facility within about five years.[4] Realistically, this process is still decades away from having an operational facility that accepts high-level waste.

In addition to the high-level nuclear waste, there is also a large amount of low- and intermediate-level waste, which will be radioactive for many years. The three existing nuclear stations generate a combined volume of roughly 5,000 – 7,000 cubic metres of low- and intermediate-level waste annually (reduced to 2,000 – 3,000 cubic metres after processing).[5] Ontario Power Generation (OPG) has been working on a proposal to develop a similar geological repository for this waste, on the site of the Bruce nuclear power plant near Kincardine (currently this waste is stored above-ground on this site).[6] The environmental assessment process for this proposal has been going on for more than a decade (initiated in 2005). Despite a favourable recommendation from the federal Joint Review Panel, the federal Minister of the Environment has not yet approved the project, and has asked OPG for additional information.[7]

The issue of radioactive waste is also relevant to reactors at their end of life. Decommissioning of a nuclear plant involves reducing radioactivity at the site to safe levels, by removing fuel and cleaning up and dismantling radioactive components. The first stage of decommissioning is "safe storage" to provide time for radioactivity levels to decline. Two units at the Pickering nuclear station were placed in this state between 2005 and 2010. Active decommissioning of Pickering will not take place until the 2050s.[8] While Ontario has not yet decommissioned a commercial nuclear reactor, nine reactors have been decommissioned in the U.S., and refurbishment involves some of the same work.[9]

Nuclear accidents

The potential for a large release of radioactivity from a nuclear accident at an operating plant is a major concern, and this fear was reignited for many by the Fukushima disaster in Japan in 2011. While there are differences in geology and nuclear technology between Ontario and Japan, Ontario's reactors also depend on cooling of the reactor fuel. If all cooling systems were to fail, temperatures in the reactor core would rise, and a release of radiation could occur.[10]

The independent Commission that reviewed the Fukushima incident concluded that the direct causes of the accident were foreseeable in advance, but the plant operator, regulator and government had failed to develop the necessary safety requirements. In the Commission's words, Fukushima was "a manmade disaster", and "the root causes were the organizational and regulatory systems that supported faulty rationales for decisions and actions".[11] These findings emphasize the importance of a vigilant safety culture within Canada's nuclear sector, among both operators and regulators.

> These findings emphasize the importance of a vigilant safety culture.

Post-Fukushima, the CNSC established an Action Plan to address the lessons learned from the Fukushima accident in order to enhance the safety of Canadian nuclear facilities.[12] Key areas of review included assessing and improving the safety of reactors, assessing any site-specific external hazards, and enhancing emergency response plans. Ontario Power Generation's actions in these areas are noted in their CNSC application for continued operation of the Pickering nuclear station.[13]

OPG's focus is on minimizing the likelihood of an accident or its consequences, through its actions at the facility. If a nuclear accident does occur, Ontario, through Emergency Management Ontario, has responsibility for off-site emergency response preparation. And although the province has recently updated its Provincial Nuclear Emergency Response Plan to enhance emergency planning,[14] some critics consider the updated plan inadequate.[15]

The CNSC has modeled the potential health impacts of a hypothetical severe nuclear accident and radiation release from the Darlington nuclear station, although the radiation release modeled was much smaller than the levels at Fukushima.[16] The study assessed the potential for increases in four types of cancer from radiation poisoning. It concluded that there would be a small increase in the rate of childhood thyroid cancer, but no impact on the other three types of cancer examined.

However, the study assumed that all of the procedures in the Provincial Nuclear Emergency Response Plan would be fully carried out – evacuation from within a certain zone around the affected plant, sheltering, and ingestion of protective potassium iodide pills, as applicable.[17] Whether this is a realistic assumption for a real incident is questionable. In particular, Pickering's location in the densely populated Greater Toronto Area would make complete implementation of the Plan very challenging should an accident happen there.

The CNSC believes that such an incident is "extremely unlikely to occur",[18] but it is a risk that not everyone wants to accept.

Financial cost of nuclear refurbishment

The province has never released an explicit cost-benefit case to support its decision to proceed with nuclear refurbishment. On the contrary, in 2015 the Ministry of Energy amended O. Reg. 53/05 to prohibit the Ontario Energy Board (OEB) from reviewing the need for the Darlington refurbishment (when the OEB assessed OPG's application to recover the costs from electricity ratepayers).[19]

> The province has never released an explicit cost-benefit case to support its decision to proceed with nuclear refurbishment.

The Financial Accountability Office of Ontario (FAO) analyzed the financial cost of the program of nuclear refurbishment, in comparison with alternative sources of electricity. The FAO concluded that, if the refurbishments are executed as planned, they will "provide ratepayers with a long-term supply of relatively low-cost, low-emissions electricity".[20] The FAO estimates that average cost of electricity from nuclear power over the next 50 years will be roughly 8.1¢ per kilowatt-hour (kWh), in 2017 dollars.[21] This is more expensive than the current cost of nuclear power (6.9¢/kWh), but cheaper than the average cost paid by customers for all generation (11.5¢/kWh).[22]

The average cost of nuclear power (from Bruce and Darlington together) is expected to go up during the refurbishment period, peaking in 2027 at around 9.5¢/kWh (in 2017 dollars), and falling below 8¢/kWh by around 2034.[23]

What if things don't go smoothly?

