Better Never than Late:

The Climate Fall-Out of Ontario's Nuclear Electricity Plan

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Greenpeace is one of the world's most effective and best-known environmental organizations, with almost three million supporters worldwide in thirty countries. Greenpeace is an independent global campaigning organization that acts to change attitudes and behaviour, in order to protect and conserve our environment and promote a peaceful future.

Greenpeace has had a long-standing interest in nuclear issues, and has worked to promote a shift away from nuclear power and fossil fuels towards sustainable energy systems based on conservation and renewable technologies.

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Ontario's climate plan is built on a faulty foundation: the Ontario Power Authority's (OPA) proposed long-term electricity plan—which assumes the province's ageing nuclear stations will operate better than they ever have historically and that a massive nuclear construction programme will be on time and on budget.

THE ELECTRICITY GAP

The province's plan to build up to 14,000 megawatts of nuclear capacity by 2025 overlooks the "electricity gap" that opens up in the years post-2010 as ageing reactors, beginning with the Pickering B nuclear station, go offline for life-extension work or permanent shutdown.

Originally it was hoped that these old reactors would retire and be replaced by new reactors built quickly to fill the gap by 2014. When it became apparent that this strategy was not realistic, however, the OPA did not change its plans. Instead of exploring a quick deployment of green energy options to address the electricity gap, the OPA remained committed to building new nuclear stations.

The OPA's proposed plan entails three undesirable options for Ontario's energy future:

- → increased greenhouse gas emissions while reactors undergo risky life-extension repairs,
- → increased greenhouse gas emissions during the wait for new nuclear stations to come online, or
- → a dangerous combination of increased greenhouse gas emissions and increased risk of nuclear accidents from running ageing and deteriorating reactors after they should be shut down.

THE CLIMATE FALLOUT OF ONTARIO'S NUCLEAR ELECTRICITY PLAN

The OPA's electricity plan threatens Ontario's climate change targets in two ways: First, it underestimates future greenhouse gas emissions by drastically overestimating future nuclear performance. Second, it opts to increase greenhouse gas emissions while waiting for long lead–time nuclear stations to be built or for life-extension repairs to take place, instead of initiating quick-to-deploy energy options to fill the gap.

- → Ontario will miss its 2014 greenhouse gas emissions target by 26 megatonnes (Mt)—a third of its 61 Mt target—and its 2020 target by 18 Mt, if Ontario's nuclear reactors perform at historic levels instead of at those optimistically assumed by the OPA.
- → If a decision is made to close the ageing Pickering B nuclear station, the OPA plans to increase fossil generation until new nuclear plants are built, which could lead to 21 to 55 Mt in additional cumulative greenhouse gas emissions between 2012 and 2022.
- → If a decision is made to rebuild the Pickering nuclear station, the six-year construction period would result in 9–23 Mt of greenhouse gas emissions, depending on whether gas generation or imported coal is used.

BETTER NEVER THAN LATE: THE RISING COSTS AND ACCIDENT RISKS OF ONTARIO'S NUCLEAR ELECTRICITY PLAN

The OPA is proposing to run reactors beyond the date they would normally be shut down in order to bridge the electricity gap until new reactors come online, which would drive up the risk of nuclear accidents at Ontario's nuclear stations. All of Ontario's reactors are entering the most dangerous stage of their operational lives and will be more prone to unplanned shutdowns and to increased risk of accidents. Despite this, the OPA assumes that Ontario's reactors will perform at their best historical level over the next 20 years.

New reactors cannot be built in time to fill the electricity gap or compensate for underperforming existing reactors. The OPA, meanwhile, is seeking to avoid scrutiny of its proposal to build new reactors and hopes Ontarians will forget about the delays, cost over-runs and poor performance and safety problems that have plagued Ontario's nuclear program. Scrutiny of Ontario's plan for new reactors is needed:

- → The estimated cost for new nuclear stations has more than doubled since the OPA first released its draft electricity supply plan in 2005. The OPA has admitted that at current cost levels new nuclear stations would not be economical.
- → The construction in Finland of AREVA's EPR reactor, which is being considered for construction in Ontario, is currently three years behind schedule and $4 billion over budget.
- → Nuclear life-extension projects remain risky, with no guarantee of reliable power. The life-extension of the Bruce A nuclear station is currently $300–600 million over budget. Two of the Pikering A reactors were abandoned after costs to rebuild them more than tripled, and the two Pickering A reactors that were rebuilt are operating miserably.

KEEPING PROMISES: PRIORITIZING RENEWABLES OVER NUCLEAR POWER

The McGuinty government has committed to greenhouse gas emissions reduction targets for 2014 and 2020. It has also stated that it will prioritize the development of renewable energy. Keeping its commitments and improving on them will require the government to dramatically increase the development of quick-to-deploy conservation and green power.

Its first opportunity to do this will be in early 2009 when it decides the fate of the Pickering B nuclear station. The OPA has given the government only bad options: either rebuilding of the Pickering B reactors, creating increased greenhouse gas emissions for the duration of the job, or shutdown of the station in 2013, using energy sources that would increase greenhouse gas emissions, until new replacement reactors come online in 2020. The government should choose neither option and direct the OPA to execute a mix of quick-to-deploy options using renewables, conservation and local generation.

1. The Electricity Gap

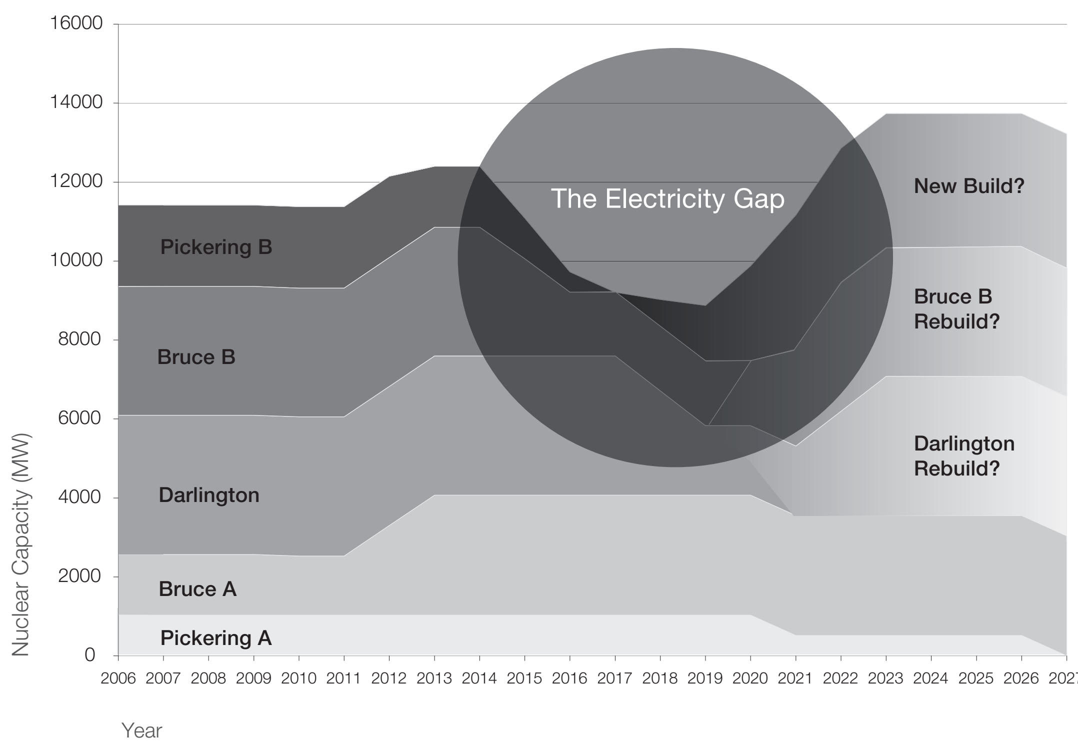
The central element of Ontario Power Authority's (OPA) long-term electricity plan is its target of building or rebuilding up to 14,000 megawatts (MW) of nuclear capacity by 2025—arguably the biggest per capita nuclear construction boom in the world. However, this commitment to nuclear projects, which have a long lead time, overlooks the "electricity gap" that will open up in the years post-2010 as ageing reactors, beginning with the Pickering B nuclear station, go offline for life-extension repairs or permanent shutdown.

According to the OPA's schedule for reactor shut-downs and restart of existing reactors, as well as for new-builds (see Appendix A), nuclear capacity will drop by 3526 MW between 2014 and 2019 and will not return to current levels until 2022. This assumes, however, that all nuclear projects go as planned, with no delays.

When Ontario's draft electricity plan was first developed in 2005, it was believed that new nuclear plants could be built quickly to fill the electricity gap that will develop in 2014. After learning in 2006 that this was impossible, the government did not rethink its energy plan and opt for quicker-to-deploy energy alternatives to fill the gap. Instead it decided to increase fossil fuel generation, and thus increase greenhouse gas emissions, or to extend the operational life of ageing reactors until new nuclear plants become operational, and thus increase the risk of nuclear accidents, as well as increase greenhouse gas emissions through the substitute energy sources.

The unquestioned commitment to long-lead-time nuclear stations is blocking the development of quicker-to-deploy energy solutions that could address the near-term electricity gap and ensure that Ontario meets its greenhouse gas reduction targets, maintains reliable electricity supply, and builds a greener, more climate-friendly electricity system.

Table 1
The Electricity Gap



Source: Based on OPA data.[1]

1 The Ontario Power Authority (OPA) refused to release its assumed reactor lifespans and refurbishment outages when these were requested by Greenpeace. Table 1 above and Appendix A were calculated by working backwards from the OPA's assumptions for cumulative nuclear capacity and secondary sources (OPA, Renewable and CHP Baseload Resources [Effective MW], Table 12, available at http://www.powerauthority.on.ca/Storage/82/7759_D-6-1_corrected_2008-08-29.pdf).

1.1 The Opening of the Gap: Shutting Down Old Reactors

In 2003, Ontario Power Generation (OPG) drastically revised its estimate of the operational lives of its nuclear stations, acknowledging that its fleet of CANDU reactors would only operate 25 years[2] instead of 40 years.[3] This failure of Ontario's nuclear stations to operate for their promised design lifespan design means Ontario suddenly faces a looming electricity crunch.

The admission that Ontario's nuclear plants would not operate as promised coincided with the election of the McGuinty government, which had made the laudable election commitment to phase out the province's coal stations. Ontario's coal plants had been working overtime to compensate for the closure of eight of the province's reactors in 1997, which led to increased smog and greenhouse gas emissions.

1.2 New Reactors—Already Delayed

In May 2005, the Ontario government tasked a new agency, the Ontario Power Authority (OPA), with developing Ontario's first long-term electricity plan in 20 years. The OPA's subsequent proposal, which the government accepted in 2006, was for a massive and risky nuclear construction program, with the aim to maintain nuclear power's contribution to the provincial electricity supply at approximately 50%.

Both the OPA and Atomic Energy of Canada Limited (AECL) originally believed that the electricity gap could be filled quickly by new nuclear stations.[4] It was hoped that ageing nuclear capacity could be replaced with new nuclear by building a CANDU-6 reactor, a model designed in the 1970s by AECL.

Because the CANDU-6 design had already been built and is operating in Quebec and New Brunswick, it was hoped the reactor could be built quickly by "grandfathering" safety standards applied to it in order to speed up licensing. Former Canadian Nuclear Safety Commission (CNSC) President Linda Keen, however, informed then–OPA president Jan Carr and Ontario Energy Board (OEB) Chairman Howard Wetston in early 2006 that "grandfathering" licensing would not be permitted. Any proposed new reactor would be subject to a review under the CNSC's modernized regulatory framework, which is based on International Atomic Energy Agency standards.[5]

In 2005, AECL, which had already initiated a pre-licensing review of its prototype Advanced CANDU Reactor (ACR), asked the CNSC in to reduce its licensing reviews of the ACR in order to begin a pre-licensing review of the "Enhanced" CANDU-6. According to CNSC documents acquired by Greenpeace, AECL's strategy was "to meet Ontario's target dates for new power (2014)." AECL requested the CNSC inform it of any "potential showstoppers" for licensing a new CANDU-6 by November 2006.[6]

AECL originally aimed to have an ACR in service by 2011,[7] but by 2005 had acknowledged that the design could only "meet the medium term needs of the province of Ontario" and had pushed back its targeted in-service date for the first ACR-1000 to "December 2016." [8]

2 John Spears, "Energy policy needed before lights go out; Nuclear plants will be worn out by 2018, Bruce Power calls for industry overhaul," *The Toronto Star,* Thursday, November 27, 2003, C1.
3 See, for example: *Ontario Hydro Final Annual Report, January 1988–March 1999*, pp. 44–45.
4 AECL told the OPA in August 2005 that it would be possible to have a new CANDU unit in operation to fill the baseload supply gap in 2014/2015. AECL maintained that because the CANDU-6 design is known to the federal regulator, a new CANDU unit could pass through licensing more quickly than a foreign design. See: Atomic Energy of Canada Limited, "Maintaining Flexibility: Ontario's Electricity Supply Gap and Implications for the Supply Mix," Submission to the Ontario Power Authority, August 26, 2005. A year earlier, in 2004, Electricity Conservation & Supply Task Force asserted that new nuclear plants would take until "at least 2011 to come online." (See: *Tough Choices: Addressing Ontario's Power Needs*, p. 67.) Subsequently, Pierre Charlevois, the Chief Nuclear Officer for OPG, told the CNSC "Accommodation of the year end 2011 in-service date proposed by the Electricity Conservation and Supply Task Force would require mobilization of the CNSC licensing staff capacity in the very near future." (See: P. Charlebois [OPG] to K. Pereira [Vice President, Operations Branch, CNSC], "Major OPG Initiatives Requiring CNSC Review and/or Licensing Action," June 9, 2004.)
5 Linda J. Keen (President, Canadian Nuclear Safety Commission) to Dr. Jan Carr (Chief Executive Officer, Ontario Power Authority), "Licensing Process for New Nuclear Power Plants in Canada," January 27, 2006. Acquired through Access to Information.
6 M. Santini to I. Grant (email), "ARPD Proposed Planning Basis Scenarios for the ACR project," March 17, 2006. Acquired through Access to Information.
7 Andrew McIntosh, "AECL gets $46M more for reactor: Critics skeptical 'renaissance' will lead to more Candu sales," *The Ottawa Citizen*, September 24, 2003, A5.
8 M. Santini to I. Grant (email), "ARPD Proposed Planning Basis Scenarios for the ACR project," March 17, 2006. Acquired through Access to Information.

In June 2006, the government accepted the substance of the OPA's *Supply Mix Advice Report* and instructed OPA to develop a long-term electricity plan (known as the Integrated Power System Plan, or IPSP) with a maximum 14,000 MW of installed nuclear capacity for 2025.[9] The government's directive for nuclear deployment is silent on the nuclear supply mix prior to 2025, when all of Ontario's existing reactors will be forced to shut down permanently or for life-extension repairs.

Meanwhile, the application of the CNSC's draft modernized safety requirements appears to have posed obstacles to the licensing of a new CANDU-6. Documents acquired by Greenpeace show that AECL opposed the CNSC's modernized standards requiring reactor core physics to be more inherently safe. AECL complained to CNSC staff that such requirements would "impact on marketing of CANDU 6 reactors" and reflect badly on CANDUs in operation.[10]

In December 2006, OPG informed Premier McGuinty that it would be unable to build the CANDU-6 because the design changes required to meet modern regulatory requirements would cause at least a two-year construction delay, erasing the principle advantage of AECL's CANDU-6 design,[11] which was that it was quick-to-deploy, with none of the construction risks associated with building a prototype reactor. In January 2007, Energy Minister Dwight Duncan told the *Toronto Star* "The one advantage the Candu 6 has is time, but it appears the nuclear regulator may have taken that away."[12]

The result of the CNSC's decision to require modern safety standards in licensing reviews meant Ontario would be unable to have new reactors online in time to fill the supply gap left by the shut-down of ageing reactors during 2014–2015. Media reports in early 2007 indicate that the Canadian nuclear lobby and the Minister of Natural Resources were upset with President Keen's decision to impose a technology-neutral licensing approach to new reactors in Canada, which eliminated a competitive advantage for CANDU technology and prevented Ontario from bringing online new nuclear generation in time to fill the electricity gap post-2014.[13]

Ontario was left with only untested and risky reactor designs to choose from. The Canadian design choice—AECL's Advanced CANDU Reactor (ACR)—was (and remains) unfinished and has not acquired licensing approval anywhere in the world. Indeed, in December 2006 the CNSC had dropped the ACR from pre-licensing, at the same time it shut down the pre-licensing of the CANDU-6 due to "resource constraints."[14]

To address the concerns about buying a non-Canadian design, the McGuinty government commissioned McKinsey and Associates[15] in May 2007 to advise the government on the economic impacts of building different reactor designs. The government did not publish the full results of the study when it was completed in late 2007. It did publish an Executive Summary, however, which indicated that the report concluded that the various reactor designs have the "potential" to be online in 2018.[16]

The OPA's final submission to the Ontario Energy Board (OEB) in August 2007 stated that "the earliest in-service date for new nuclear generation is 2018" [17]—four years later than was hoped for in 2005. Before environmental reviews, licensing, and construction of new plants have even begun, then, Ontario's proposed new reactors have already suffered a significant delay due to optimistic assumptions about licensing standards.

9 The Honourable Dwight Duncan, Minister of Energy, to Jan Carr, Chief Executive Officer, Ontario Power Authority, "Integrated Power System Plan," June 13, 2006.
10 D. Serghiuta, memorandum: "S-337 Outstanding Issue # 18—Reactor Core Neutronic Design," April 13, 2007.
11 Ken Pereira to Linda Keen (email), "Call from Pierre Charlebois," December 19, 2006. Acquired through Access to Information.
12 Tyler Hamilton, "Could reactors withstand blast? Report that regulator will impose new safety standards may pose a big hurdle for AECL nuclear sale in Ontario," *The Toronto Star,* January 19, 2007, F01.
13 Karen Howlett and Murray Campbell, "Feud threatens Ontario's energy supply; Nuclear watchdog at odds with Ottawa over safety standards for new reactors," *The Globe and Mail,* February 5, 2007, A4.
14 Office of the Auditor General of Canada, *Special Examination Report—Atomic Energy of Canada Limited,* 5 September 2007, p. 3.
15 Tyler Hamilton, "McKinsey to report on reactor options," *Toronto Star*, June 1, 2007.
16 McKinsey & Company (2007), *A Strategic Assessment of Ontario's Economic and Technology Options in the Growing Nuclear Market—Executive Summary,* p. 5.
17 Ontario Power Authority, EB-2007-0707, Exhibit D, Tab 6, Schedule 1, p. 17.

1.3 Designed to Fail: Ontario's Nuclear-Based Climate Plan

The Intergovernmental Panel on Climate Change (IPCC) has stated that to avoid the worst impacts of climate change, global greenhouse gas emissions have to stabilize no later than 2015,[18] and then begin to undergo dramatic reductions. Developed countries such as Canada need to reduce emissions by up to 40 per cent below 1990 levels by 2020, and 95 per cent by 2050.[19] Energy policy decisions must, then, result in actual greenhouse gas reductions over the next ten years in order to stop dangerous climate change.[20]

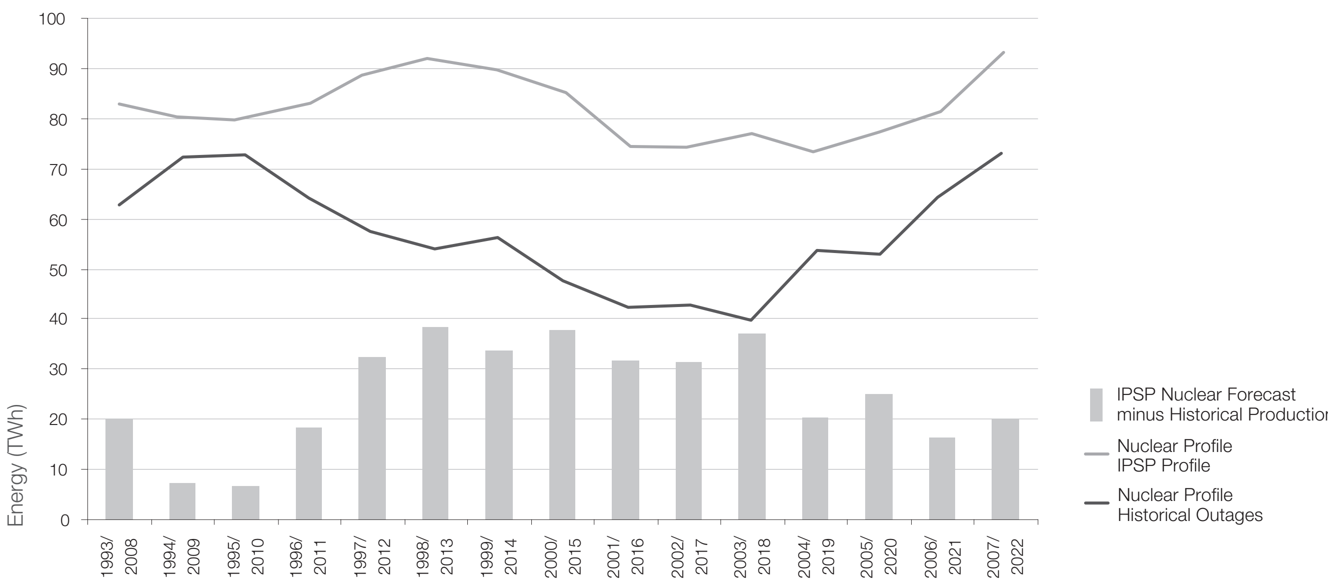
Ontario, however, is going to fall short on its targets for reducing greenhouse gas emissions if it continues to underestimate these by overestimating the future output from Ontario's ageing nuclear stations.

In June 2007, the Ontario government released its Go Green Climate Action Plan, which aims to reduce greenhouse gas emissions to 6% below 1990 levels by the end of 2014, or by 61 Mt.[21] Forty-four per cent of this reduction is to come from the electricity sector,[22] primarily through the replacement of Ontario's coal stations with large, gas-fired facilities that are less carbon-intensive but inefficient and polluting.

Ontario's climate plan is founded on the forecasting assumptions the OPA used in its Integrated Power System Plan (IPSP), which assumes Ontario's nuclear reactors will perform better than they ever have historically. The OPA bases its nuclear performance forecasts on the average performance of Ontario's nuclear fleet in 2005 and 2006[23]—which is equivalent to assuming Ontario's reactors will perform at their best level of the past 20 years, for the next 20 years.

Table 2 shows the large difference between the OPA's projected nuclear performance and historic nuclear performance, expressed in terawatt hours (TWh).

Table 2
Comparison of Historical Nuclear Production and the OPA's Forecast Production



Source: Ontario Power Authority.[24]

18 IPCC (2007), Summary for Policy Makers, in: *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer [eds]), Cambridge University Press, Cambridge, United Kingdom, and New York, NY, USA, Table SPM.5, p. 15.

19 T. Barker *et al*., Technical Summary, in: *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer [eds.]), Cambridge University Press, Cambridge, United Kingdom, and New York, NY, USA, p. 90.

20 The international scientific community, as represented in the publications of the IPCC, has noted that the global mean temperature increase above pre-industrial levels must be limited to less than 2 degrees Celsius. A greater increase will cause dramatic disruptions of climate systems and ecosystems. In order to prevent this, global emissions will need to begin declining within the next decade.

21 The Government of Ontario, *Go Green: Ontario's Action Plan on Climate Change*, August 2007, p. 6.

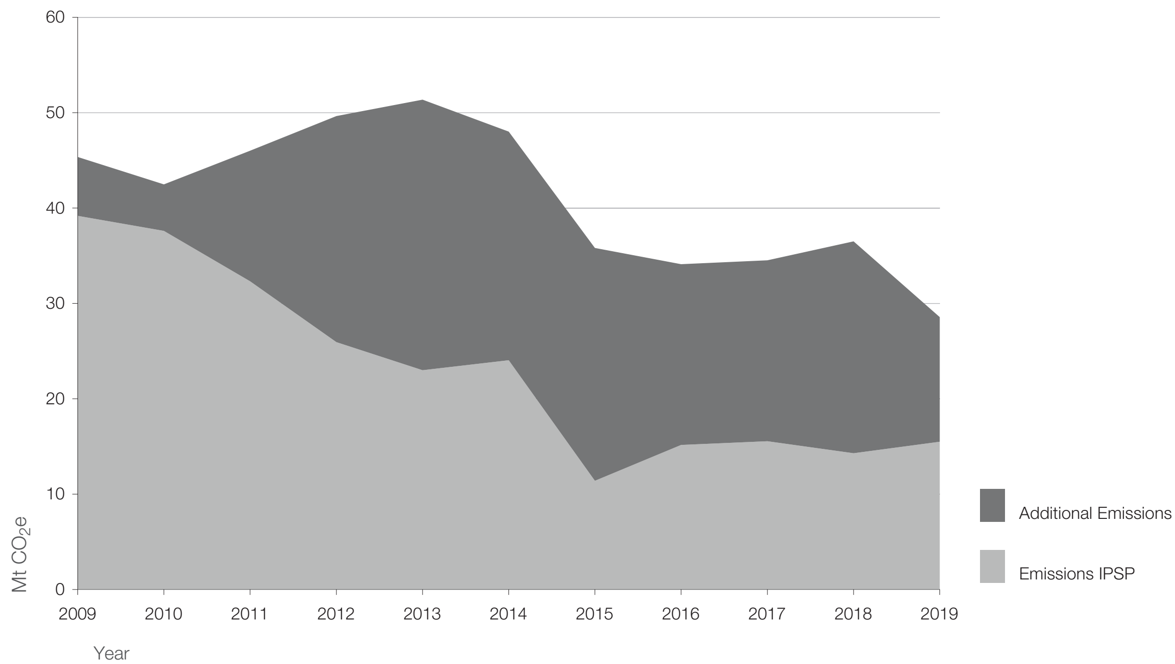
22 The Government of Ontario, *Ontario Greenhouse Gas Emissions Targets: A Technical Brief,* Monday, June 18, 2007, p. 8.

23 Ontario Power Authority, EB-2007-0707, Exhibit D, Tab 6, Schedule 1, p. 31.

24 Ontario Power Authority, EB-2007-0707, Exhibit 1, Tab 43, Schedule 2, Corrected: June 25, 2008, p. 6.

Table 3 shows how this over-estimation of future nuclear performance may drastically underestimate greenhouse gas emissions, expressed in megatonnes (Mt) of carbon dioxide equivalent (CO_2e), over the next fifteen years.

Table 3
Impact of Historic Nuclear Performance on Future Greenhouse Gas (GHG) Emissions



Source: Ontario Power Authority.[25]

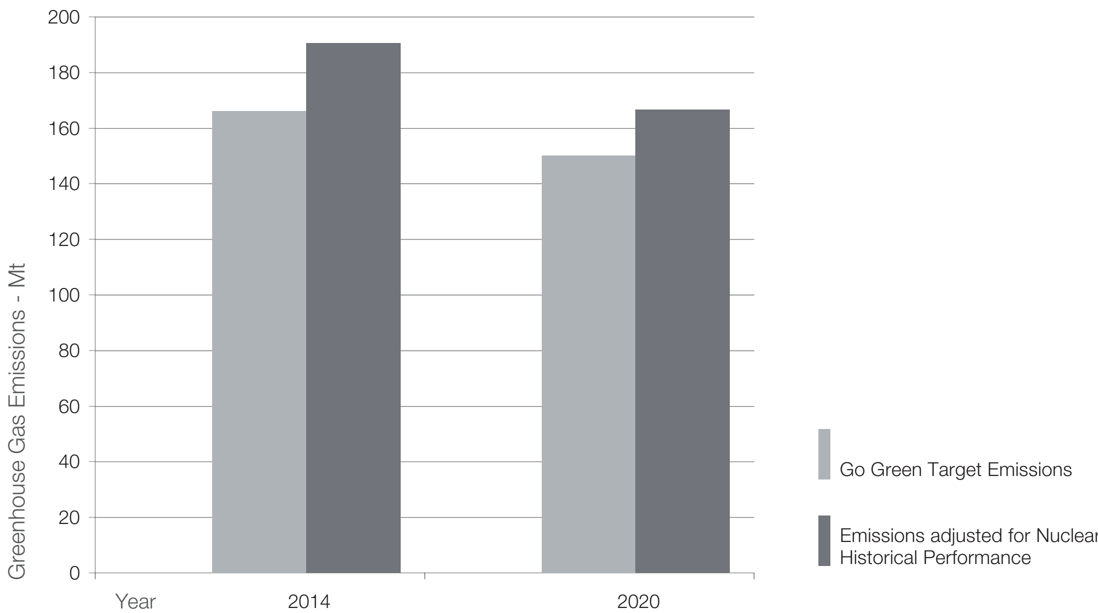
If historic nuclear performance is used to predict future emissions, Ontario will miss its greenhouse gas emissions reduction target of 61 Mt by 2014 by more than a third—26 Mt. Ontario will also fall 18 Mt short of its 2020 target of a 150-Mt reduction.

The OPA states that if such a scenario were to take place, a range of "feasible remedies" could be deployed to compensate for deficiencies in generation. Those remedies include "revisions to anticipated insurance coal requirements in the period 2008 and 2014," and "the use of interconnections," which would involve the import of coal-fired electricity from the United States.[26]

25 Ontario Power Authority, EB-2007-0707, Exhibit 1, Tab 43, Schedule 2, Corrected: June 25, 2008.
26 Ontario Power Authority, EB-2007-0707, Exhibit 1, Tab 43, Schedule 2, Corrected: June 25, 2008, p. 5.

Table 4 shows how Ontario will miss the greenhouse gas reduction targets in its Go Green plan if the province's nuclear stations perform as they have historically.

Table 4
Comparison of "Go Green" Targets with Historic Nuclear Performance



Source: Ontario government and OPA.[27]

As will be discussed, the government's unrealistic assumptions on nuclear performance will be compounded by the approaching end-of-life of the province's reactors. The impacts of reactor ageing may reduce nuclear performance and even potentially require the shutdown of reactors earlier than planned. Either scenario, if changes in energy strategy are not made, will lead to decreased nuclear supply.

1.4 The False Choice: Risky Nuclear and Greenhouse Gas Emissions or Risky Nuclear and Greenhouse Gas Emissions

The OPA's electricity plan threatens Ontario's climate change targets for two reasons. First, the OPA has over-estimated future nuclear performance. Second, the OPA did not adjust its strategy to fill the near-term electricity gap when it became known that new reactors could not be licensed quickly enough to bring new nuclear capacity online by 2014.

To fill the electricity gap, the OPA proposes three options that all entail undesirable effects:

1. Increased greenhouse gas emissions while reactors undergo risky life-extension repairs.
2. Increased greenhouse gas emissions while waiting for new replacement nuclear stations to come online.
3. A dangerous combination of increased greenhouse gas emissions and increased risk of nuclear accidents while extending the life of ageing nuclear stations.

Worse, delays in any of the proposed new-build or refurbishment projects may further increase greenhouse gas emissions or nuclear accident risks.

27 See calculations in Appendix B.

2. Waiting for New Reactors—Too Little, Too Late, Too Expensive

The nuclear industry claims that the cost over-runs and delays that plagued the construction of the last generation of reactors will not happen again. This claim ignores historic and current experience with the construction of new nuclear stations. It also threatens to divert investments from effective strategies to reduce greenhouse gas emissions, and to cost the federal taxpayer and provincial ratepayer billions.

Many variables can lead to delays at each stage of reactor development—planning, regulatory approvals, construction and commissioning. As discussed, new nuclear construction in Ontario has already suffered a delay at the planning stage due to optimistic assumptions regarding safety requirements. The target date for having new reactors online has already undergone a four-year delay, having been pushed back from 2014 to 2018. Historic experience shows that further delays are almost inevitable.

The Integrated Power System Plan (IPSP) submitted by the OPA to the OEB assumes new nuclear reactors will come online in 2018 and 2019 (see Appendix A). Any delay in completing these reactors will lead to a widening of the electricity gap, resulting in increasing greenhouse gas emissions or in reliance on ageing nuclear reactors.

The Ontario government has attempted to fast-track new nuclear construction by exempting IPSP from an environmental assessment. The province also made a policy decision in December 2006 not to participate in the federal environmental panel review of nuclear stations. Previously, the Ontario government claimed publicly that the provincial environmental assessment process was not applicable to nuclear projects. Documents acquired by Greenpeace, however, indicate that the province made a policy decision in December 2006 to not participate in federal environmental assessments on new nuclear stations, in order to limit "the threat of legal challenge to the Province and the threat that the scope of the environmental assessment will be expanded to include provincial issues such as power system planning." [28]

This fast-tracking, which has come at the expense of public consultation and rigorous environmental reviews, still does not limit the remaining risks of delays during the federal environmental review and the licensing review.

ONTARIO AVOIDS SCRUTINY OF NEW NUCLEAR

The McGuinty government has always publicly claimed it has no role or responsibility to subject nuclear projects to provincial environmental assessments.

When it approved the OPA's Integrated Power System Plan (IPSP) in June 2006, the McGuinty government secretly passed a special regulation to exempt the plan from a provincial environmental review, depriving Ontarians of an opportunity to objectively examine alternatives to the $40 billion in nuclear spending proposed in the plan. Then–Environment Minister Laurel Broten claimed that the regulation simply "confirms" the law, but refused to release the government's legal opinions on the issue.

The government asserted that new nuclear reactors would be assessed individually through federal environmental assessments and that the province had no obligation to subject such projects to environmental assessments. Documents acquired by Greenpeace through Access to Information, however, indicate that while the province was making these claims publicly it was considering its legal options behind closed doors. Six months after it announced commitment to build new reactors, the McGuinty decided *not* to participate in federal environmental reviews of its proposed new nuclear stations to limit "…the threat of legal challenge to the Province and the threat that the scope of the environmental assessment will be expanded to include provincial issues such as power system planning."

Ontarians were again deprived of the opportunity to examine green energy alternatives to building new nuclear stations.

28 Cedric Jobe (Min. of Energy) and Rick Jennings (Min of Energy), "RE: The Provincial Role in the Federal EA Process," December 11, 2006. Acquired through Access to Information.