The FAO estimate of nuclear electricity costs assumes that the refurbishments will be executed as planned, at the costs currently projected. What happens if the refurbishments do not go smoothly? The FAO analysis reviews the consequences of some financial risks associated with the refurbishment, including refurbishment cost overruns and opportunity costs, but does not consider others, such as underestimates of waste management or decommissioning costs, and liability risks in the event of a nuclear accident.

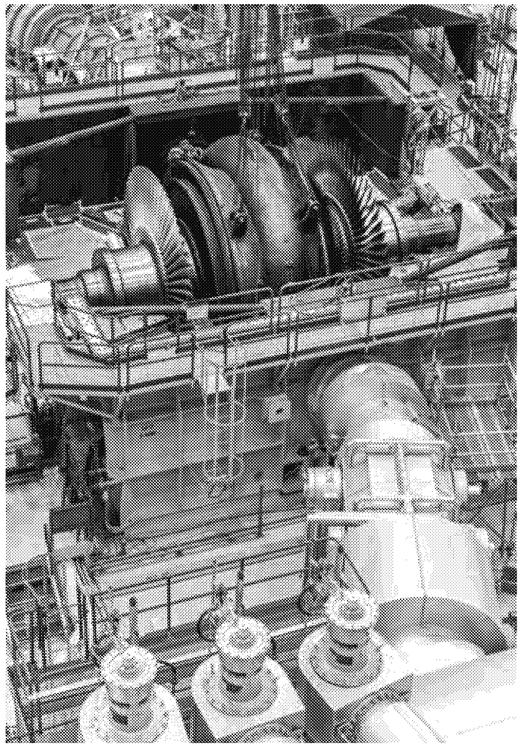
The risk to Ontarians is different for the Darlington and Bruce refurbishments. The government of Ontario owns OPG, while Bruce Power is a private company. This means that all of the financial risk for the OPG refurbishment is borne by Ontarians, partly through electricity rates, and partly through the impact of OPG's profits and losses on provincial government finances.[24] With the Bruce refurbishment, the financial risks are split between ratepayers and Bruce Power. This applies in particular to the risks of refurbishment cost overruns and poor operating performance, discussed below. The converse is true as well – if the refurbishments come in under budget or have lower operating costs than anticipated, Ontarians receive the full benefit for Darlington, but only about 50% of the savings for Bruce.[25]

Financial risks the FAO considered

Refurbishment risk: Nuclear construction projects have a history of going over budget. How would cost overruns affect the estimated cost of nuclear power? The FAO notes that because of the long lifetime of nuclear reactors, the capital cost of the refurbishment itself is only a minor portion of lifetime costs (the largest share is ongoing operating costs). This means that refurbishment costs would have to be significantly higher than expected to greatly change the estimated cost of nuclear power. An increase in refurbishment cost therefore results in a much smaller proportional increase in the lifetime cost (e.g., a 50% increase in refurbishment cost translates into a 9% increase in the overall unit cost of nuclear power).[26] This assumption only holds true if the plants end up being used for their full lifetime of almost 50 years – if not, the impact of refurbishment cost overruns would be more significant (see the discussion of "Opportunity cost risk" below).

> The Darlington refurbishment is off to a good start.

The Ministry of Energy advises that the Darlington refurbishment is off to a good start with the refurbishment of the first unit (Unit 2) tracking on time and budget. The Ministry has therefore given OPG the go-ahead in February 2018 to refurbish the second unit (Unit 3).[27]



Turbine removal in the Darlington refurbishment.
Source: Ontario Power Generation.

Station performance risk: Another risk is that the nuclear stations will perform worse than expected. The FAO refers to this as "station performance risk". Nuclear plants have high fixed operating costs that do not vary much with the amount of power produced. This means that the portion of time the plant is up and running and delivering electricity has a large impact on the unit cost of electricity. The FAO assumed that the refurbished Darlington and Bruce units would deliver 88% of maximum power over the course of their operating lives (88% capacity factor), and did not quantitatively assess how poorer station performance would affect cost projections.

> The OEB commented on the "poor management" and "poor performance" of OPG's nuclear division.

After the FAO report was issued, the OEB issued a decision on OPG's application to increase its rates. In total, OPG spends more than $2.8 billion every year to operate its nuclear plants, but has missed many of its own power production forecasts. In its December 28, 2017 rate decision, the OEB commented on the "poor management" and "poor performance" of OPG's nuclear division:

> OPG benchmarks itself annually against other North American nuclear operators on 20 measures. Of these 20, three have been identified as "key metrics": total generating cost (TGC), which is the "all-in" cost for generating electricity expressed on a $/MWh basis; the Nuclear Performance Index (NPI), which is a weighted composite of ten safety and performance indicators; and Unit Capability Factor (UCF), which measures a plant's actual output as a percentage of its potential output over a period of time….[28]

OPG's nuclear operations benchmarking results have been a concern to the OEB since it began regulating OPG in 2008. In all three previous cost of service cases the OEB has noted OPG's poor performance relative to its peers, and has made disallowances at least partially on account of this…

Since OPG began benchmarking… its overall results have been very poor. Since 2008 its ranking for each of the three key metrics has been either at or near the bottom in every year. Both the OEB and OPG expect better than this, and ratepayers should expect better too.[29]

Much of this poor performance is driven by the old Pickering units, and may be more relevant for the decision on Pickering extended operation (discussed later in the chapter), than for the Darlington refurbishment. Pickering is the one of the highest cost nuclear plants in North America, per unit of electricity produced:

> OPG argues that its poor results are driven to a large extent by the Pickering units. Pickering's performance is hampered by its small unit size, first generation CANDU technology, and low capability factor.[30]
>
> Despite the challenges of operating an older facility, OPG is responsible for Pickering's performance and should be expected to achieve at least its own performance targets. OPG set its targets with full knowledge of the facility and its condition. Despite that, OPG has continuously failed to meet its own targets.[31]

The OEB expects OPG's overall nuclear benchmarking results to get worse in the next five years, due to the high fixed operating costs and lower power production during the Darlington refurbishment.[32] OPG responds that Pickering's performance was much improved in 2017.[33]

Opportunity cost risk: In the ECO's opinion, the biggest economic risk identified in the FAO report is the opportunity cost risk. Unlike the short extension proposed for Pickering, the unit cost of nuclear power from the refurbishment of Bruce and Darlington assumes the plants will provide power for almost 50 years. If low-carbon electricity alternatives become cheaper than nuclear during the next 50 years, Ontario may not be able to take full advantage, due to sunk costs and economies of scale.

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For the next decade, the government has "off-ramps" that could allow it to terminate the remaining Bruce and Darlington refurbishments under certain circumstances.[34] For Bruce Power, there are two different types of off-ramps – "threshold" off-ramps that can only be exercised for each reactor refurbishment if Bruce Power's updated cost estimate for the refurbishment is more than 30% higher than the original estimate, or if the proposed duration for the reactor refurbishment exceeds certain thresholds. "Economic" off-ramps are more general and address opportunity cost risk – they allow the IESO to terminate future Bruce refurbishments if demand has dropped, or more cost-effective supply is available, and can only be exercised prior to the 3rd and 5th (of 6) Bruce reactor refurbishments. These decisions would need to be made in approximately 2024 and 2027, using the current refurbishment timeline (a year before these refurbishments are scheduled to commence). For OPG, the FAO's assessment is that the government can cancel refurbishments at Darlington for any reason at any time. However, because the Darlington refurbishments will happen sooner than at Bruce, any off-ramps would need to be taken sooner (by roughly 2023 for the last unit).

The front-loading of refurbishment costs and economies of scale reduce the value of the off-ramps.[35] For example, cancelling two out of six refurbishments saves much less than one third of the cost. Significant design and planning costs are sunk ahead of the first unit refurbishment at a nuclear plant (of the estimated $12.8 billion total cost of the Darlington refurbishment, $2.9 billion had already been spent by the time of the 2016 Ontario Energy Board review).[36] In addition, ongoing operations costs at nuclear stations do not scale in a linear fashion with the number of reactors – in other words, the average cost of nuclear electricity would be higher if fewer reactors at a station were refurbished. These factors mean that alternatives would have to drop well below the cost of nuclear quickly for a mid-stream refurbishment cancellation to make sense. For the Bruce refurbishment, if Ontario exercises the economic off-ramps and Bruce Power ends up having to recover its invested capital and operating costs from a smaller number of operating reactors, the risk of stranded costs would be shared between Bruce Power and Ontario ratepayers.[37]

Once the refurbishments are completed, estimated for 2033, Ontario will have no further off-ramps to reduce its nuclear commitment, except to wait for the reactors to reach the end of their useful life between 2044 and 2064 (Figure 14.1). Ontarians will still incur much of the cost of nuclear power from their annual operating costs. In the U.S., several nuclear plants have already had to close because their operating costs are too high to compete with gas-fired or renewable power. Ontario could do the same at some point in the future, but it would mean writing off a large sunk cost. Another way to think about this: The average cost of nuclear power per kWh will turn out to be much higher if the substantial refurbishment costs cannot be amortized over the planned 40 years of operation.

Financial risks the FAO did not consider

Scoped out of the FAO report is any analysis of economic risks related to decommissioning, nuclear waste management, or radioactive releases.[38] OPG's budgeted costs of nuclear waste management and decommissioning are included in the FAO's estimate of the price of electricity from nuclear power, but the FAO did not assess whether these costs are accurate, and what the impact would be if they are not.

Scoped out of the FAO report is any analysis of economic risks related to decommissioning, nuclear waste management, or radioactive releases.

OPG is responsible for the costs of nuclear waste management and decommissioning from all of Ontario's commercial reactors, including the Bruce facility. OPG must pay into segregated funds established under the Ontario Nuclear Funds Agreement (ONFA) to address nuclear waste management and decommissioning. OPG estimated that these funds would be valued at $18.198 billion dollars on January 1, 2018, which is in excess of the liability it estimates for these activities.[39]

There is some oversight of the estimated costs of nuclear waste management and decommissioning at both the federal and provincial levels. The estimated liability for the costs for nuclear waste management and decommissioning are established by OPG in a Reference Plan that is updated at least once every five years, and must be submitted to and approved by the province, pursuant to ONFA, an agreement between the province and OPG.[40] This Reference Plan is confidential. The Ontario Financing Authority, which implements ONFA for the province, has told the ECO that it hires a consulting firm with engineering and technical expertise in nuclear energy, including nuclear liabilities, to perform a review of OPG's Reference Plan, including its technical programs for nuclear decommissioning and waste management and the cost estimates on the Ontario government's behalf. This analysis is not made public.[41]

The CNSC requires that a nuclear operator provide a financial guarantee for its nuclear liabilities for decommissioning and waste management. As part of this, OPG submits to the CNSC its cost and liability estimates. Following a public hearing, in October 2017

the CNSC accepted OPG's updated liability estimate and the value of the nuclear segregated funds as adequate to satisfy the CNSC's financial guarantee requirement.[42]

If the actual costs for decommissioning or nuclear waste management turn out to be higher than expected,[43] Ontarians will have to pay those additional costs, whether through their electricity rates or their taxes.[44] Experience with decommissioning of plants internationally, and the work being done in Finland on final disposal of high-level waste should help better refine these cost estimates. As some of the same activities are carried out in refurbishment and decommissioning, Ontario's refurbishments will also provide information on Ontario-specific decommissioning costs.