According to Ontario's schedule for reactor deployment, construction must begin in mid-2012.[29] Ontario originally hoped to have selected a reactor design by December 2008, but has had to delay this date by at least three months.[30] This leaves less than three years for a new reactor design to pass through safety approvals. In contrast, it typically takes from 3 to 6 years for a new reactor design to acquire design certification by the Nuclear Regulatory Commission (NRC) in the United States. The CNSC, on the other hand, has not yet even put in place a modernized regulatory framework to licence proposed new reactors, raising uncertainties regarding its ability to licence new stations.

These tight timelines proposed by the provinces, as well as regulatory uncertainties, raise doubts about the province's ability to meet its target date for beginning reactor construction in mid-2012.

The timelines for construction may also suffer delays due to a lack of availability of certified component manufacturers, availability of labour and availability of materials, such as steel. The stagnation in nuclear construction since Chernobyl has led to a lack of competent personnel and a smaller choice of companies. For example, a recent study by GE-Toshiba identified a potential shortage of craft labour within a 400-mile radius of the Bellefonte site, in Tennessee, forcing the adoption of a longer construction schedule, while other nuclear industry publications have pointed to the potential for skill labour shortages if nuclear construction expands.[31] This dearth of competency combined with the complicated nature of project structures (e.g., the construction of Areva's Okliluoto-3 in Finland involves over 1,000 subcontractors in over 25 countries) makes quality assurance problematic.

These labour issues will be compounded by the fact that Ontario foresees building new reactors at the same time as it may also be rebuilding existing reactors at the Pickering B, Bruce B and Darlington nuclear stations. To put this in context, the refurbishment underway of two reactors at Bruce A currently ranks No. 1 on *ReNew Canada*'s list of the 100 biggest infrastructure projects in the country.[32] OPG submits that the proposed life-extension of the Pickering B nuclear station, which would take place in the same period OPG proposes to build new reactors at the Darlington site, would require upwards of 2,000 workers.[33]

Regulatory issues have already caused Ontario to push back its targeted date for new reactor operation from 2014 to 2018. The tight timelines for environmental and licensing approvals, as well as regulatory risks and labour or material shortages, pose a significant risk that this date will be pushed back even further.

2.1 Case Study: AREVA's European Pressurized Reactor

Ontario is considering three reactor designs for construction: Atomic Energy of Canada Limited's (AECL) Advanced CANDU Reactor (ACR), AREVA's Evolutionary Pressurized Reactor (EPR), and Westinghouse's AP-1000. Each of these designs is currently a prototype, with no operating model anywhere in the world.

AREVA's EPR is often seen as having an edge over AECL's ACR and Westinghouse's AP-1000 because it is currently under construction at two sites—Olkiluoto in Finland, and Flamanville in France. Like the ACR-1000 and the AP-1000, AREVA's EPR is promoted as more mature, safer, cheaper and more reliable than past designs. Promotional materials promise that, for example: "The EPR is the direct descendant of the well proven N4 and KONVOI reactors, guaranteeing a fully mastered technology. As a result, risks linked to design, licensing, construction and operation of the EPR are minimized, providing a unique certainty to EPR customers." [34]

The progress of construction of the EPR in both Finland and France, however, shows that the EPR is already not delivering on the promises to be cheaper, safer and more reliable. It also shows how the cumulative delays at the planning, licensing and construction stages can significantly lengthen construction timelines, increase costs and undermine effective greenhouse gas reduction initiatives.

29 Ministry of Infrastructure, Nuclear Procurement Project—Schedule 2 to the Request For Proposals, March 7, 2008, p. 4.
30 Infrastructure Ontario, *News Release,* "Nuclear Procurement Project Announces Additional Bilateral Meetings", July 25, 2008, and "Phase 2 of Nuclear RFP Latest Step in Ontario's 20-Year Plan to Bring Clean, Affordable and Reliable Electricity to Ontarians," June 16, 2008.
31 Cited in: Jim Harding, "Overnight Costs of New Nuclear Reactors," Pre-filed testimony on the application of the Ontario Power Authority for review and approval of the Integrates Power System Plan, Exhibit L Tab 8 Schedule 4, pp. 4–5, July 2008.
32 August 14, 2008 Press Release "Bruce Power Reports Second Quarter Results", available at http://www.brucepower.com/page-content.aspx?navuid=1211&dtuid=83793.
33 Canadian Nuclear Safety Commission (CNSC), Draft Environmental Assessment: Refurbishment and Continued Operation of the Pickering B Nuclear Generating Station, July 2008, p. 51.
34 Framatome ANP: EPR; brochure, March 2005.

2.1.1 EPR: COST AND DELAYS

When the decision was made to build an EPR in Finland in 2002, the government promised that it would cost €2.5 billion and take only four years to build. The final contract, three years later, put the price at €3.2 billion and construction time was set at 4.5 years. It was originally hoped that EPR could pass through licensing, construction and commissioning in time to be online within seven years.

Since construction began in 2005, a variety of technical problems have led to a three-year delay, extending the construction period to at least 7.5 years. The estimated additional cost is €1.5 billion, raising the current price tag to €4.7 billion, almost double the initial estimate. More problems, delays and cost overruns are likely to occur before the project is completed.

The estimated cost for future EPR reactors is also increasing. AREVA admitted in 2008 that new EPR projects would cost approximately €4.5 billion compared to the targeted cost of €3.2 billion for the Olkiluoto-3 project.[35]

2.1.2 A DISTRACTION FROM EFFECTIVELY FIGHTING CLIMATE CHANGE

In 2004, the International Energy Agency (IEA) warned Finland that relying on the on-time construction of Olkiluoto-3 could inhibit its ability to meet its greenhouse gas reduction targets, if any delays were to occur.[36] Olkiluoto-3 was forecast to reduce Finnish emissions by 7–10 Mt annually, beginning in 2009, meaning an average annual reduction of 5–7 Mt in the 2008–2012 period as called for under the Kyoto Protocol.[37]

This warning proved to be true. With the start-up of Olkiluoto-3 pushed back until at least 2012, the plant will make a negligible impact on Finland's Kyoto targets. If further delays occur, it will make no contribution to lowering greenhouse gas emissions. Meanwhile, the high-cost commitment of building Olkiluoto-3 has eliminated movement towards accelerated adoption of quicker-to-deploy energy options, such as rewewables, conservation and local supply. Indeed, former Finnish environment minister Satu Hassi MEP has admitted that once the decision was made to build Olkiluoto-3, Finland lost interest in renewable energy resources.[38]

2.1.3 THE PUSH TO BUILD QUICKLY: COMPROMISING SAFETY

The tight timelines and considerable pressure to control costs have led to a series of quality control issues at the Olkiluoto nuclear station in Finland and at the Flamanville-3 construction site in France. Such quality control issues can have a significant impact on the safety margins of the reactor once operation has begun.

The unrealistic cost estimate and construction timetable of Olkiluoto-3 have been a strong incentive for AREVA NP (a daughter company of AREVA, formerly known as Framatome ANP) to cut costs and to refuse to perform time-consuming corrections when problems arise.[39] AREVA's attempts to reduce costs reportedly have led the company to select cheap, incompetent subcontractors and overlook safety-related problems. In addition, nuclear safety training was not provided to workers.[40]

Because of fast-track licensing, Olkiluoto-3 subcontractors have used outdated blueprints, and Finnish authorities have at times been unable to supervise work because the necessary design documents were unavailable. New reactor designs are inherently harder to build and control because of their larger size. The EPR, for example, is the largest reactor ever built, with a reactor core that contains more radioactive elements than that of any other reactor. This increased size requires increased robustness in reactor containment in the case of an accident.

35 Ann MacLachlan, "Areva official says costs for new EPR rising, exceeding $6.5 billion," *Nucleonics Week*, Volume 49, Number 36, September 4, 2008, p. 1.

36 International Energy Agency, *Energy Policies of IEA Countries*, Finland 2003 review, IEA, 2004. http://www.iea.org/textbase/nppdf/free/2000/finland2003.pdf.

37 Lauri Myllyvirta (Greenpeace Finland) to S.P. Stensil (Greenpeace Canada), personal communication, 26 August 2008.

38 Satu Hassi MEP (Finnish Environment Minister 1999–2002), "Deciding on Nuclear," Briefing to UK Parliamentary and Sustainable Energy Group (PRASEG), November 2005. Available at: http://www.satuhassi.net/puheet/praseg.pdf. See also: Satu Hassi MEP, "How Kyoto was used as an argument and what happened afterward," October 18, 2005. Available at http://www.satuhassi.net/puheet/kyoto181005.htm.

39 Management of safety requirements in subcontracting during the Olkiluoto-3 nuclear power plant construction phase, Investigation report 1/06, STUK (Finland's Radiation and Nuclear Safety Authority), 10 July 2006, p. 18.

40 *Ibid*., at 23.

The stagnation of nuclear construction over the last decade has resulted in a shortage of competent personnel and companies.[41] In France, reports from nuclear regulator inspections repeatedly mentioned that the problems arise from "haste without any quality assurance process." [42] The Finnish nuclear safety authority STUK detected and documented 1,500 safety and quality problems in the EPR project.

2.2 New Reactor Costs: Already Rising

Historic and current experience with new reactor construction shows that nuclear costs are consistently underestimated. Even before construction has begun, the estimated cost for building new reactors has more than doubled since the OPA first developed its long-term electricity plan in 2005. The OPA has admitted that at these levels it would be uneconomical to build new reactors. Historic and international experience shows that once construction has begun these costs may increase again.

Every nuclear reactor built in Ontario has experienced massive budget over-runs. Table 5 outlines the cost over-runs that occurred during the construction of each of Ontario's nuclear stations.

Table 5
Cost Over-Runs for Nuclear Plant Construction in Ontario

PROJECT	ESTIMATED COST	ACTUAL COST	OVER-RUN 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

Source: Ontario Hydro[43]

The nuclear industry has promised that the next generation of nuclear reactors will be cheaper. Before construction has even begun, however, the cost estimates for new reactors have grown significantly since the OPA put forward its *Supply Mix Advice Report* in 2005.

The OPA used the cost of AECL's CANDU-6, a reactor it hoped to build and which has been constructed in five countries, as a "conservative" estimate of the cost of a new nuclear station because of the comparatively lower—and unverified—cost estimates for building the prototypes of next-generation reactor designs, which were claimed to be cheaper.

41 Greenpeace Finland's briefing on Olkiluoto 3, March 2008. Available at http://www.greenpeace.org/international/press/reports/fact-sheet-olkiluoto-3.

42 ASN letter from Flamanville-3 inspection, dated January 25th, 2008.

43 Pickering A Estimated Cost: Ontario Hydro, Demand Supply Plan Hearing Interrogatory No. 9.7.62, February 1991, p. 1., Pickering A Actual Cost: Ontario Hydro, A Journalist's Guide to Nuclear Power, 1988, p.2., Pickering B: Ontario Hydro, Demand Supply Plan Hearing Interrogatory No. 9.7.62, February 1991, Attachment 1, p. 1-1., Bruce A Estimated Cost: Ontario Hydro, Demand Supply Plan Hearing Interrogatory No. 9.7.62, February 1991, p. 1., Bruce A Actual Cost: Ontario Hydro, A Journalist's Guide to Nuclear Power, 1988, p. 4., Bruce B: Ontario Hydro, Demand Supply Plan Hearing Interrogatory No.9.7.62., February 1991, Attachment 2, p. 2-1., Darlington: Estimated cost is from Ontario Hydro in 1983. Sources: Ontario Energy Board Docket No. H.R. 12, Exhibit No. 7.3.1, June 13, 1983; and letter from OPG to Ravi Mark Singh, Ontario Clean Air Alliance, April 27, 2004, obtained from R.C. Watson, Freedom of Information Coordinator.

The cost estimates for new-build nuclear plants have more than doubled since the OPA cited the CANDU-6 as a conservative cost estimate.

→ In 2005, the Ontario Power Authority cited the cost of a CANDU-6 at $2,972/kW, as a conservative cost estimate for new nuclear plants.[44]

→ The CANDU-6 cost was used as a "conservative" estimate by the OPA because it was higher than the estimated costs of prototypes of next-generation designs, such as Advanced CANDU Reactor-700, at $2,400/kW; Advanced CANDU Reactor-1000, at $2,500/kW; and Westinghouse's AP-1000, at $1,900/kW.[45]

→ In May 2007, Standard & Poor's released a report on coal, gas, nuclear, and wind costs, and how competitiveness would be affected by carbon taxes. It estimated the capital cost for new nuclear stations at $4000/kW.[46]

→ In October 2007, Moody's Investment Service estimated the capital cost for new reactors at $5000–6000/kW.[47]

→ In May 2008, Moody's estimated the capital cost for new reactors at $7500/kW.[48]

In spite of the increase in the estimated capital cost for new nuclear stations, the OPA did not revise its cost assumptions for new nuclear construction when it submitted its Integrated Power System Plan (IPSP) to the Ontario Energy Board in August 2007. The OPA has admitted during cross-examination at the Ontario Energy Board (OEB) that if the cost of new nuclear stations is in the current range of estimates, it would be uneconomical to proceed with building new stations.[49] Instead of moving to re-evaluate its plan, however, the OPA has asserted via the provincial government's initiation of the Request for Proposals from nuclear vendors that new nuclear plants are already "committed" under the plan.

Nuclear vendors and operators, meanwhile, have been examining ways to transfer the increasing risks and costs of building new reactors in Ontario.

Members of "Team CANDU"—the alliance of companies hoping to participate in the construction of ACR in Ontario—asked the federal government in July 2008 to provide subsidized financing and protection for cost overruns and delays in order to "compete" with similarly subsidized foreign reactor vendors, such as AREVA.[50] OPG has begun pursuing "cost recovery mechanisms" and exploring "financing options" for building new reactors at its Darlington nuclear station.[51] "Cost recovery mechanisms" would most likely involve the Ontario ratepayer providing up-front loans while the station was under construction.

Both the federal taxpayer and the Ontario ratepayer may be forced to subsidize the rising cost of new nuclear construction in Ontario.

44 Canadian Energy Research Institute, *Electricity Generation Technologies: Performance and Cost Characteristics,* Prepared for the Ontario Power Authority, August 2005, p. 7.
45 Ontario Power Authority, EB-2007-0707,Exhibit D, Tab 3, Schedule 1, Attachment 1, p. 8.
46 Standard & Poor, "Which Power Generation Technologies Will Take the Lead in Response to Carbon Controls?," S&P Viewpoint, May 11, 2007.
47 Moody's Investors Service, "New Nuclear Generation in the United States: Keeping Options Open versus Addressing an Inevitable Necessity," October 10, 2007.
48 Moody's Investors Service, "New Nuclear Generating Capacity: Potential Credit Implications for US Investor Owned Utilities," May 2008.
49 In response to questioning at the Ontario Energy Board, the OPA admitted that at an overnight capital cost of $3,600 with an additional 2 cents in operating and maintenance costs and an 8% discount rate, nuclear stations would be uneconomical. See: Ontario Power Authority, EB-2007-0707, Exhibit, Tab 43, Schedule 3.
50 Tyler Hamilton, "AECL rapped for touting design," *The Toronto Star*, August 8, 2008.
51 Ontario Power Generation Reports 2008 Second Quarter Financial Results, August 22, 2008, p. 3.

2.3 Historic International Construction Time for Nuclear Power Plants

The average construction time for building a nuclear power plant has increased over time (see Table 6).

The significant increase in construction time in the period between 1980 and 2000 was due in part to the political impacts of the Chernobyl accident. Aside from public opposition to nuclear construction projects, the Chernobyl accident caused changes to be made to the design requirements for new reactors, which also affected construction time. More recent construction projects have accounted from the design stage for such regulatory requirements, improving construction periods. Average construction time is seven years.

Table 6
Historic Time for New Nuclear Construction

REFERENCE PERIOD	NUMBER OF REACTORS	AVERAGE CONSTRUCTION TIME (MONTHS)
1965–1970	48	60
1971–1976	112	66
1977–1982	109	80
1983–1988	151	98
1995–2000	28	116
2001–2005	18	82

Source: International Atomic Energy Agency.[52]

The average historic construction time for new nuclear plants in Ontario has also consistently increased (see Table 7).

Table 7
New-Build Construction Time in Ontario

STATION	START DATE	COMPLETION DATE	MONTHS
Pickering A	May 1, 1965	June 17, 1973	98
Pickering B	July 1, 1974	February 28, 1986	144
Bruce A	October 1, 1969	January 18, 1978	100
Bruce B	January 7, 1976	January 5, 1987	132
Darlington	January 7, 1977	December 1, 1992	191

Source: Ontario Hydro.[53]

52 Alexandro Clerici (European Regional Study Group), The Future Role of Nuclear Energy in Europe, World Energy Council, ABB Italy, 13 June 2006. The post-2000 estimates are based on the PRIS database, available at http://www.iaea.org/programmes/a2/index.html.
53 Response to Interrogatory from Coalition of Environmental Groups, Demand Supply Hearings, ID # 9.7.74, August 2, 1991.

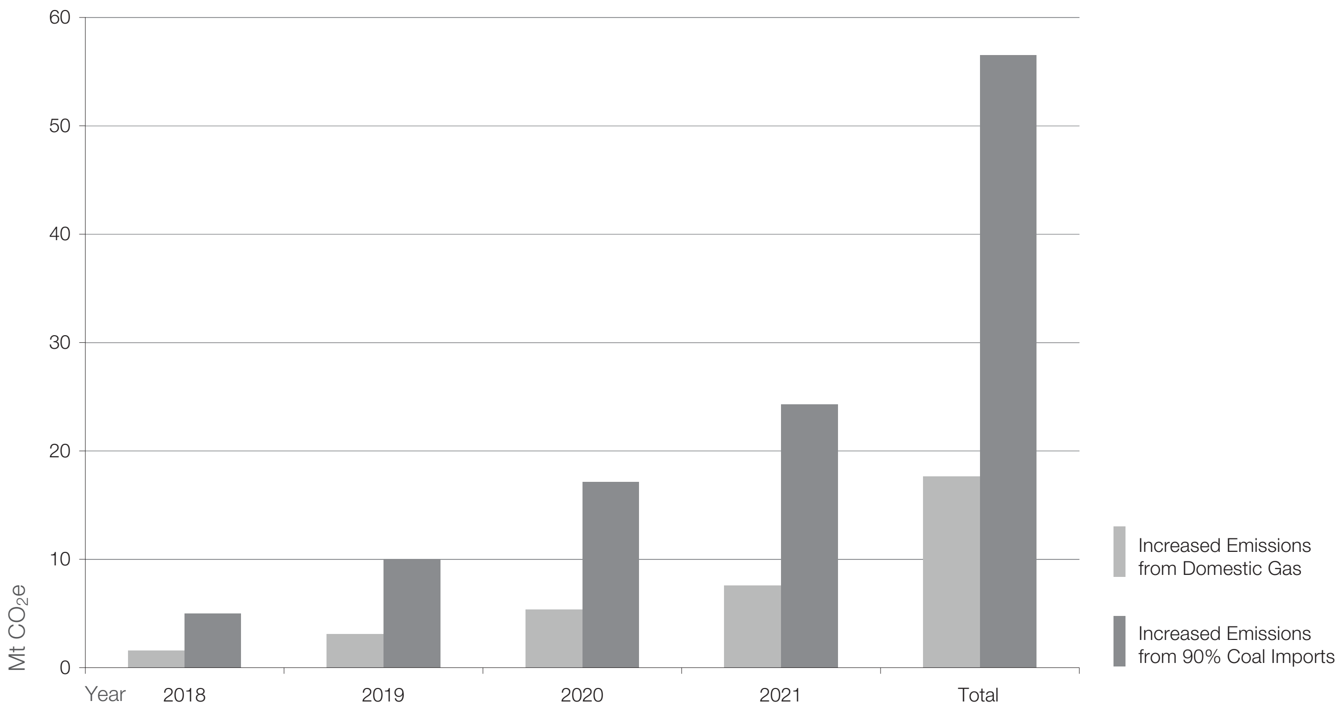
2.4 Impact of New-Build Delays on Greenhouse Gas Emissions

Following environmental and safety reviews, Ontario foresees a construction period of just over 4 years. Because of the large size of the reactors being proposed in Ontario, any delays in new nuclear generation will lead to an increased reliance on fossil generation and to increased greenhouse gas emissions.

The OPA's IPSP foresees 700 MW of new nuclear generation coming online in 2018 and 2019. If a decision is made to not rebuild the Pickering B nuclear station, the OPA foresees an additional 1,000 MW in reactors will come online in 2020 and 2021.[54] Delay in new nuclear generation would also coincide with planned closure of the Darlington units between 2018 and 2021 (see Appendix A).

If all new reactors were delayed until 2022, the province would be forced to rely on either increased domestic gas-fired generation or imported coal–fired generation. By 2022, the cumulative increase in greenhouse gas emissions would range from 17.6 Mt if solely gas generation were used, to 56 Mt if only imported coal were used[55] (see Table 8). Such delays would cause Ontario to miss its greenhouse gas reduction target for 2020 by 5 Mt, with gas generation, or by 17 Mt, with coal imports.

Table 8
Potential Increase in Greenhouse Gas Emissions from New-Build Delays



Source: See calculations in Appendix B.

54 Ontario Power Authority, EB-2007-0707, Exibit D, Tab 2, Schedule 1, p. 8.
55 See methodology, Appendix B.

3. Rebuilding Nuclear: Too Expensive, Too Late

When the Ontario government announced in 2006 its intention to build up to 14,000 MW of nuclear generation by 2025, Energy Minister Dwight Duncan stated that only "1,000 megawatts" of this capacity would be new nuclear generation.[56] The rest would be acquired by rebuilding ageing nuclear facilities at the Pickering, Darlington and Bruce nuclear stations, all of which reach the end of their operational lives before 2025.

The OPA acknowledges that it will be the plant operators—OPG and Bruce Power—that will make decisions on whether to proceed with the nuclear station life-extensions,[57] which could possibly result in large supply gaps under the OPA's long-term electricity plan.

The fate of the Pickering B nuclear station will be the first to be decided. According to the OPA's IPSP, the Pickering B reactors will shut down for life-extension repairs or permanently in 2013. The reactors at the Bruce B nuclear station begin to reach the end of their operational lives in 2015, followed by the Darlington station in 2018 (see Appendix A).

If a decision is made to not proceed with the life-extension of Pickering, the OPA's IPSP assumes that Pickering B will be replaced by increased fossil-fired generation until additional nuclear reactors come online in 2020 and 2021.[58] It does not provide similar contingency plans if decisions are made to shut down Bruce B and Darlington, stating that such scenarios will be considered in future iterations of the IPSP.[59]

It takes over ten years to build new nuclear stations, making it impossible for the Pickering B and Bruce B nuclear stations to be replaced by new nuclear units without a supply gap resulting—the OPA intends to bridge with energy sources that would increase greenhouse gas emissions. Given the risks and high cost of extending the life of CANDU reactors, Ontario needs to examine quicker-to-deploy green energy portfolios to fill this gap.

3.1 CANDU Life-Extension: High Risk, High Cost

Extending the life of a CANDU reactor is a risky, complex and high-cost undertaking, requiring up to six years of planning and approvals.[60]

The work required to extend the life of a CANDU reactor—often referred to as retubing—involves 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, and the upgrading of plant systems to meet modern regulatory requirements.

Past and recent life-extension projects show that retubing projects risk delays and cost over-runs and are no guarantee of reliable power resulting. The only example of a complete retubing project occurred when a pressure tube failure in 1983 required all four Pickering A reactors to be retubed, between 1983 and 1994. Despite this, the four Pickering A reactors were shut down again in 1997 as part of Ontario Hydro's Nuclear Asset Optimization Plan.[61]

56 Tyler Hamilton, "Huge nuclear plant in works," *The Toronto Star,* Mar 14, 2008.
57 Ontario Power Authority, EB-2007-0707, Exhibit D, Tab 6, Schedule 1, p. 19.
58 Ontario Power Authority, EB-2007-0707, Exhibit D, Tab 6, Schedule 1, p. 19.
59 Ontario Power Authority, EB-2007-0707, Exhibit D, Tab 6, Schedule 1, p. 19.
60 Ontario Supply Mix: Presentation to the Ontario Power Authority, Ontario Power Generation, September 26, 2005.
61 "Ontario Hydro Moving Ahead on Major Overhaul of its Production Facilities", Ontario Hydro News Release, August 13, 1997.

Table 9 provides a summary of recent reactor refurbishment projects in Ontario, showing how they have continued the historic pattern of cost over-runs.

Table 9
Recent Ontario Refurbishment Cost Over-Runs

PROJECT	ESTIMATED COST	ACTUAL COST	OVER-RUN FACTOR
Pickering A Unit 4 (1999–2003)	$457 million	$1.25 billion	2.7
Pickering A Unit 1 (1999–2005)	$219 million	$995 million	4.5
Bruce A Units 3 & 4 (2001–2004)	$375 million	$725 million	1.9
Bruce A Units 1 & 2 (2005–In progress)	$2.75 billion	$3.1 to $3.4 billion	1.1–1.2

Source: Pickering "A" Review Panel, Ontario Power Generation, and the Auditor General of Ontario.[62]

3.2 Case Study: Pickering A Restart

After the shut-down of the four Pickering A reactors in 1997, Ontario Hydro said it would restart all four reactors, at a cost of $ 780 million,[63] with the first reactor to restart in June 2000[64] and all four reactors back online by December 2001. The costs of the restart project, however, quickly escalated and schedules were delayed.

In 2003, a review committee appointed by then-premier Mike Harris released its assessment of the reasons for the delays and cost over-runs at Pickering A. The Pickering Review Panel blamed management practices at OPG and overlooked any problems associated with nuclear technology.[65] The review estimated that it would cost $3–4 billion to restart all four reactors and acknowledged that $1.25 billion had already been spent in order to restart one reactor by September 2003. In 2004, the McGuinty government announced it would proceed with the restart of Unit 1 at Pickering "A" at a cost of $900 million—more than four times the revised 1999 estimate of $213 million and roughly double the OPG Review Committee's estimate of $500 million just several months earlier.[66]

Shortly after the restart of Unit 1, OPG announced in August 2005 that it would not proceed with restarting the remaining two Pickering A reactors, due to the "the costs and the risks" of restarting the remaining two units.[67] OPG acknowledged that a contributor to the cost escalation was "the discovery of feeder pipe thinning in areas not previously identified" during the restart of Pickering A Unit 1. This resulted in the need to shut down Unit 4, which had been restarted, in order to carry out feeder repairs.[68] Despite claims by review committees that the problems with the Pickering restart were simply managerial, it was problems with the technology that caused the abandonment of the project.

62 Estimated and Actual costs of restarting Pickering A Unit 4: Jake Epp, Peter Barnes and Robin Jeffrey, Report of the Pickering "A" Review Panel, (December 2003), pp. 3–4., Estimated cost for of Pickering A Unit 1: Jake Epp, Peter Barnes and Robin Jeffrey, Report of the Pickering "A" Review Panel, (December 2003), p. 3., Actual cost for Pickering A Unit 1: Ontario Power Generation News Release, September 27, 2005., Bruce A Units 3 & 4: Letter to James Gillis, Ontario Deputy Minister of Energy, from CIBC World Markets Inc., October 17, 2005; and OPA, Ontario's Integrated Power System Plan: Discussion Paper 4: Supply Resources, p. 66., Bruce A Unit 3, which was restarted in 2003, will have to be closed again in 2009 for an additional $1.15 billion worth of work. Source: Office of the Auditor General of Ontario, "Special Review for the Minister of Energy: The Bruce Power Refurbishment Agreement," April 5, 2007, p. 6..
63 KPMG, Ontario Power Generation Inc., Financial Review of Operations, March 15, 2004, p. 20.
64 Ontario Hydro, 1998–2000 Ontario Hydro Corporate Business Plan, February 17, 1998, p. 22.
65 Pickering Review Panel, Report of the Pickering "A" Review Panel, December 4, 2003. The three panel members were Jake Epp, Chair, Peter Barnes and Dr. Robin Jeffrey.
66 OPG Review Committee, Transforming Ontario's Power Generation Company, March 15, 2004, p. 49.
67 Ontario Power Generation, *Annual Report 2006*, p. 17.
68 *Ibid*., at 18.

Notably, the two restarted Pickering A reactors have failed to perform at the targeted 85%[69] capacity. Since 2005, Pickering A Unit 1 has operated at a capacity of 50% and Unit 4 at 65%.[70] The cost of simply operating the two restarted reactors, in 2005–2007, was 11.3 cents/kWh. This cost excludes historic investment, such as from restarting them between 1998 and 2005, and the costs associated with the Pickering 2/3 isolation project (safe storage at Units 2 and 3).[71]

Delays and cost over-runs resulted in the abandonment of the restart of Pickering A nuclear station in 2005. Because of its commitment to restarting the station, the province was distracted from developing other alternate energy strategies that could have lowered its dependence on coal-fired generation.

3.3 Case Study: Point Lepreau

In July 2005, then-premier of New Brunswick Bernard Lord announced the province would proceed in 2008 with the life-extension of the Point Lepreau nuclear station, at a cost of $ 1.4 billion. Premier Lord also admitted the province had assumed more risk in the project than it would have preferred.[72]

The project had already seen an escalation in its estimated cost. In 2002, New Brunswick Power estimated the total cost for the project at $845 million.[73] After a review, the Public Utilities Board of New Brunswick ruled that, due to the economic risks, the life-extension of Point Lepreau was "not in the public interest." It recommended against proceeding with the refurbishment of Point Lepreau.[74]

New Brunswick then proceeded to renegotiate its contracts with Atomic Energy of Canada Limited (AECL) in order to pass on more of the project's financial risks to the federal taxpayer. Premier Lord also asked the federal government for an $800-million, interest-free loan to finance the project.[75] In addition, Premier Lord threatened to build a coal station if the federal government refused to provide financing or subsidies for the project. Documents acquired by Greenpeace show that after announcing that he would allow the life-extension of Point Lepreau to proceed, Premier Lord approached the federal government again to request low-interest loans to "reduce the price of power from the refurbished facility to New Brunswick consumers." [76]

The Point Lepreau life-extension shows how delays in the production of relatively small components can potentially lead to delays in the overall project. In August 2008, AECL filed a lawsuit against Precision Nuclear, a company contracted to supply replacement fuel channel components for the Point Lepreau and South Korea Wolsung-3 life-extension projects. AECL's lawsuit blames Precision Nuclear for failing to supply the components on time, which may potentially delay both projects. Precision Nuclear has countered that AECL should accept responsibility for some of the delays.[77] While AECL has yet to admit any delays, the date for the removal of the feeder pipes from the reactor has been delayed from July to August 2008.[78]

69 OPG Review Committee, Transforming Ontario's Power Generation Company, March 15, 2004, p. 50.
70 *Nucleonics Week Statistics Monthly*, August 2008.
71 EB-2007-0905, Association of Major Power Consumers in Ontario Argument, July 21, 2008, pp. 43–44.
72 Simon Tuck, "N.B.'s Premier relents, okays nuclear facelift," *The Globe and Mail*, July 30, 2005.
73 NB Power, Project Execution Plan, Appendix A-4, February 2002, Table 1-1, p. 1. This includes an "overnight" cost of $633 million, with escalation and interest, during construction of $211 million.
74 Decision of the New Brunswick Board of Commissioners of Public Utilities on the Proposed Refurbishment of the Point Lepreau Nuclear Generating Facility, September 24, 2002, p. 16.
75 Chris Morris, "N.B. premier seeking almost $1 billion in federal loans for nuclear plant," Canadian Press, April 12, 2005.
76 Memorandum to the Minister, "Request by the Honourable Bernard Lord, New Brunswick's Premier for federal support for the refurbishment of the Point Lepreau nuclear reactor," March 7, 2006. Acquired through Access to Information.
77 Daniel McHardie, "Contractual Meltdown," *Telegraph-Journal*, Thursday September 4, 2008.
78 Canadian Nuclear Safety Commission, CMD 08-M47, "Status Report on Power Reactors," August 21, 2008.

3.4 Case Study: Bruce A— A "Test Case" for the Future of Nuclear Power in Ontario?

In October 2005, the Ontario government signed a contract with Bruce Power for the return to service of Bruce A Units 1 and 2. The restart would include the retubing of the two units in order to extend their operational lives an additional 30 years. The estimated capital cost for restarting the station was $2.75 billion. Bruce Power CEO Duncan Hawthorne said his company's ability to come in on time and on budget would be a "test case" for future nuclear projects in Ontario.[79]

In April 2008, Bruce Power announced that the restart was $300–600 million over budget,[80] increasing the total cost of $3.1 to $3.4 billion. It is noteworthy that the Auditor General of Ontario criticized the provincial government for increasing without sufficient justification the total contracted cost estimate for restarting Bruce A by $250 million before the contract was signed with Bruce Power in 2005. The Auditor General also noted that Bruce Power and government experts had concluded that the risk of a cost over-run exceeding $2.8 billion was "small" because most of the refurbishment work would be sub-contracted through the use of fixed-price contracts, minimizing risks to the ratepayer. [81]

According to CNSC staff inspections in January 2008, there is "about a 6 month lag in the retube work." [82] Originally both Bruce A Units 1 and 2 were supposed to come in to service in 2009.[83] Bruce Power has admitted that at least one of the units will not be online until 2010.[84]

79 Steven Erwin, "Ontario's Nuclear Future at Risk If New Project Goes Over Budget: Bruce CEO," *Canadian Press,* October 20, 2005.
80 Keith Leslie and Romina Maurino "Ont. electricity consumers on hook for Bruce Power cost overruns; critics say," Canadian Press, April 17th, 2008.
81 Office of the Auditor General of Ontario, Special Review for the Minister of Energy: The Bruce Power Refurbishment Agreement, April 5, 2007, p. 8.
82 CNSC Inspector J. Stevenson, CNSC Walk Down of Bruce A Units 1 & 2, January 25, 2008.
83 CIBC World Markets, Review of the Bruce A Agreement, October 17, 2005.
84 Press release, "TransCanada Reports 10 Per Cent Increase in Comparable Earnings for 2007, Common Share Dividend Increased by Six Per Cent," January 29, 2008.