Another financial risk not assessed by the FAO is the cost of a nuclear accident. The federal Nuclear Liability and Compensation Act means that nuclear power plant operators are only responsible for the first $1 billion in civil damages resulting from an accident at their plant (this liability limit was raised in 2015 from $75 million).[45] Any damages above this amount are to be covered by the federal government, i.e. the taxpayer. This is an important subsidy to the nuclear industry; its cost is not included in any of the estimates of the cost of Ontario's nuclear power.

Are there alternatives?

The FAO concluded that "there are currently no alternative generation portfolios that could provide the same supply of low emissions baseload electricity generation at a comparable price to the Base Case Nuclear Refurbishment Plan" (i.e., at the projected price of 8.1¢/kWh).[46]

The ECO agrees with this assessment. However, it is worth considering again whether a combination of renewables, conservation, imports of clean power and storage could replace some portion of Ontario's nuclear capacity, before Ontario makes a final commitment to each of the future reactor refurbishments.

Renewables?

The FAO's estimated average cost of refurbished nuclear is similar to the current price of new renewable electricity in Ontario (almost the same as large wind projects, and less expensive than large solar projects). Costs for wind and solar used to be much higher, but, particularly for solar, have been dropping rapidly. Ontario's 2016 renewable procurement awarded wind contracts with an average price of 8.6¢/kWh, very close to the projected nuclear price.[47] The price of renewables has come down even further since then; Alberta recently signed wind contracts at 3.7¢/kWh, although it has more favourable wind resources than Ontario.[48]

The unit cost of power is not enough on its own to determine whether non-hydro renewables could replace nuclear. Variable wind and solar would require significant additional costs (e.g., storage) and operational changes. As Q6 discusses, operating an electricity system with a large fraction of intermittent renewables does have challenges, although an increasing number of jurisdictions around the world have large and growing renewable supplies, and are learning how to manage them. Nuclear also has challenges matching demand, as it works best when it runs at full power around the clock, and has poor flexibility to adapt to the fluctuations in demand that Ontario experiences (Q3).

Conservation is cheaper than nuclear.

Conservation?

Conservation is cheaper than nuclear (at an average historical cost of roughly 3-4¢/kWh saved; even lower in 2016). Ontario's conservation programs have delivered an increasing amount of savings in recent years, and the role of conservation should grow in the future (Q19). However, as Ontario is already planning for a large amount of conservation (30 TWh by 2032), only additional savings beyond this will contribute to reducing the role the LTEP foresees for nuclear power.

Imports from Quebec?

Waterpower is more predictable and dependable than wind and solar for baseload power, and Quebec has abundant waterpower production, which Ontario can potentially make better use of, through imports. Quebec imports can also work well to balance the intermittency of wind and solar. In 2016, Ontario signed an electricity trade agreement with Quebec that secured 2 TWh of electricity from Quebec through 2023.[49]

The FAO concluded that Quebec imports are not a workable replacement for the entire program of refurbishing Ontario's nuclear plants, for three reasons: (1) Quebec is forecasting less electricity available for export in the future, (2) there will be increasing competition for this electricity from US markets, therefore driving up prices and (3) the cost of upgrading transmission lines to deliver large amounts of power from Quebec to Ontario could be significant, likely requiring new interties.[50] The Ministry of Energy notes that it is continuing to explore the potential for smaller import agreements with Quebec.[51]

We may need all of these and more

Each resource described above has the potential to replace part of the electricity provided by nuclear. But we may need all of these resources and the full amount of nuclear power from the refurbishments, if electricity demand rises to meet new energy uses such as heating and transportation that are currently supplied by fossil fuels (Q15).

As the ECO and other parties have noted, the government has never explained the process or the criteria that it will use when assessing whether to take the nuclear off-ramps.[52] Prior to giving the final go-ahead on each refurbishment commitment, Ontario should do an updated needs assessment, accounting for refurbishment costs, changes in demand, and changes in the prices of alternative resources. This would be particularly valuable for the two Bruce economic off-ramps described earlier. A lot may change in the decade before the final Bruce unit refurbishments are scheduled to begin.

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The special case of continued operation at Pickering

The Long-Term Energy Plan's decision to "extend" operations at the Pickering nuclear station is quite different from its commitment to "refurbish" Darlington and Bruce. The proposed financial commitment, timeline, scope of work and potential electricity production benefits of the extension are all much lower than they would be for a full refurbishment. Two of the eight reactors at the Pickering nuclear station are

already permanently out of service; the other six are currently scheduled to close in 2020. The government now hopes to keep all six active reactors running until 2022, and four of these six until 2024, by which time three units at Darlington and one unit at Bruce may have returned to service after refurbishment.