4.The Next Life-Extension Decision: Pickering B

The Ontario government is set to decide the fate of the Pickering B nuclear station in the first quarter of 2009. According to the OPA plan, the first Pickering B reactor will be closed for repair work or permanently in 2013 (see Appendix A).

The OPA's long-term electricity plan proposes two unacceptable choices: Either rebuild the Pickering B reactors, which, due to their proximity to Toronto and design flaws, would never be permitted to be built today; or shut down Pickering and use energy sources that would increase greenhouse gas emissions, until new replacement reactors can come online in 2020.

In 2006, OPG initiated the environmental assessment and safety review required to win approval from the CNSC to extend the life of Pickering B. These studies were also intended to inform the business case for rebuilding. The safety review—known as an Integrated Safety Review—is particularly important for developing the business case because it determines the range of upgrades required to bring the station closer to modern standards. This has an obvious impact on cost.

OPG originally intended to provide a business case for rebuilding Pickering B by April 2008,[85] but the delays with environmental and safety reviews required for the project have pushed back the decision until the first quarter of 2009.[86] OPG has yet to release a cost estimate for rebuilding the four reactors at the Pickering B nuclear station, but media reports cite estimates of around $5 billion.[87] The OPA, however, has assumed that the cost of rebuilding Pickering B will be equivalent to building a new nuclear station.[88]

New nuclear plants cannot be built in time to replace Pickering B. The OPA's current proposal, which would increase greenhouse gas emissions until new nuclear plants come online in 2020, is unacceptable. To stop dangerous climate change, greenhouse gas emissions must be reduced dramatically within the next decade.

The solution would be to shut down Pickering B in 2014 and avoid increased greenhouse gas emissions by replacing the plant's capacity with quick-to deploy green options that can be online in time for Pickering B's permanent retirement.

4.1 Unacceptable Outcome 1: Increased Greenhouse Gas Emissions

The first option the OPA names to bridge the gap between Pickering B's closure and the start-up of new nuclear stations is "additional natural gas-fired resources (whether though [sic] new-build, extension of service to existing plants, expansions on existing site, or conversions)." It also notes potential "arrangements to procure resources from outside of Ontario," which likely would come from coal-fired generation in the United States, "or other options as available." [89]

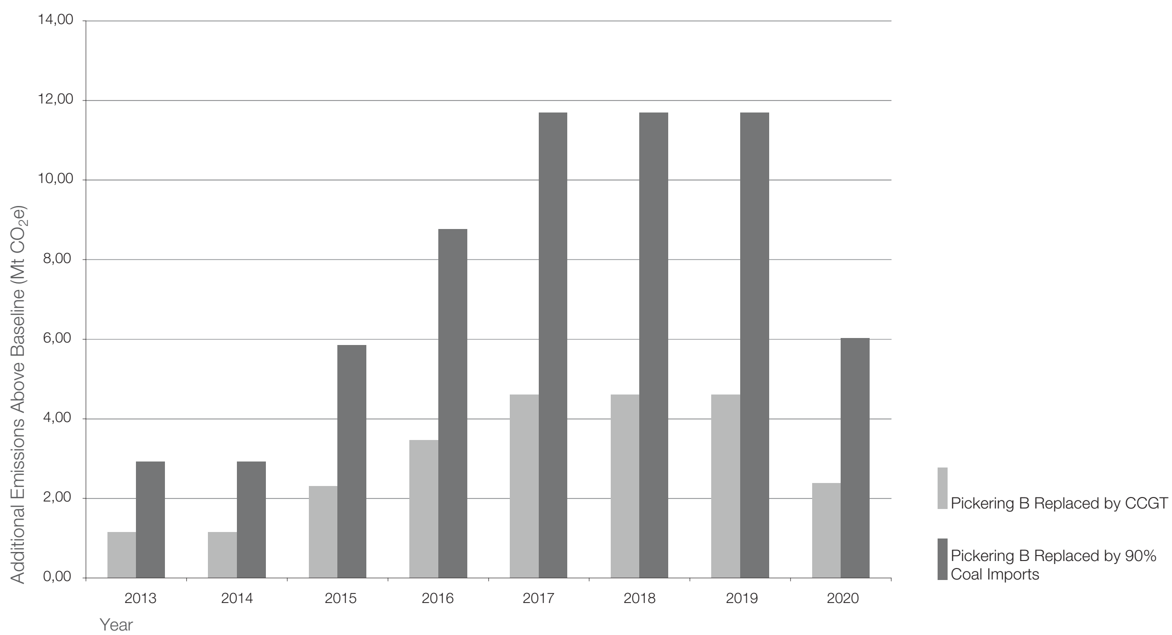
Table 10 shows the range of increased greenhouse gas emissions that would be produced by relying on domestic gas generation or imported coal–fired generation to replace Pickering B until new replacement nuclear stations come online in 2020 and 2021. The cumulative greenhouse gas increases range from 21 to 55 Mt, between 2013 and 2020, depending on whether gas or imported coal is used.[90]

Even if a decision is made to rebuild Pickering B, greenhouse gas emissions will still increase. The OPA assumes that it will take six years to rebuild the four Pickering B reactors. OPG, however, estimates that the life-extension of the four Pickering B reactors would take "8 to 12 years depending on the scope of the work," with reactors being "refurbished in sequence, based on a refurbishment outage of 2 to 2.5 [years] per unit." [91]

85 Ontario Power Generation Reports, 2006 Financial Results, February 16, 2007, p. 10.
86 Ontario Power Generation Reports, 2007 Financial Results, February 29, 2008, p. 12.
87 Tyler Hamilton, "Hydro supply feels the heat; Reactor outages, sticky temperatures prompt first call for energy conservation", *The Toronto Star*, June 27, 2007, B1.
88 Ontario Power Authority, EB-2007-0707,Exhibit G, Tab 2, Schedule 1, p. 3.
89 Ontario Power Authority, EB-2007-0707, Exhibit D, Tab 9, Schedule 1, p. 15.
90 See calculations in Appendix B.
91 Laurie Swami (Director of Licensing, Plant Life Extension Projects Division, OPG) to S.P. Stensil (Greenpeace), "Request for Information," September 25, 2006.

The cumulative greenhouse gas emissions produced during the refurbishment would range from 9 Mt, if gas generation were used, to 23 Mt, if imported coal were used.[92]

Table 10
Implications of Waiting for New Nuclear to Replace Pickering B: Greenhouse Gas Emissions



Source: See calculations in Appendix B.

4.2 Unacceptable Outcome 2: Increased Risk of Reactor Accidents

The second option the OPA proposes in order to bridge the gap between Pickering B's closure and the start-up of new nuclear stations is "service extensions to some or all of the Pickering B Units." [93] By "service extensions," the OPA is proposing to run reactors beyond the date by which OPG or Bruce Power would typically shut down a reactor due to the increasing costs of operating it safely. This would increase the accident risks already associated with the OPA's projected reactor lifespan, which have not been verified from a safety perspective.

As will be discussed, the OPA has based its long-term electricity plan on a projected schedule for reactor retirements and life-extension outages (see Appendix A). The feasibility of Ontario's ageing nuclear stations safely operating to the retirement dates set by the OPA, however, has not been verified from a safety perspective, raising the risk of supply shortages.

Indeed, the OPA appears to have based its reactor lifespan estimates on factors other than nuclear safety. The OPA stated in 2006 that it would "sequence" reactor retirements and life-extensions, "given that many of the reactors currently in service will require refurbishment within a narrow time window, and that there is limited technical capability available province wide for refurbishment." [94]

92 The amount of greenhouse gas emissions produced during the refurbishment of Pickering B was calculated by converting the megawatts lost during the refurbishment outage to terawatt hours, using the OPA's assumed capacity factor of 83%. Based on the OPA's assumptions, imports were assumed to be 10% clean energy and 90% coal-fired generation.
93 Ontario Power Authority, EB-2007-0707, Exhibit D, Tab 9, Schedule 1, p. 15.
94 Ontario Power Authority, IPSP Scope Paper, p. 15. Acquired through Access to Information.

Notably, the CNSC has no criteria for determining the end-of-life of Canada's nuclear stations. Instead, the CNSC requires licensees to demonstrate the "fitness-for-service" of its reactors through near-term projections of component integrity. Licensees, meanwhile, determine the operational life of their reactors based on the ability of "life-limiting components"—such as feeder pipes, pressure tubes, and steam generators—to operate while economically meeting safety goals established by the CNSC. The operational life dates claimed by nuclear operators, then, have not been assessed or approved by a nuclear safety regulator.

Proposals for "service extensions" could lead to increased accident risks and the possibility of interrupted electricity supply. Running reactors longer as components deteriorate will increase the need for more-frequent reactor shutdowns for inspections and repairs, resulting in both increased operational costs and lowered generation capacity.

Hydro-Quebec originally assumed it could operate the Gentilly-2 nuclear station until 2013 before it would need to be shut down or rebuilt. In 2005, however, Hydro-Quebec informed the CNSC that it had decided it would be uneconomical to operate the Gentilly-2 reactor safely past 2010, due to increased frequency of maintenance shutdowns and inspections as well as the high cost of replacement components.[95] In order to ensure that it could operate its Point Lepreau Nuclear Station until its planned refurbishment date in 2008, in 2004—four years before its end-of-life according to its original design—New Brunswick Power lowered the output of the plant.[96]

The proposal to extend the lives of ageing plants while coordinating life-extension outages (which may also involve delaying shutdowns) in order to maintain electricity supply, and the problem of balancing the labour and resource requirements of carrying out several mega-projects at once, warn of looming conflict between nuclear safety and electricity supply. This conflict will come at a time when Ontario's reactors will be experiencing the unpredictable impacts of ageing, increasing risks of accidents, and the possibility of supply shortages if reactors are unexpectedly forced to shut down for safety reasons.

As will be discussed, there is no guarantee that Ontario's nuclear stations will be able to operate safely until the retirement dates set out by the OPA, especially at the historically high capacity factors assumed by the OPA.

95 Michel R. Rhéaume (Hydro-Quebec) to Patsy Thompson (CCSN), "Lettre du 30 mai 2005 de M.R Cacchione, président d'Hydro-Québec Production à M. R. Joly chef de service, Services des projets industriels et en milieu nordique, Ministère du Développement durable, de l'Environnement et des Parcs," July 14, 2005.

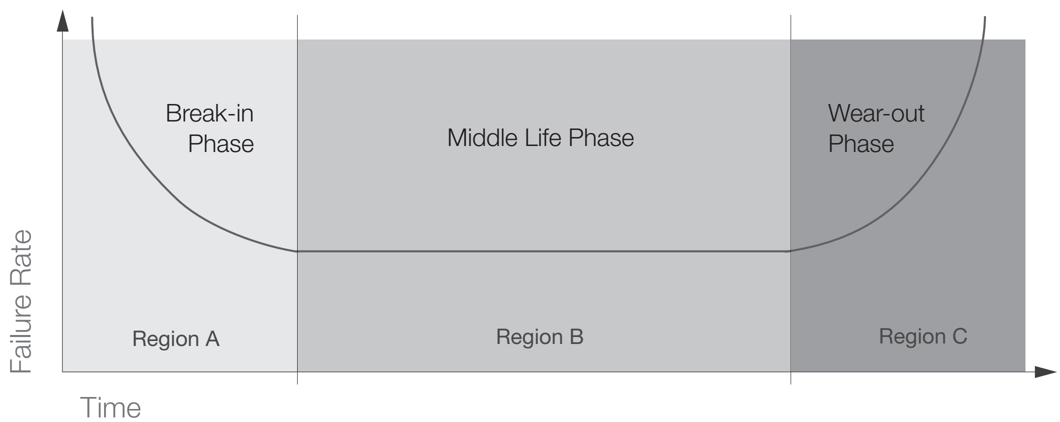
96 Mac Tueman, "Point Lepreau's capacity reduced to extend life; NB Power engineers hope holding plant to lower output will help avoid early shutdown," *Telegraph-Journal*, October 26, 2004.

5. Ageing Reactor Risks—High and Rising

All of Ontario's reactors will reach the end of their anticipated operation life between 2010 and 2020. This final period of the reactors' operational lives can be understood by a concept widely used by engineers to assess the impacts of ageing—the "bathtub curve." The increased probability of unpredictable shutdowns associated with this phase of a nuclear station's life is at odds with the OPA's assumption that Ontario's nuclear reactors will perform at their best historic levels for the next twenty years.

The bathtub curve (see Table 11) plots the hypothetical failure rates of components of an engineered system, such as a nuclear reactor, over its life-time. The graph shows three stages, with different hazard profiles: the break-in phase, the middle-life phase, and the wear-out, end-of-life phase.[97]

Table 11
The Bathtub Curve



Source: Adapted from NASA (2001), in D. Lochbaum, *op. cit.*

The two highest-risk phases are the break-in phase and the wear-out, end-of-life phase. During the break-in phase, for example, a reactor will have a higher risk of accidents as construction and design flaws manifest themselves. Several well-known international nuclear accidents occurred during or shortly after the start-up of new reactors, notably the Fermi, Three Mile Island, and Chernobyl accidents.

In Canada, a significant, unforeseen accident occurred at the Pickering A nuclear station in 1983 when a metre-long break ruptured a pressure tube in Pickering Reactor 2, spilling 17 kilograms (kg) of heavy water per second onto the floor of the reactor vault. The leak rate was gradually reduced as the coolant pressure dropped. The leak was stopped two weeks later. The Canadian nuclear industry, however, had always argued that pressure tubes will always leak before rupturing, allowing time to shut the reactor down before a loss-of-coolant accident occurs, which could result in losing control of the nuclear reaction. Because of the design flaw revealed by the accident, the fuel channels in all four Pickering A reactors at the Pickering A nuclear were replaced, at a cost—about $1 billion—more than double the capital cost of building the station.[98]

97 David Lochbaum, *U.S. Nuclear Plants in the 21st Century: The Risk of a Lifetime*, Union of Concerned Scientists, May 2004.
98 Ontario Hydro, *A Journalist's Guide to Nuclear Power*, 1988, p. 2.

Pickering B and Ontario's other nuclear stations are now entering the wear-out, end phase of the bathtub curve. This phase is when materials and components deteriorate after years of operation, leading to increased risk of system failures and accidents. Given the complexity of a nuclear plant, the impacts of ageing are not well understood and often only become apparent after component failures, such as tubes bursting. The unpredictability of the impacts of reactor ageing increases the likelihood of a greater number of shutdowns and inspections for shutdown and maintenance.

As the CANDU reactor design is based on a lattice-work of several hundred fuel channels containing both the fuel and coolant, degradation of the piping is caused by metal defects and chemical exposure, as well as vibrations and mechanical stress, or by heat stress caused by start-up and shutdown cycles. Thinning, cracking and sagging of tubing in CANDU reactors increase the risk of a loss-of-coolant accident (LOCA), which, when combined with shutdown failure, can result in a dramatic increase in reactor power within four to five seconds,[99] resulting in possible fuel damage and meltdown.

Over time, discoveries regarding gaps or inadequacies in the original safety framework for Ontario's nuclear plants have revealed safety margins that are drastically inadequate, leading CNSC staff to be concerned the margins may be insufficient to deal with new safety issues "such as those that may arise due to plant aging," [100] and raising doubt about the degree of protection they provide against severe accident.

As Ontario's reactors age, then, it can be assumed that they will be increasingly prone to unplanned shutdowns or reduced performance, which will have a negative impact on Ontario's already stressed electricity supply. Eroded safety margins and the impacts of ageing will also increase the risk of nuclear accidents.

> The inadequacy of safety margins has been discovered to be so large that CNSC staff are concerned the margins may not be sufficient for dealing with new safety issues, "such as those that may arise due to plant aging."

5.1 A Slippery Slope—Nuclear's Decline

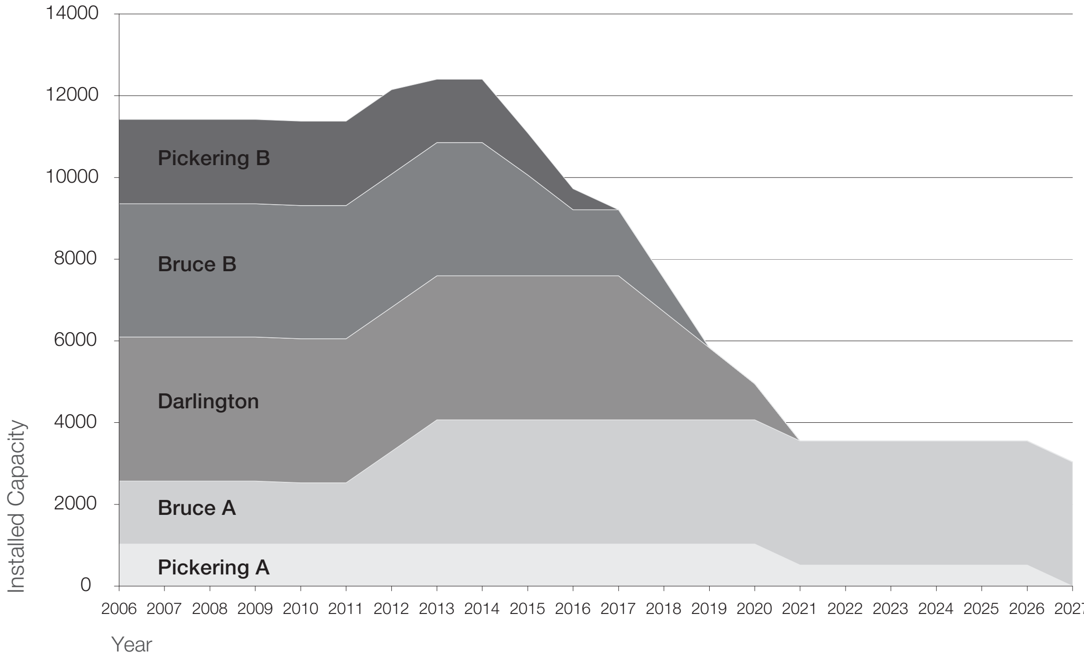
Ontario's nuclear stations are entering the wear-out phase of their operational lives, during which component degradation and failures increase the potential for accidents and the need for reactor shutdowns for maintenance or inspections.

The OPA plan proposes a "sequenced" reactor retirement and refurbishment schedule in order to balance supply and the technical expertise needed to carry out complex reactor life-extension projects. Given the federal regulator's approach to safety assessment, however, the OPA's end-of-life assumptions for nuclear stations have not been verified from a safety perspective.

Ontario's electricity gap, then, is at risk of deepening if unforeseen effects force the early or unplanned shutdown of reactors at any of the province's three nuclear stations. The risks inherent in Ontario's ageing nuclear stations cast doubt on the OPA's assumption that the province's nuclear plants will operate better than they ever have historically. The electricity gap could also deepen and widen if decisions are made not to rebuild Bruce B Nuclear Station.

99 J.S. Foster and W.B. Loewenstein, *The Pickering NGS "A" Shutdown Systems: A Review of the Need for, and the Nature of Possible Enhancements*, Toronto: Ontario Hydro, January 29, 1992.
100CNSC, "Technical Support Brand, "COG-07-9012 Draft Report on Large LOCA Margins and Void Reactivity in CANDU Reactors: Screening Review," October 10, 2007, p. 22. Acquired through Access to Information.

Table 12
Nuclear Capacity Decline



Source: Ontario Power Authority.[101]

5.2 Pickering B

The Pickering B reactors may not reach the OPA's targeted end-of-operation dates between 2013 and 2016.

It is noteworthy that in early 2006 OPG changed the estimated end of life for Pickering B from 2009 to 2014.[102] The motivation for pushing back the end-of-life date for the Pickering B reactors may have been due to the planning schedule needed to prepare for rebuilding a CANDU nuclear station. OPG informed the OPA in 2005, for instance, that extending the life of a CANDU reactor requires up to six years of planning and approvals,[103] making it impossible for OPG prepare in time for a refurbishment of Pickering B in 2009. In June 2006, the McGuinty government instructed OPG to begin the environmental and safety reviews to establish the business case for or against rebuilding Pickering B.

The OPA states: "There is a risk that Pickering B units may reach the end of their operating life ahead of schedule. For risk analysis purposes it was assumed that there is a 10% probability that each Pickering B unit will cease operation one year before its schedule end-of-life date." [104]

If Pickering B reactors are forced to shut down two years before the OPA's proposed retirement dates between 2013 and 2016, the cumulative greenhouse gas increases from replacement energy sources would range from 4 Mt, if gas generation were used, to 11 Mt, if imported coal were used (see Appendix B for calculations).

101 See Appendix A.
102 Ontario Power Generation (OPG), *2006 Annual Report: It's all About Performance*, p. 83.
103 Ontario Power Generation, "Ontario Supply Mix: Presentation to the Ontario Power Authority", September 26, 2005.
104 See: Energy Board-2007-0707, Exhibit D, Tab 2, Schedule 1, Attachment 2, p. 5.

5.3 The Future of Bruce B: No Contingency Plan

According to the OPA's submission to the OEB, the Bruce B reactors reach their end of life on a schedule similar to that of the Pickering B reactors, with one reactor a year going offline between 2015 and 2019 (see Appendix A).

There is, however, uncertainty regarding the end of life of the Bruce B reactors and the viability of the life-extension of the Bruce B reactors. OPG states in its 2007 annual report that it extended the service life of Bruce B nuclear generating station to 2014 for depreciation purposes, effective January 1, 2008, "*after reviewing future capacity plans in the OPA's IPSP* [emphasis added], and historical information regarding the service lives of major life limiting components of the station." [105]

Pickering B is forecast to begin shutting down in 2013 and Bruce B in 2015. Despite the similarities in timelines to Pickering B operational life, the OPA, in its OEB submission, has not produced alternate scenarios that consider the possibility that the Bruce B nuclear station not be rebuilt, stating that "[s]imilar scenarios with respect to the refurbishment of Bruce B and Darlington or replacement with new nuclear build will be considered in future Plans." [106]

Furthermore, any proposal to extend the life of the Bruce B reactors will trigger a screening review under the Canadian Environmental Assessment Act, as well as an Integrated Safety Review (ISR) by the CNSC.[107] Because the environmental review and safety reviews that are required to approve a life-extension take up to six years,[108] the environmental review should begin in 2008. Bruce Power, however, has yet to begin this approvals process.

The decision to refurbish or close the Bruce B reactors is also in question. Bruce Power CEO Duncan Hawthorne has stated that "[i]t's better than 50 per cent likely" that he will close the Bruce B reactors and replace them with new reactors.[109] A decision by Bruce Power to close Bruce B in favour of new nuclear reactors would cause supply issues not addressed in the IPSP.

There is evidence that Bruce Power is considering "service extensions" of the Bruce B reactors until new reactors come online. When Bruce Power filed its application for building new reactors with the CNSC in 2006, it claimed in its project description that new reactors could be online by 2014 to replace the Bruce B reactors when they begin reaching the end of their operational lives.[110] In September 2008, however, Bruce Power CEO Duncan Hawthorne claimed the Bruce B reactors would be good "until 2017, 2018." [111]

If the reactors at the Bruce B nuclear station were to go offline two years ahead of schedule, replacement energy sources could increase greenhouse gas emissions by 11 Mt, if gas generation were used, to 38 Mt, if imported coal were used (see Appendix B for calculations).

5.4. Darlington: Ageing Rapidly

The four Darlington reactors have an installed capacity of 3,524 MW.[112] OPG currently states that the Darlington nuclear station will operate until 2018 before permanent shutdown or undergoing refurbishment for life-extension is necessary.[113]

Darlington Nuclear Station, which is Ontario's youngest nuclear station, is already experiencing age-related degradation of components, including the thinning of pressure tubes and feeder pipes. OPG informed the CNSC in 2001 that the anticipated life of the station's feeder pipes was approximately half of their designed lifetime.[114] Inspections attributed the thinning to "flow-assisted corrosion." [115]

105 OPG 2007 Annual Report, p. 45.
106 See Ontario Power Authority, EB-2007-0707, Exhibit D, Tab 6, Schedule 1, p. 19.
107 See CNSC regulatory guide RD-360, "Life Extension of Nuclear Power Plants." This guide was produced after complaints by Greenpeace.
108 Ontario Power Generation, "Supply Mix: Presentation to the Ontario Power Authority," September 26, 2005.
109 Pat Halpin, "Some Bruce reactors will likely be replaced, chief executive says," *The Record*, Thursday, November 8, 2007, B2.
110 See Figure 4 in Bruce Power, "Bruce Power New Build Project Environmental Assessment: Project Description," August 2006.
111 Scott Dunn, "Bruce Power gets vote of confidence," *The Owen Sound Sun Times,* Tuesday, September 16, 2008, A1.
112 Ontario Power Authority, EB-2007-0707, Exhibit D, Tab 6, Schedule 1, p. 10.
113 CMD o7-H20, Information and recommendations from the Canadian Nuclear Safety Commission Staff regarding Ontario Power Generation Inc.—Renewal of the Darlington Nuclear Generating Station Operating Licence Public Hearing Day, 1 November 2007.
114 Letter, D. Lafrate to L. Macdonald, "Darlington NGS—Feeder Inspections," July 11, 2001.
115 Letter, D. Lafrate to L. Macdonald, "Darlington NGS—Unit 3: Feeder Inspections," May 3, 2002.

OPG has initiated a number of programs to mitigate feeder ageing and avoid the need to replace the feeder pipes before the project refurbishment date. These programs include: injecting titanium dioxide into the heat transport system to slow thinning; the development of "weld overlay" to avoid the need for feeder replacement; and replacement of a significant number of feeders on a three-year schedule, to avoid the need for a long outage to replace them all at once.[116]

The success of these programs, however, is difficult to predict. An internal CNSC staff briefing in 2005 noted that if these programs are successful, the first refurbishment outage at Darlington would probably take place in 2016. If the programs are not successful, the first feeder replacement outage "may occur as early as 2011." [117]

OPG informed the OPA in 2005 of the possibility that Darlington units may require refurbishment as early as 2013.[118] This risk of a premature shut down of the Darlington reactors, however, was not acknowledged in the OPA's final submission to the OEB. Indeed, OPA only assumes a 0.1% likelihood that none of the Darlington units would be available in the 2015–2027 period.[119] The OPA has stated that the possibility of Darlington's coming offline early will only be addressed post-2010, when the IPSP is reevaluated.[120]

If the reactors at the Darlington nuclear station were to go offline two years ahead of schedule, replacement energy sources could increase greenhouse gas emissions by 15 Mt, if gas generation were used, to 39 Mt, if imported coal were used.

5.5 Pickering A: Won't Make It

Two of the four 515-MW Pickering A reactors are operating, after being restarted in 2005. The other two reactors have been permanently laid up due to the high cost of restarting them and their questionable future operational reliability. The four Pickering A reactors, which began operation between 1971 and 1973, are the oldest commercial reactors in Canada.

The OPA's electricity plan assumes Unit 4 will operate until 2026 and Unit 1 will operate until 2021.[121] These are optimistic estimates, given the age and operational history of the Pickering A reactors, and would be a longer span than they have been capable of operating previously. Pickering A Unit 1 began operation in 1971 and was shut down in 1984 for retubing, restarting five years later. Unit 4 began operation in 1973 and was shut down in 1991, restarting in 1993. Both reactors were shut down again in 1997 as part of the Nuclear Asset Optimization Plan.[122]

It is notable that the Pickering A reactors have experienced poor performance since being restarted, with Unit 1 operating at a capacity factor of 50% and Unit 4 at 65%,[123] when the units were intended to operate at 85% capacity.[124] The cost of simply operating these two reactors during 2005–2007 is 11.3 cents/kWh. This cost excludes historic investment, such as restarting them between 1998 and 2005 and the costs associated with the Pickering 2/3 isolation project.[125]

Pickering A's poor performance has had an impact on greenhouse gas emissions. Because of an unplanned shutdown in 2007 to repair an electrical back-up system, coal-fired generation increased 19% compared to the same three-month summer period in 2006.[126] The OPA is hoping that the two ageing Pickering A reactors will be able operate longer than they actually have historically.

If Pickering A reactors 1 and 4 are forced to shut down just two years before the OPA's proposed retirement dates in 2020 and 2026, the cumulative greenhouse gas increases from replacement energy sources would range from 4 Mt, if gas generation were used, to 11 Mt, if imported coal were used (see Appendix B for calculations).

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116 Briefing Note—Darlington, November 2005. Acquired through Access to Information.
117 Briefing Note—Darlington, November 2005. Acquired through Access to Information.
118 Ontario Power Generation, "Ontario Supply Mix: Presentation to the Ontario Power Authority," September 26, 2005.
119 Ontario Power Authority, EB-2007-0707, Exhibit D, Tab 2, Schedule 1, Attachment 3, p. 4.
120 Bob Gibbons, Director of Resource Integration, Ontario Power Authority, "Integrated Power System Plan Modeling Workshop," April 25, 2008, Toronto.
121 Ontario Power Authority, EB-2007-0707, Exhibit D, Tab 6, p. 10.
122 Ontario Hydro, "Ontario Hydro Moving Ahead on Major Overhaul of its Production Facilities," news release, August 13, 1997.
123 *Nucleonics Week Statistics Monthly*, August 2008.
124 OPG Review Committee, "Transforming Ontario's Power Generation Company," March 18, 2004, p. 60.
125 Ontario Power Authority, EB-2007-0905, Association of Major Power Consumers in Ontario argument, July 21, 2008, pp. 43–44.
126 Karen Howlett, "Coal plants keeping the lights on," *The Globe and Mail*, Saturday, August 18, 2007, p. A6.

6.The Safety Case for Shutting Down Pickering B and Ontario's Other CANDU Stations

OPG is currently preparing the business case to determine whether it is more economical to rebuild or to close the Pickering B Nuclear Station. The Ontario government is expected to make a decision early in 2009 on whether to rebuild. Based on safety reasons alone, however, the Pickering nuclear station should be permanently shut down.

OPG is proposing to extend the life of Pickering B, which was designed and built in the 1960s, until 2060, nearly one hundred years. This is an extraordinary experiment in reactor operation. No nuclear station has operated for such a length of time, raising unprecedented questions regarding the impacts of ageing on safe operation.

There are six operating reactors at the Pickering nuclear station—two at the older Pickering A station and four at the Pickering B station. In addition to the design flaws it shares with Ontario's other multi-unit CANDU stations, Pickering has unique flaws that should over-ride any economic case for extending the life of the station. The two older stations, for example, share linked safety systems, including those of containment and of emergency core cooling, as well as a common vacuum building, a situation which poses a higher risk of accidents than at other facilities.

Worse, Pickering is closer to a major population centre (the city of Toronto) than any other nuclear station in the world. While the nuclear industry maintains that the risk of a catastrophic nuclear accident is low, it would be unacceptable today to allow the construction of a new nuclear station to be built at the Pickering site.

6.1 The Chernobyl and CANDU Design Flaw: Positive Reactivity

The nuclear industry's rule of thumb for averting significant nuclear accidents is summarized in the following three-level hierarchy of nuclear safety: "control, cool, contain." Otherwise put, if reactor power can be *controlled*, nuclear fuel sufficiently *cooled* and, in a worst case, radioactivity can be *contained,* the public and the environment will be protected from nuclear accidents.

The CANDU design shares an inherent design flaw with the Chernobyl RBMK reactor design that significantly weakens its ability to control and cool the nuclear reaction in accident situations. Specifically, the reactor core design of both the CANDU and Chernobyl reactors builds in "positive reactivity;" that is, the reactor power has a tendency to increase, potentially in an explosive pulse.

Positive reactivity poses significant challenges to controlling and cooling a reactor. In particular, loss-of-coolant accidents (LOCAs) are of concern for reactors with positive reactivity. In a CANDU reactor, such an event can cause a power pulse that overheats the fuel (loss of reactor control) at the same time that the reactor's ability to cool the reactor is degraded.

An important contributor to the 1986 Chernobyl accident was the presence of steam in the fuel channels, which, due to the reactor's positive reactivity, quickly led to a loss of control of the nuclear reaction and an explosive power pulse. The sequence of events was as follows: A rise in reactor temperature resulted in increased production of steam, which has a lower density than water used as the coolant. This created steam "voids" The lower-density steam voids resulted in increased reactivity (loss of control), raising the power level, which resulted in even more heat and thus increased the steam voids in the fuel channels. This created an explosive feedback loop of reactor power.

> Documents acquired by Greenpeace show AECL has opposed modernized requirements for negative reactivity, claiming it "would impact on marketing of CANDU 6 reactors" and reflect badly on operating CANDUs because "every current reactor design has some inherent characteristics that may increase reactivity in certain design-basis events."

The ensuing Chernobyl disaster resulted in a revision of international safety standards to include a prejudice against positive reactivity in reactor designs.

As noted, only the CANDU reactor shares a substantial positive void effect with the Soviet era RBMK reactors. By contrast, light water reactors (LWRs), which dominate the world market, have a negative reactivity. The Atomic Energy Control Board, the predecessor to the CNSC, suggested the positive void coefficient for the CANDU is approximately one-third that of RBMK reactors.[127] It has been noted however, that even at this lower level, there could be serious, perhaps uncontrollable, loss of regulation.[128]

After Chernobyl, ongoing discoveries regarding the magnitude of positive reactivity at Ontario's nuclear stations have required a reduction in power output in order to maintain safety margins. The Bruce B reactors, for instance, were significantly down-rated in the earlier 1990s to 90% power due to the threat of "prompt criticality behaviour" in the case of a loss-of-coolant accident. Bruce Power is currently proposing to change from natural uranium fuel to slightly enriched uranium (1% of U235), otherwise known as low void reactivity fuel (LVRF), to improve the performance of the station during LOCAs and increase output from the station.[129]

New discoveries regarding positive reactivity continue to erode safety margins at Ontario's nuclear stations. In 2001, CNSC staff requested that licencees revisit and confirm that the safety case for each of Ontario's stations still conformed with the licensing basis, because of doubts that computer codes were adequately estimating the impacts of positive reactivity on reactor behaviour.[130] The revised analysis for the Pickering B station "resulted in prediction of consequences which are substantially worse than reported previously." [131] According to CNSC staff, the new analysis indicates a "large reduction of previously reported safety margins …" [132]

According to internal CNSC documents, the operating restrictions and financial support required to address safety and regulator issues related to positive reactivity issues have resulted in "significant increase in costs " for nuclear operators. Despite all of the efforts to address the safety issues related to positive reactivity, "the possibility of further erosion of the safe available safety margins as well as the imposition of additional operational and procedural limits cannot be precluded *a priori* for current CANDU reactors." [133] As noted, CNSC staff are also concerned that cumulative erosion in safety margins has been so large that reduced safety margins may not be able to cover new safety issues "such as those that may arise due to plant aging." [134]

Since Chernobyl, international standards have developed to favour more inherently safe reactor designs—that is, designs not dependent on engineered safety systems or operational procedures for the control of risk, to prevent accidents—to the disadvantage of reactor designs having positive void reactivity, specifically the Chernobyl RBMK and CANDU designs.