Operating safety at the Pickering station is a concern for many, given the location of the station (close to large populations in the GTA) and the age of two of the reactors (in operation since the early 1970s). In particular, the uranium fuel channels in their reactor cores have already been used for more than 210,000 operating hours, which was originally assumed to be their design life. They are now well past this number. Based on technical studies of their fitness-for-service, their operating lifetime has already been extended once, and OPG is now seeking a second extension, to 295,000 operating hours.[53] The CNSC is the federal regulator responsible for overseeing nuclear safety issues. The Pickering plant cannot continue to operate past August 31, 2018 without an operating license extension from the CNSC. The CNSC has therefore held a public hearing to assess whether this extension should be granted. The CNSC's decision is expected later in 2018.

Should the CNSC decide that Pickering is safe for continued operation, the Pickering extension is still not a done deal. The 2017 Long-Term Energy Plan requires OPG to seek final approval from the Ontario government to proceed with the extension.[54] Should Ontario give such approval?

There has been no independent review of whether the Pickering extension still makes environmental and financial sense for Ontario.

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In 2015, the IESO concluded that the Pickering extension would deliver a net benefit to electricity customers of between $300 million and $500 million, while keeping greenhouse gas emissions low. However, the economic case was not clear-cut – with small changes to some of the assumptions (e.g. amount of expected electricity production from Pickering, capital and operating cost, natural gas prices), the same computer model would predict that the Pickering extension will cost electricity customers money.[55] The IESO did not offer a final recommendation as to whether continued operation of Pickering was in the province's interest.

The FAO did not assess the economic case for extending the operation of the Pickering station through 2024, nor did the OEB. The OEB approved OPG's plans to do some preliminary work, but only because the government had already decided, before and in the LTEP, to proceed with the extension. OEB staff noted that they were not asked to review whether the extension should take place, and that "it is an open question as to whether the PEO {Pickering Extended Operation} would still show benefits if the model were re-run today".[56] Ontario is not yet irrevocably committed to the costs of the Pickering extension. 2/3rd of the $300 million in enabling costs will not be spent until 2019 or 2020, and the primary cost of the Pickering extension will be the operating cost of running the plant beyond 2020 ($1.4 billion in 2021 alone).[57]

Does Ontario's electricity system need Pickering?

Can Ontario get by without the electricity produced by Pickering, and have adequate electricity capacity to meet peak demand, from 2021 to 2024?[58]

Electricity consumed

Pickering currently provides about 20 TWh of electricity per year. In 2015, the IESO predicted that only about half of the electricity provided by the Pickering extension would be useful to Ontarians. The other half (delivered at times of lower electricity demand) would lead to higher exports (at less than average cost) or curtailment of existing renewable power.[59] Given that Ontario's annual grid-supplied electricity demand has dropped sharply since then (down 4.9 TWh between 2015 and 2017),[60] an updated analysis might find that even less of Pickering's electricity would be useful to Ontarians. Another way of looking at this is that the effective cost per unit of electricity from Pickering is roughly twice as high, if we cannot make productive use of the other half of the power it produces.

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Q16 of this report notes that fuel switching from fossil fuels to electricity will be needed to meet Ontario's climate obligations, which will drive an increase in overall electricity demand. However, the two to four years covered by the Pickering extension would likely be over before significant electrification occurs, and much of the additional demand from electrification could be focussed off-peak, when Pickering electricity is not needed.

The useful fraction of Pickering's electricity could be obtained from Ontario's existing gas-fired generators and/or imports, supplemented with conservation and new renewables. If it were all replaced with gas-fired power, this would increase greenhouse gas (GHG) emissions by 8-17 MT over the four years.[61] The emissions impact would be lower if much of this energy came from low-emission power, such as Quebec waterpower. However, Ontario's existing electricity trade agreement with Quebec is already counting on using much of the existing intertie capability to bring in Quebec power at times of high demand to reduce the use of gas-fired generation, so there may not be much remaining potential.[62] Better use of Ontario's surplus off-peak renewable electricity, perhaps with existing pumped storage (see Q16), may help, as could more conservation and new renewables. Still, a decision to not extend Pickering would likely increase GHG emissions to some degree, although the exact amount is uncertain.

Peak capacity

The other issue is whether Ontario can, at a reasonable cost, without major infrastructure upgrades, replace the capacity that Pickering provides to reliably meet peak demand. As discussed in Q5, Ontario does not have significant excess capacity at summer peak, even with Pickering operating. Extending the life of Pickering would help Ontario avoid procuring new capacity for a few years.[63] Quebec may or may not be able to assist Ontario here. Evidence suggests that the existing Quebec interties could be made firm for the purposes of meeting Ontario's reliability requirements at a reasonable cost (this would not necessarily lead to an increase in the actual amount of electricity moving annually across the lines)[64] if Quebec will commit to delivering this power. While Quebec will not guarantee additional capacity at its winter peak, Ontario currently has its peak load in the summer when Quebec has substantial capacity available. Another option identified in the OEB hearing was demand response (reducing electricity use at times of peak demand), which may be able to replace some or all of the capacity provided by Pickering at a lower cost.[65]

In the ECO's view, the OEB hearing raised some doubt that extended operation of Pickering is in the best interests of Ontarians. The GHG reduction benefits may justify continued operation of Pickering even at

If the government decides to go ahead with Pickering instead of making better use of the renewable power we already pay for, reducing peak demand, encouraging new renewables and importing only the extra power that Ontario needs, Ontarians have a right to know why.

the price of higher electricity system costs, but if so, the government should explain why the Pickering extension is the most cost-effective way to reduce GHG emissions. If the government decides to go ahead with Pickering instead of making better use of the renewable power we already pay for, reducing peak demand, encouraging new renewables and importing only the extra power that Ontario needs, Ontarians have a right to know why.