In line with the direction of international standards, the CNSC's 2005 draft design guide states that "priority shall be given to nuclear reactor's inherent negative feedbacks that shall mitigate any rapid increase in reactivity and reactor power." [135] Internal CNSC documents acquired by Greenpeace show AECL has opposed the requirement for negative reactivity, claiming it "would impact on marketing of CANDU 6 reactors" and reflect badly on operating CANDUs because "every current reactor design has some inherent characteristics that may increase reactivity in certain design-basis events." [136]

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127 Atomic Energy Control Board, *The Accident at Chernobyl*, May 1987, p. 18.
128 W. Sweet, "Canada's Post Chernobyl Challenge," *Technology Review*, Vol. 92, No. 5, July 1989, p. 50.
129 CNSC Enviornmental Assessment for the Operation of Bruce B Reactors with CANFLEX-LVRF, June 17, 2008, p. 3.
130 P.H. Wigfull to G. Preston, "CNSC Position Statement on Generic Action Item (Gal) 00G01: Channel Voiding During a Large LOCA," April 30, 2001.
131 T.E. Schaubel (Director, Pickering Regulatory Program Division) to D.P. McNeil (Senior Vice President, OPG) "CNSC Staff Review of Pickering NGS-B Integrated Safety Review—Safety Analysis Safety Factors Report," April 7, 2008, p. 17.
132 *Ibid.*, at 14.
133 CNSC, "Problem Statement: Large LOCA Safety Margins & Positive Reactivity Feedback," between April 1 and June 30, 2008, p. 1.
134 CNSC, Technical Support Brand, "COG-07-9012 Draft Report on Large LOCA Margins and Void Reactivity in CANDU Reactors: Screening Review," October 10, 2007, Acquired through Access to Information, p. 22.
135 CNSC, "Pre-Consultation Draft—Requirements for the Design of Nuclear Power Plants," March 2005, p. 50.
136 D. Serghiuta, Memorandum, "S-337 Outstanding Issue # 18—Reactor Core Neutronic Design," April 13, 2007.

On the other hand, AECL's goal for its proposed Advanced CANDU design is, in fact, to have negative reactivity. Its ability to meet this design objective, however, is in doubt. In 2008, AECL abandoned the start-up of the MAPLE reactors at Chalk River, which were intended to produce medical isotopes and replace the fifty-year old NRU reactor. The MAPLE reactors were designed to exhibit negative reactivity, but when started were found actually to have positive reactivity.[137]

Because of the inherent hazard of positive reactivity in CANDU reactors, Ontario's nuclear stations would be difficult to license internationally.

6.2 Containment and Ontario's Multi-Unit Nuclear Stations

All of the nuclear stations originally built by Ontario Hydro at Pickering, Bruce and Darlington are unusual in that they are multi-reactor stations, with the same safety and support systems shared among multiple reactors. While the sharing of systems does occur at other nuclear stations around the world, it is generally among fewer reactors than occurs in Ontario.

Stations at Bruce A, Bruce B and Darlington each have four reactors with shared safety systems, but Pickering is unique in that eight reactors share both the containment and the emergency coolant injection systems.

The Canadian nuclear industry and its regulator have always maintained that without a breach of reactor containment, no reactor accident will cause a release of radioactivity to the environment.[138]

Containment at Pickering consists of eight individual reactor buildings connected to one vacuum building by the pressure relief duct. In the event of a serious accident, the vacuum building is designed to suck up radioactive material and steam, and is able to douse the steam with water in order to reduce pressure on the containment system. This containment system is designed to handle 530 gigajoules (GJ) of thermal energy (stored energy and radioactive decay heat) from one reactor during a one-hour period after shutdown.[139] Thus, the containment system can only deal with one accident at one reactor.

Pickering's design was clearly motivated by a desire to reduce construction costs by not building individual containment systems for each reactor. The designers ignored the possibility of simultaneous accidents at two or more reactors. Such accidents (known as common mode failures) can be caused by external events such as earthquakes, weather-related problems, electricity failures, or acts of malice due to war, terrorism or sabotage.

Similarly, the emergency coolant injection system (ECIS) at Pickering is a shared system. Pickering A did not originally have ECIS; the system was built during construction of Pickering B. It was designed to provide a flow rate of 640 litres per second (l/s), in order to deal with the largest assumed leak at one reactor.[140] Thus, the system can only deal with one accident at one reactor. Like the containment system, ECIS cannot deal with common mode failures resulting in major loss-of-coolant accidents (LOCAs).

In its review of the OPG's Probabilistic Risk Assessment, CNSC staff note the following significant omission:

> "At Pickering B some initiating events could produce multiunit accidents. For instance, a medium or large steam line break event at one unit might produce a harsh environment in the common powerhouse leading to common cause accidents at all units with multiple failures of mitigating systems. Since these types of accidents are major contributors to the plank risk according to PRA results, additional risk from adjacent units may not be negligible. Furthermore, if multiple mitigating systems fail due to the harsh environment, several units may have severe core damage simultaneously. This may create such a challenge to the containment that its failure may not be precluded. We think these scenarios should be considered."[141]

137 Rennie Mackenzie, "AECL abandons plans to develop Maple isotope production reactors," *Nucleonics Week*, Volume 49, Number 21, May 22, 2008, p. 4.
138 For instance, the environmental assessment report for the restart of the Pickering A nuclear station stated that: "Unless the containment envelope is breached, there can be no major environmental impacts even for a severe accident" (CNSC [2000], *Screening Report on the Proposal to Restart the Pickering A Nuclear Station*, pp. 7, 3–14).
139 Ontario Hydro, "Pickering NGS A Safety Report," Toronto, 1969, with revisions.
140 Ontario Hydro, "Pickering NGS A Safety Report," Toronto, 1969, with revisions.
141 Y. Zeng to T. Schaubel, "Preliminary PBRA Review Report—JMS 17668," August 8, 2007.

6.3 Canadian Containment Failures

Notably, there is also a documented history of containment failures in Canada. Such failure, if combined with a failure to control and cool the reactor, could lead to a catastrophic release of radioactivity.

For example, a nine-week-long impairment of the Bruce NGS-B containment system existed in 1990 after a control technician incorrectly set the calibration on radioactivity monitors, relying on memory only.[142] Had there been an accident requiring use of containment during this period, the automatic isolation of the system would have been delayed, allowing the release of radioactivity.

During the once-per-decade test of the containment system at Pickering in 1990, seals on the pressure relief duct expansion joints failed at about half the design pressure.[143] The pressure relief duct is the ½-kilometre-long elevated concrete tunnel on the south side of the reactors, linking each reactor to the vacuum building. It was estimated that the Pickering nuclear station containment system had been inadequate for the previous 7½ years, due to the expansion of joint seals.[144]

6.4 The Terrorist Threat

None of Canada's nuclear power plants was designed to withstand an aerial terrorist attack, such as was seen on September 11, 2001.

Although the design of new nuclear stations will be required to be robust enough to resist certain terrorist attacks, the CNSC has allowed existing nuclear stations to forgo expensive design changes to adapt to the post–September 11 reality. Indeed, while increasing the security measures and infrastructure against non-aerial attack, the CNSC's response to September 11 is largely symbolic: establishing no-fly zones over Canada's nuclear stations.

CNSC staff admitted the vulnerability of the Pickering station to an aerial attack in the environmental assessment guidelines for the life-extension of the Pickering B Nuclear Station, stating that "nuclear power plants, like other public infrastructure, are not required to be designed to withstand this type of event." [145] The multi-unit design and shared system of the Pickering Nuclear Station makes it particularly vulnerable to catastrophic accidents in the event of a terrorist attack.

Nor would a terrorist be required to achieve a direct hit on the containment of the nuclear station to cause a catastrophic accident and release of radioactivity. When asked, during CNSC hearings in November 2006 regarding the Gentilly-2 nuclear station, CNSC security expert Colin Moses admitted that an aerial attack on the control room would "have fairly serious consequences to the station." [146]

6.5 Pickering: 30 Kilometers from Toronto

Because of the high population density, regulatory authorities would not allow a new plant to be built at Pickering today. A Chernobyl-scale accident at the Pickering nuclear station would have a devastating impact on the health and environment of southern Ontario and demolish the economy of Canada's largest city, Toronto.

Currently, 4,057,745 people live within 50 kilometers of the Pickering nuclear station. Extending the life of Pickering will only compound the siting issue, as the population within 50 kilometers of the plant is predicted to double in the not-distant future, to almost 8 million. It should be noted that Pickering is an area designated for population intensification under the McGuinty government's Place to Grow Act: the population within ten kilometers of the plant is projected to grown from 218,091 today to 403,773 in 2060.[147]

142 Event Report # 90-57, Bruce B.
143 Pickering Event Report #90-55.
144 Atomic Energy Control Board Annual Staff Report on PNGS, May 1991.
145 CMD 07-H2, Appendix D—"Dispositioning of Comments from Stakeholders Refurbishment and Continues [sic] Operation of Pickering B Nuclear Generating Station Draft EA Guidelines," p. 59.
146 Transcripts, CNSC hearing on the environmental assessment of Gentilly-2, November 8, 2006.
147 See Chapter 7, "Description of Credible Malfunctions and Accident Scenarios," in *Refurbishment and Continued Operation of Pickering B Nuclear Generating Station Environmental Assessment*, prepared for Ontario Power Generation Inc., by SENES Consultants Limited, December 2007, pp. 5–23.

Notably, the environmental assessment for the life-extension of the Pickering B nuclear station has identified a nuclear accident scenario involving release of radioactivity that the regulatory body views as "credible." That is, the CNSC views the scenario as probable enough that its potential impacts should be evaluated. Typically, the CNSC considers such accidents as of such a low probability that they don't merit consideration.

According to Emergency Management Ontario (EMO), radiation levels from this accident scenario could necessitate evacuating up to a 10-kilometre (km) radius around Pickering B.[148] Such an accident would arguably have a greater economic impact on Toronto than the SARS epidemic had. There are currently 238,088 people within 10 km of the Pickering nuclear station;[149] the costs of evacuation and lost economic activity would be enormous.

However, even a small-scale accident involving a radioactive release at Pickering would have a destructive impact on the city of Toronto. To use a similar scenario as an indication, a recent federal government study estimated that the cost of the damage from a "dirty bomb" attack in downtown Toronto that spreads radioactivity for four kilometres would be $23.5 billion.[150]

148 "Pickering B Refurbishment Environment Assessment—Summary of February 7, 2008 Meeting between CNSC, EMO, and OPG and CNSC Staff Recommendations Regarding an Evacuation Study," March 6, 2008.

149 "Credible Malfunctions and Accident Scenarios—Technical Support Document Refurbishment and Continued Operation of PNGS B Environmental Assessment, Submitted to Ontario Power Generation Inc." Prepared By SENES Consultants Limited, December 2007, p. 5–23.

150 Jim Bronskill and Sue Bailey, "Fallout from a dirty bomb," *The Toronto Star*, July 3, 2007, A12.

7.Nuclear: Standing in the Way of Green Energy

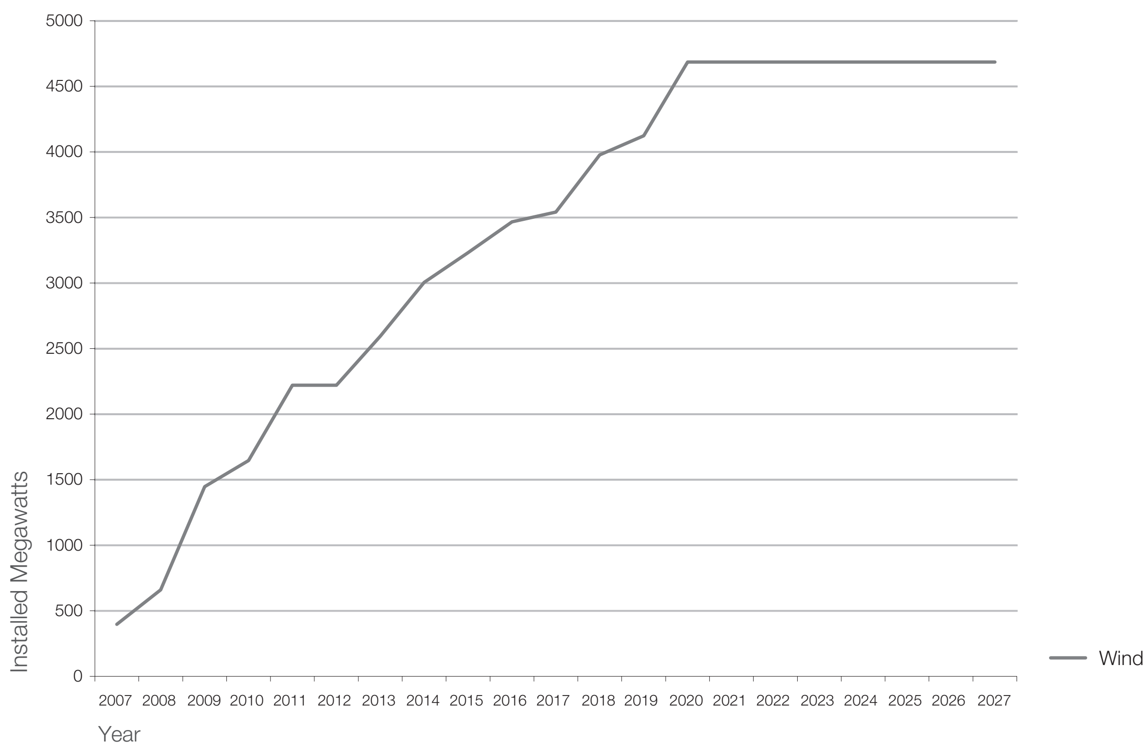
Because of its commitment to long lead–time nuclear construction, Ontario's proposed long-term electricity plan caps the development of renewable energy in Ontario at 5312 MW of wind, solar and biomass.[151] This falls well short of the rapid deployment of renewables that is occurring in other jurisdictions.

In 2006, the Ontario government gave the OPA *minimum* targets for renewable development over the next 20 years, while giving it a *maximum* for nuclear development.[152] The OPA, however, has interpreted these minimum targets for renewables as maximums in the long-term energy plan it submitted to the Ontario Energy Board in 2007.

Instead of ambitiously developing renewables, conservation, and efficient local generation to fill the supply gap left by Ontario's ageing nuclear facilities, the OPA has underestimated the cost of new nuclear facilities in order to rationalize meeting the maximum level set by the provincial government of 14,000 MW by 2025. It has also ignored the supply risks and greenhouse gas emissions associated with waiting for new nuclear stations instead of developing quicker-to-deploy energy options to fill the electricity gap.

Indeed, while Ontario sought to develop renewables and conservation relatively ambitiously until 2010,[153] it will slow the deployment of these post-2010 in order to make space for long lead–time nuclear projects. Table 13 shows how wind development is planned to stop in 2020 after new nuclear stations come online in 2018 and 2019.

Table 13
Future Wind Development in Ontario

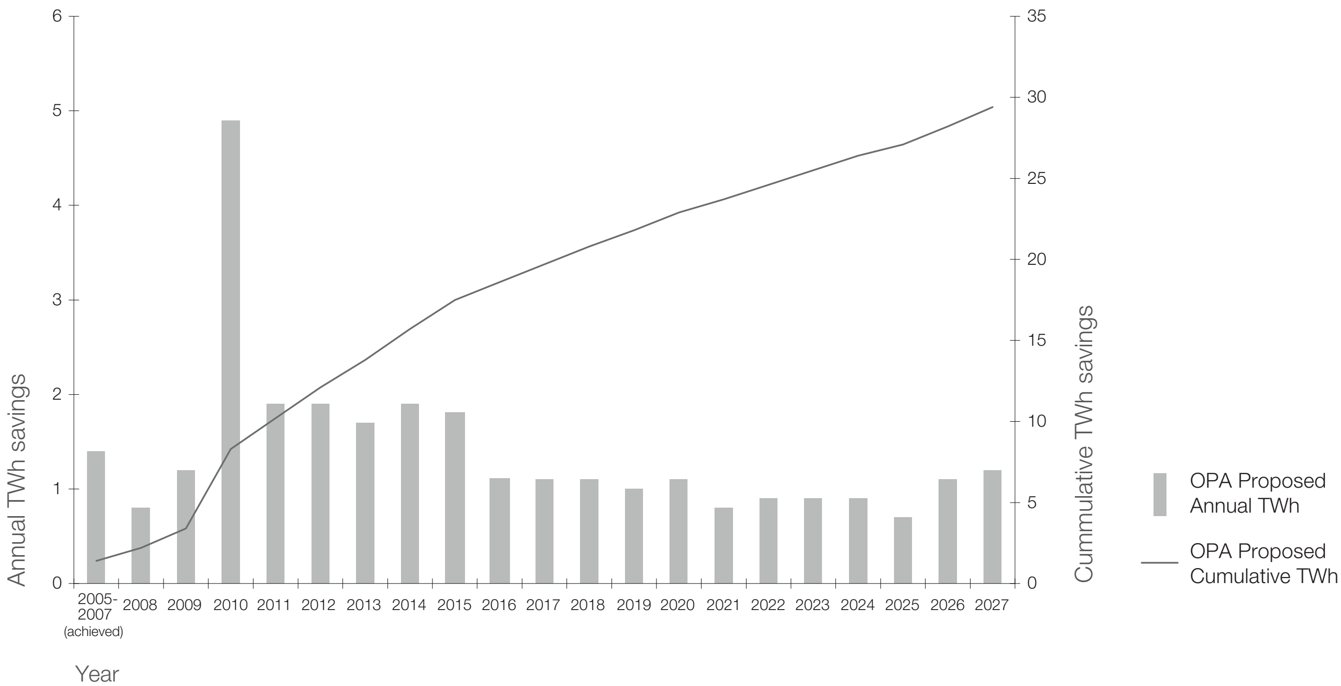


Source: Ontario Power Authority. EB-2007-0707, Exhibit D, Tab 9, schedule 1, p. 8.