RECOMMENDATION: If Pickering's operating license is extended by the Canadian Nuclear Safety Commission, Ontario should report to the public whether the Pickering extension still makes sense, and if so, why.

Conclusion

Ontario is making an all in, 50-year commitment to nuclear power. Refurbishment of Bruce and Darlington should provide a large amount of low-carbon electricity at a reasonable price, and appear to be important components of a future where more of Ontario's energy needs must be met with low-carbon electricity. However, they may restrict Ontario from taking advantage of cheaper alternatives in the future. Extending the operating life of the Pickering nuclear station is a more questionable choice that needs review. Much of its power is not needed when there may be less costly low-carbon alternatives for Ontario electricity consumers.

Endnotes

1. All units together at Bruce and Darlington can supply approximately 75 TWh of production, but this includes the two units at Bruce (Bruce 1 and 2) where refurbishment has already been completed.
2. Henry Fountain, "On Nuclear Waste, Finland Shows U.S. How It Can Be Done", The New York Times (9 June 2017), online: <www.nytimes.com/2017/06/09/science/nuclear-reactor-waste-finland.html>.
3. "Study Areas", Nuclear Waste Management Organization, online: <https://www.nwmo.ca/en/Site-selection/Study-Areas>. [Accessed 15 March 2018]
4. Nuclear Waste Management Organization, information provided to the ECO in response to ECO inquiry (27 February 2018).
5. Joint Review Panel, Environmental Assessment Report: Deep Geologic Repository for Low and Intermediate Level Radioactive Waste Project (Ottawa: Minister of Environment, Government of Canada, 6 May 2015) at 54, online: <www.ceaa-acee.gc.ca/050/documents/p17520/101595E.pdf>;
6. "What is the Deep Geologic Repository (DGR)", Ontario Power Generation, online: <opg.dr.com>. [Accessed 20 March 2018]
7. Joint Review Panel, Environmental Assessment Report: Deep Geologic Repository for Low and Intermediate Level Radioactive Waste Project (Ottawa: Minister of Environment, Government of Canada, 6 May 2015) at xiii, online: <www.ceaa-acee.gc.ca/050/documents/p17520/101595E.pdf>; Letter from Minister of the Environment to Ontario Power Generation (18 February 2016), online:<www.ceaa-acee.gc.ca/050/documents/p17520/104964E.pdf>.
8. Ontario Power Generation, Preliminary Decommissioning Plan – Pickering Generating Stations A & B (OPG: December 2016) at 19, online: <www.opg.com/generating-power/nuclear/Documents/P-PLAN-00960-00001_PNGS_PDP.pdf>.
9. "Decommissioning Nuclear Power Plants", Nuclear Energy Institute, online: <www.nei.org/resources/fact-sheets/decommissioning-nuclear-power-plants>. [Accessed 20 March 2018]
10. Anna Mehler Paperny, "Fukushima's ripple effects on nuclear power in Canada", The Globe and Mail (7 April 2011), online: <www.theglobeandmail.com/news/politics/fukushimas-ripple-effects-on-nuclear-power-in-canada/article575784/>.
11. National Diet of Japan, The official report of the Fukushima Nuclear Accident Independent Investigation Commission (National Diet of Japan, 2012) at 16, online: <www.nirs.org/wp-content/uploads/fukushima/naiic_report.pdf>.
12. Canadian Nuclear Safety Commission, On the Lessons Learned From the Fukushima Daiichi Nuclear Accident (CNSC, August 2013), online: <www.nuclearsafety.gc.ca/eng/pdfs/reports/FTFR-CNSC-Integrated-Action-Plan.pdf>.
13. Letter from Ontario Power Generation to the Canadian Nuclear Safety Commission (28 August 2017), "Application for Renewal of Pickering Nuclear Generating Station Power Reactor Operating Licence" at section 2.4.6, online: <www.opg.com/generating-power/nuclear/stations/pickering-nuclear/Documents/P-CORR-00531-05055_PickeringNGS_License_Renewal.pdf>.
14. Ontario Ministry of Safety and Correctional Services, News Release, "Strengthening Ontario's Nuclear Preparedness: Province Releases Updated Nuclear Emergency Response Plan" (21 December 2017).
15. Rob Ferguson, "Ontario's long-awaited new nuclear emergency plan falls short, Greenpeace says", The Toronto Star (28 December 2017), online: <www.thestar.com/news/queenspark/2017/12/22/ontarios-long-awaited-new-nuclear-emergency-plan-falls-short-greenpeace-says.html>.
16. Canadian Nuclear Safety Commission, Study of Consequences of a Hypothetical Severe Nuclear Accident and Effectiveness of Mitigation Measures (Ottawa: CNSC, September 2015) at table 3.2, online: <www.nuclearsafety.gc.ca/eng/pdfs/health-studies/Severe-Nuclear-Accident-Study-eng.pdf>.
17. Only after the draft study had been released did the CNSC require reactor operators to ensure that the potassium iodide pills (which protect against absorption of radioactive iodine and thus reduce thyroid cancer risk) were distributed to residents living within 10 km of nuclear plants, previously these were only available at local pharmacies and schools. Daniel Otis, "East end given iodine pills as nuclear disaster precaution", The Toronto Star (10 November 2015), online: <www.thestar.com/news/gta/2015/11/10/east-end-given-iodine-pills-as-nuclear-disaster-precaution.html>.
18. Canadian Nuclear Safety Commission, Study of Consequences of a Hypothetical Severe Nuclear Accident and Effectiveness of Mitigation Measures (Ottawa: CNSC, September 2015) at 73, online: <www.nuclearsafety.gc.ca/eng/pdfs/health-studies/Severe-Nuclear-Accident-Study-eng.pdf>.
19. O Reg 353/15, which amended Payments Under Section 58.1 of the Act, O Reg 53/05. Section 12(v) of O Reg 53/05 requires the OEB to accept the need for the Darlington refurbishment.
20. Financial Accountability Office of Ontario, Nuclear Refurbishment: An Assessment of the Fiscal Impact of the Province's Fair Hydro Plan (Toronto: FAO, Fall 2017) at 45, online: <http://www.fao-on.org/web/default/files/publications/Nuc%20Refurb%20nov%202017/Nuclear-Refurb-EN.pdf>.
21. Ibid, at 45. This estimate is in 2017 dollars. The FAO analysis is a blended average price for all nuclear generation from 2016 to 2064 (not just the power produced from reactors after refurbishment, but also the power produced in this timeframe from Pickering, the power from the Bruce units that have already been refurbished, and the power from Bruce/Darlington units before they go down for refurbishment), so the actual unit cost of post-refurbishment power is likely slightly higher. It is not possible to separate this spending and provide an accurate cost estimate of only the refurbished generation (Financial Accountability Office of Ontario, information provided to the ECO in response to ECO inquiry (8 January 2018).
22. Ibid, at 7.
23. Ibid, at 24.
24. The OEB could prevent OPG from recovering certain cost overruns from electricity customers, but this would just mean that OPG would earn lower profits, to the detriment of the province.
25. Financial Accountability Office of Ontario, Nuclear Refurbishment: An Assessment of the Fiscal Impact of the Province's Fair Hydro Plan (Toronto: FAO, Fall 2017) at 31, 37-38.

26. Ibid, at 12.

27. Joel Wittnebel, "Refurb of Darlington's Unit 2 reactor reaches halfway point", The Oshawa Express (21 February 2018), online: <oshawaexpress.ca/refurb-of-darlingtons-unit-2-reactor-reaches-halfway-point/>.

28. Ontario Energy Board, Decision and Order EB-2016-0152 Ontario Power Generation Inc. Application for payment amounts for the period from January 1, 2017 to December 31, 2021 (OEB, 28 December 2017) at 46, online: <www.rds.oeb.ca/HPECMWebDrawer/Record/595053/File/document>.

29. Ibid, at 49.

30. Ibid.

31. Ibid at 50.

32. Ibid at 51.

33. Ontario Power Generation, information provided in response to ECO inquiry (6 February 2018).

34. Financial Accountability Office of Ontario, Nuclear Refurbishment, An Assessment of the Financial Risks, of the Nuclear Refurbishment Plan (Toronto: FAO, November 2017) at 11.

35. Ibid, at 12.

36. Ontario Energy Board, Decision and Order EB-2016-0152 Ontario Power Generation Inc. Application for payment amounts for the period from January 1, 2017 to December 31, 2021 (OEB, 28 December 2017) at 26, online: <www.rds.oeb.ca/HPECMWebDrawer/Record/595053/File/document>.

37. Bruce Power L.P. and the Independent Electricity System Operator, Amended and Restated Bruce Power Implementation Agreement (Bruce Power and IESO, 3 December 2015) at article 4.11 and exhibit 4.11, online: <www.ieso.ca/-/media/files/ieso/document-library/power-data/supply/amended-and-restated-bruce-power-refurbishment-implementation-agreement.pdf?la=en>. These sections of the contract indicate that the contract price for electricity from Bruce Power would be adjusted if Ontario exercises its option to terminate some of the refurbishments.

38. Financial Accountability Office of Ontario, Nuclear Refurbishment, An Assessment of the Financial Risks of the Nuclear Refurbishment Plan (Toronto: FAO, November 2017) at 19.

39. Letter from Ontario Power Generation to Mr. M. LeBlanc, Commission Secretary, Canadian Nuclear Safety Commission, "Request for Acceptance of OPG's Financial Guarantee" (4 August 2017) at Tables 7 and 8, online: <www.opg.com/generating-power/nuclear/Documents/Financial_Guarantee_Commission_Member_Document.pdf>.

40. Ontario Nuclear Funds Agreement between the Minister of Finance and Ontario Power Generation (1 April 1999, amended 28 October 2004), online: <www.opg.com/about/regulatory-affairs/Documents/2017-2021/OPG_IRR_Issue_8.0_20170210.pdf>

41. Ontario Financing Authority, information provided in response to ECO inquiry (9 March 2018).

42. Canadian Nuclear Safety Commission, Financial Guarantee for the Future Decommissioning of Ontario Power Generation Inc.'s Facilities in Ontario (Ottawa: EGD, 11 October 2017), online: <www.suretenucleaire.gc.ca/eng/the-commission/pdf/RecordofDecision-OPG-FG-e.pdf>

43. Of course, many of these costs would be incurred regardless of the decision on refurbishment, as all nuclear sites will eventually need to be decommissioned regardless, and have already generated significant amounts of high-level waste. Refurbishment will add incremental costs.

44. The Ontario Nuclear Funds Agreement specifies the division of responsibility for liabilities between the province and Ontario Power Generation. Since the province is the sole shareholder of Ontario Power Generation, Ontarians will bear this risk in either case.

45. "The Nuclear Liability and Compensation Act", online: Natural Resources Canada <www.nrcan.gc.ca/energy/uranium-nuclear/19224>. [Accessed 21 March 2018]

46. Financial Accountability Office of Ontario, Nuclear Refurbishment, An Assessment of the Financial Risks of the Nuclear Refurbishment Plan (Toronto: FAO, November 2017) at 47.

47. "News Releases: IESO Announces Results of Competitive Bids for Large Renewable Projects", online: Independent Electricity System Operator <www.ieso.ca/corporate-ieso/media/news-releases/2016/03/ieso-announces-results-of-competitive-bids-for-large-renewable-projects>. [Accessed 21 March 2018]

48. "Rep Round 1 Results", online: Alberta Electric System Operator <www.aeso.ca/market/renewable-electricity-program/rep-round-1-results/>. [Accessed 21 March 2018]

49. Independent Electricity System Operator, "Overview of Electricity Trade Agreement Between Quebec and Ontario" (presentation, 10 May 2017), slide 5, online: <www.ieso.ca/-/media/files/ieso/document-library/sac/2017/sac-20170510-ontario-hydro-quebec-agreement.pdf?la=en>.

50. Financial Accountability Office of Ontario, Nuclear Refurbishment, An Assessment of the Financial Risks of the Nuclear Refurbishment Plan (Toronto: FAO, November 2017) at 61-63.

51. Ontario Ministry of Energy, information provided in response to ECO inquiry (28 February 2018).

52. Environmental Commissioner of Ontario, Developing the 2017 Long-Term Energy Plan, A special report to the Legislative Assembly of Ontario (Toronto: ECO, December 2016) at 23; Canadian Environmental Law Association/Greenpeace/Lake Ontario Waterkeeper/Ontario Clean Air Alliance, Application for Request for Review to the Ministry of Energy at Tab B, online: <www.cela.ca/publications/nuclear-reactor-life-extensions-request-review>.

53. Ontario Power Generation, Pickering Nuclear Generating Station Power Reactor Operating Licence Application (Toronto: OPG, August 2017) at 36-37, online: <www.opg.com/generating-power/nuclear/stations/pickering-nuclear/Documents/P-CORR-00531-05055_PickeringNGS_Licence_Renewal.pdf>.

54. Ontario Ministry of Energy, Ontario's Long-Term Energy Plan 2017, Delivering Fairness and Choice (Toronto: Ontario Ministry of Energy, October 2017) at 51.

55. Independent Electricity System Operator, "Assessment of Pickering Life Extension Options" (presentation, November 2015), slides 15-19, online: <www.opg.com/about/regulatory-affairs/Documents/2017-2021/F2-02-03_Pickering_Extended_Operations_20161110.pdf>.

56. Ontario Energy Board staff submission, Ontario Power Generation Inc. 2017-2021 Payment Amounts, Ontario Energy Board File no. EB-2016-0152 (Toronto: OEB, 19 May 2017) at 97, online: <www.rds.oeb.ca/HPECMWebDrawer/Record/571945/File/document>.

57. Ontario Energy Board, Decision and Order EB-2016-0152 Ontario Power Generation Inc. Application for payment amounts for the period from January 1, 2017 to December 31, 2021 (OEB, 28 December 2017) at 58-59, online: <www.rds.oeb.ca/HPECMWebDrawer/Record/595053/File/document>.

58. Given the short timeframe, it would likely need to do this with existing infrastructure.

59. The exported electricity could provide regional benefits in reducing greenhouse gas emissions outside Ontario (Independent Electricity System Operator, "Assessment of Pickering Life Extension Options" (presentation, November 2015), slide 12, online: <www.opg.com/about/regulatory-affairs/Documents/2017-2021/F2-02-03_Pickering_Extended_Operations_20161110.pdf>).

60. Ontario demand in 2015 and 2016 was identical at 137.0 TWh ("2017 Electricity Data", online: Independent Electricity System Operator <www.ieso.ca/corporate-ieso/media/year-end-data>. [Accessed 21 March 2018]).

61. Independent Electricity System Operator, "Assessment of Pickering Life Extension Options" (presentation, November 2015), slide 8, online: <www.opg.com/about/regulatory-affairs/Documents/2017-2021/F2-02-03_Pickering_Extended_Operations_20161110.pdf>

62. Independent Electricity System Operator, Ontario-Quebec Interconnection Capability - A Technical Review (Toronto: IESO, May 2017) at 30, online: <www.ieso.ca/-/media/files/ieso/document-library/power-data/supply/intertiereport-20170508.pdf?la=en >.

63. Independent Electricity System Operator, "Assessment of Pickering Life Extension Options" (presentation, November 2015), slide 5, online: <www.opg.com/about/regulatory-affairs/Documents/2017-2021/F2-02-03_Pickering_Extended_Operations_20161110.pdf

64. According to the IESO, it could make firm 1,250 MW of existing intertie capacity with Quebec (and potentially 1,650 MW - about 80% of Pickering B's nominal capacity) for about $20 million plus operational changes (Independent Electricity System Operator, Ontario-Quebec Interconnection Capability - A Technical Review (Toronto: IESO, May 2017) at 23). The remaining gap would be less than 400 MW. Demand response may also be able to fill some of this gap.

65. Submissions of Environmental Defence, Application by Ontario Power Generation pursuant to S. 78.1 of the OEB Act for payment amounts for the period January 1 2017 and December 31 2021, Ontario Energy Board EB-2016-0152 (Toronto: ED, May 2017) at 11, online: <www.rds.oeb.ca/HPECMWebDrawer/Record/572671/File/document>.