151 Ontario Power Authority, EB-2007-0707, Exhibit D, Tab 9, Schedule 1, p. 8.
152 OEB, *Report of the Board on the Review of, and Filing Guidelines Applicable to, the Ontario Power Authority's Integrated System Plan and Processes*, p. 5–6. Available at http://www.oeb.gov.on.ca/documents/cases/EB-2006-0207/IPSP_report_final_20061227.pdf.
153 The government's 2006 directive to the OPA (Dwight Duncan, Minister of Energy, to Jan Carr, Chief Executive Officer, OPA, 13 June 2006, available at http://www.energy.gov.on.ca/index.cfm?fuseaction=english.news&back=yes&news_id=134&backgrounder_id=106) states that 2,700 MW of renewable generation should be deployed by 2010. The long-term energy plan, however, significantly reduces the rate of deployment by capping it at 5,312 MW in 2025. Similarly, the directive tells the OPA to use conservation and demand management (CDM) to reduce peak demand by1,350 MW by 2010, but subsequently slow down conservation initiatives to 3,600 MW by 2025.

Table 14 shows the electricity savings achieved in Ontario between 2005 and 2007, as well as the OPA's proposed conservation targets to 2027. Conservation reaches a peak in 2010 at 4.9 TWh and then drops to 2 TWh a year for the following five years. Conservation rates then drop again to approximately 1 TWh a year for the next 12 years.[154]

Table 14
The OPA's Proposed Annual and Cumulative Electricity Conservation



Source: S. H. Parker, Vermont Energy Investment Corporation. *Optimizing the CDM Resources in Ontario*.

7.1 The Solution: Quick-to-Deploy Green Energy

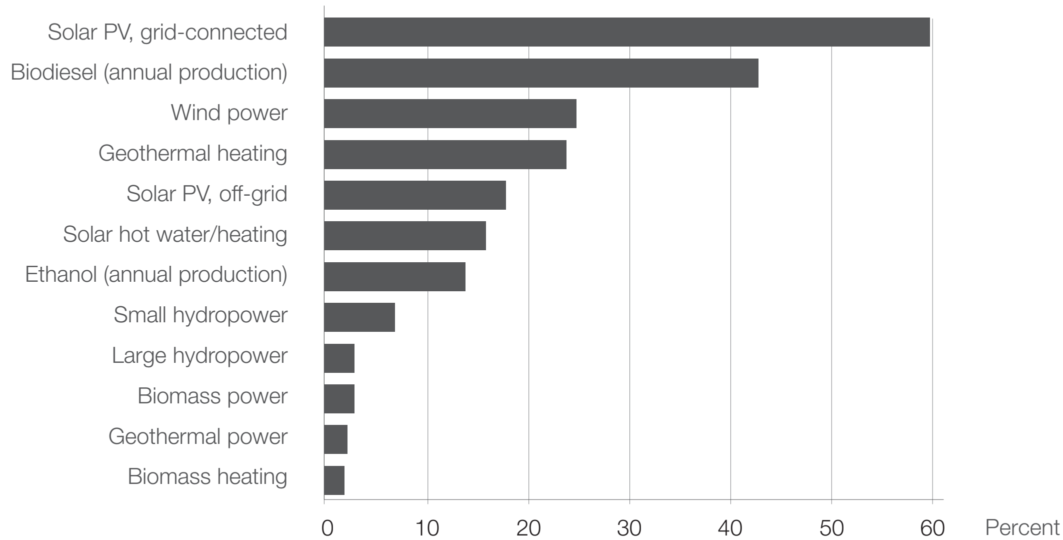
Despite the claims of a "nuclear renaissance," the growth rates for renewable energy outpace nuclear development globally.

In 2007, global installed nuclear capacity grew by less than 2,000 megawatts, attributable to the completion of three new reactors in India, China, and Romania.[155] This is equivalent to just one-tenth of the new-installed wind power built globally in 2007,[156] which grew by 28% in 2007.[157]

World renewable energy capacity increased at rates of 15–30 percent annually between 2002 and 2006 (see Table 15).[158]

154 Scudder H. Parker, Vermont Energy Investment Corporation, *Optimizing the CDM Resources in Ontario,* prepared for the Green Energy Coalition, p. 31. (EB-2007-0707, Exhibit L, Tab 8, Schedule 3).
155 See Power Reactor Information System, at www.iaea.org/programmes/a2.
156 U.S. Department of Energy, Energy Efficiency & Renewable Energy, "Global Wind Energy Capacity Increases 27% in 2007," *EERE NEWS*, 6 February 2008; Bernie Woodall, "U.S. Wind Power Grew 45 percent in 2007: AWEA," *Reuters*, 17 January 2008.
157 Renewable Energy and Policy Network for the 21st Century, *Renewables 2007: Global Status Report*, p. 6.
158 Renewable Energy and Policy Network for the 21st Century, *Renewables 2007: Global Status Report*, p. 10.

Table 15
Average Annual Growth Rates of Renewable Energy Capacity, 2002–2006



Source: Renewable Energy and Policy Network for the 21st Century. *Renewables 2007 Global Status Report* (Paris: REN21 Secretariat; and Washington, DC: Worldwatch Institute).

In contrast, the growth of nuclear generation remains small and plagued by construction delays. In 2007, thirty-four reactors were under construction worldwide. Twelve of these reactors, however, have been under construction for 20 years or more.[159] China, France, Russia, and South Korea began the construction of seven reactors, totalling 5,190 megawatts, which is approximately 100 megawatts fewer than was added in 2006.[160]

With so few new construction starts, world nuclear generation actually faces the prospect of declining capacity in the coming decades as plants reach the end their operational lives. While no reactors were permanently shut down in 2007, the global nuclear industry has closed 124 reactors, equaling 36,800 megawatts, since 1964.[161] In Ontario, OPG decided to permanently shut down Units 2 and 3 of the Pickering A nuclear station in 2005, citing the high costs of restarting the units.

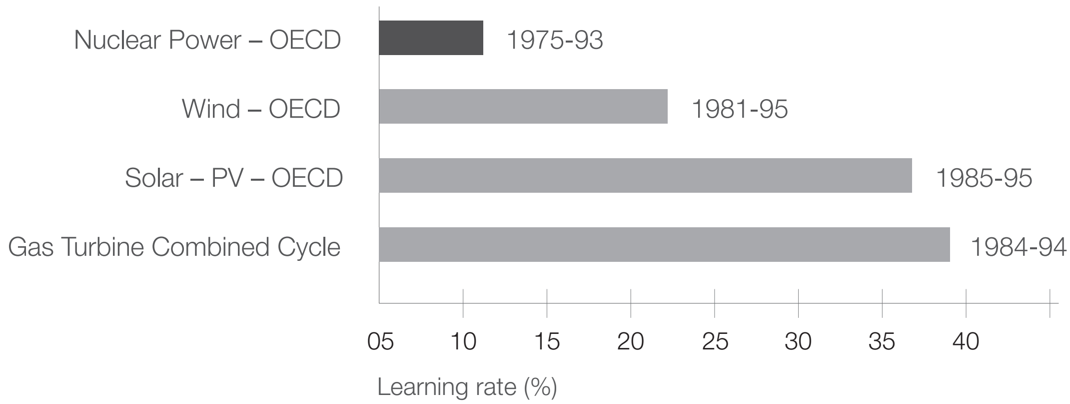
159 Mycle Schneider with Antony Froggat, *The World Nuclear Industry Status Report 2007* (Brussels: The Greens–European Free Alliance in the European Parliament, January 2008), p. 7–8.
160 Based on Worldwatch Institute data base compiled from statistics from IAEA. See: *Power Reactor Information System*, at www.iaea.org/programmes/a2.
161 See International Atomic Energy Agency (IAEA), *Power Reactor Information System*, at www.iaea.org/programmes/a2.

7.2 Green Power: Quick-to-Learn

Despite over fifty years of development and policy support by governments worldwide, nuclear power has exhibited a relatively low learning rate compared to other technologies, such as renewables (see Table 16).

The costs of renewable energy technologies, however, are coming down quickly as innovations are tested and deployed year-to-year. For instance, RBC Capital Markets predicts that photovoltaic power will be cost-competitive with traditional energy sources by 2014, due to ongoing innovation and the economies of scale brought about by increased production.[162] In contrast, the long lead times for bringing new reactors online results in a slow pace of lessons learned and improvements derived from the experience in design and operation.

Table 16
Learning Rates of Selected Energy Technologies



Source: Alan McDonald and Leo Schrattenholzer (2001). "Learning rates for energy technologies," *Energy Policy* 29, 255–261.

> "The costs of energy production and use from all technologies have fallen systematically with innovation and scale economies in manufacture and use, apart from nuclear power since the 1970s."
>
> —*The Stern Report*, the UK Government's review of the economic impact of climate change

162 RBC Capital Markets Corp., "Investing in Solar Now," April 30, 2007.

8. Conclusions

- Ontario is going to fall short of its greenhouse gas reduction targets if it depends on ageing nuclear power plants' operating better than they ever have historically.
- New reactor construction has already been delayed in Ontario, having been pushed back from 2014 to 2018. Historic and international experience shows that further delays can be expected.
- The Ontario Power Authority has given the provincial government a false choice for replacing Pickering: Either rebuild the Pickering B reactors, allowing an increase in greenhouse gas emissions during at least six years needed for the job, or build new replacement reactors, allowing an increase in greenhouse gas emissions during the wait for these reactors to come online after 2020.
- The Ontario Power Authority has failed to provide any contingency scenario for replacing the Bruce B reactors if a decision is made to extend their operational life. The Bruce B reactors start going offline in 2015.
- The operating lifespan for Ontario's reactors that has been assumed in Ontario's long-term electricity plan has not been verified from a safety perspective.
- Ontario's ageing reactors will be more prone to unpredictable shutdowns, lowered performance and increased accident risks.
- Since beginning operation, the discovery of design flaws at Ontario's nuclear stations has revealed erosion in the safety margins of Ontario's nuclear stations to the point that further discoveries related to the impacts of ageing may require the shutdown of the reactors.
- The Darlington nuclear station is prematurely ageing. The OPA has not considered the possibility of an early shutdown of the Darlington reactors in its Integrated Power Supply Plan.
- Ontario's existing multi-unit CANDU reactors contain design flaws that would not be permitted under modern international safety standards. They should be shut down.
- Both the federal taxpayer and the Ontario ratepayer may be forced to subsidize the rising cost of new nuclear construction in Ontario.
- Because of its commitment to long lead–time nuclear projects, Ontario's long-term electricity plan caps the develop of renewable power in the province.

Appendix A: OPA's Nuclear Plan

Unit	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Pickering A1	515	515	515	515	515	515	515	515	515	515	515	515	515	515	515	0	0	0	0	0	0	0
Pickering A2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pickering A3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pickering A4	515	515	515	515	515	515	515	515	515	515	515	515	515	515	515	515	515	515	515	515	515	0
Total Pickering A	1030	1030	1030	1030	1030	1030	1030	1030	1030	1030	1030	1030	1030	1030	1030	515	515	515	515	515	515	0
Pickering B5	516	516	516	516	516	516	516	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pickering B6	516	516	516	516	516	516	516	516	516	0	0	0	0	0	0	0	0	0	0	0	0	0
Pickering B7	516	516	516	516	516	516	516	516	516	516	0	0	0	0	0	0	0	0	0	0	0	0
Pickering B8	516	516	516	516	516	516	516	516	516	516	516	0	0	0	0	0	0	0	0	0	0	0
Total Pickering B	2064	2064	2064	2064	2064	2064	2064	1548	1548	1032	516	0	0	0	0	0	0	0	0	0	0	0
Bruce A1	0	0	0	0	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750
Bruce A2	0	0	0	0	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750
Bruce A3	770	770	770	770	0	0	770	770	770	770	770	770	770	770	770	770	770	770	770	770	770	770
Bruce A4	770	770	770	770	0	0	0	770	770	770	770	770	770	770	770	770	770	770	770	770	770	770
Total Bruce A	1540	1540	1540	1540	1500	1500	2270	3040	3040	3040	3040	3040	3040	3040	3040	3040	3040	3040	3040	3040	3040	3040
Bruce B5	848	848	848	848	848	848	848	848	848	848	0	0	0	848	848	848	848	848	848	848	848	848
Bruce B6	802	802	802	802	802	802	802	802	802	802	802	802	0	0	0	802	802	802	802	802	802	802
Bruce B7	797	797	797	797	797	797	797	797	797	0	0	0	797	797	797	797	797	797	797	797	797	797
Bruce B8	814	814	814	814	814	814	814	814	814	814	814	814	814	0	0	0	814	814	814	814	814	814
Total Bruce B	3261	3261	3261	3261	3261	3261	3261	3261	3261	2464	1616	1616	1611	1645	1645	2447	3261	3261	3261	3261	3261	3261
Darlington 1	881	881	881	881	881	881	881	881	881	881	881	881	0	0	881	881	881	881	881	881	881	881
Darlington 2	881	881	881	881	881	881	881	881	881	881	881	881	881	0	0	881	881	881	881	881	881	881
Darlington 3	881	881	881	881	881	881	881	881	881	881	881	881	881	881	0	0	881	881	881	881	881	881
Darlington 4	881	881	881	881	881	881	881	881	881	881	881	881	881	881	881	0	0	881	881	881	881	881
Total Darlington	3524	3524	3524	3524	3524	3524	3524	3524	3524	3524	3524	3524	2643	1762	1762	1762	2643	3524	3524	3524	3524	3524
Total Pickering A	1030	1030	1030	1030	1030	1030	1030	1030	1030	1030	1030	1030	1030	1030	1030	515	515	515	515	515	515	0
Total Pickering B	2064	2064	2064	2064	2064	2064	2064	1548	1548	1032	516	0	0	0	0	0	0	0	0	0	0	0
Total Bruce A	1540	1540	1540	1540	1500	1500	2270	3040	3040	3040	3040	3040	3040	3040	3040	3040	3040	3040	3040	3040	3040	3040
Total Bruce B	3261	3261	3261	3261	3261	3261	3261	3261	3261	2464	1616	1616	1611	1645	1645	2447	3261	3261	3261	3261	3261	3261
Total Darlington	3524	3524	3524	3524	3524	3524	3524	3524	3524	3524	3524	3524	2643	1762	1762	1762	2643	3524	3524	3524	3524	3524
Total	11419	11419	11419	11419	11379	11379	12149	12403	12403	11090	9726	9210	8324	7477	7477	7764	9459	10340	10340	10340	10340	9825
New Build 1	0	0	0	0	0	0	0	0	0	0	0	0	700	700	700	700	700	700	700	700	700	700
New Build 2	0	0	0	0	0	0	0	0	0	0	0	0	0	700	700	700	700	700	700	700	700	700
New Build 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1000	1000	1000	1000	1000	1000	1000	1000
New Build 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1000	1000	1000	1000	1000	1000	1000
Total	0	0	0	0	0	0	0	0	0	0	0	0	700	1400	2400	3400	3400	3400	3400	3400	3400	3400
Total	11419	11419	11419	11419	11379	11379	12149	12403	12403	11090	9726	9210	9024	8877	9877	11164	12859	13740	13740	13740	13740	13225

Note: The Ontario Power Authority (OPA) refused to release its assumed reactor lifespans and refurbishment outages when requested by Greenpeace. The figures in this table were calculated by working backwards from the OPA's assumptions for cumulative nuclear capacity and secondary sources (OPA, Renewable and CHP Baseload Resources [Effective MW], Table 12, available at http://www.powerauthority.on.ca/Storage/82/7759_D-6-1_corrected_2008-08-29.pdf).

Appendix B: Projected Greenhouse Gas Emission Assumptions

Assumptions in Table 3: Impact of Historic Nuclear Performance on Greenhouse Gas Emissions

Terawatt (TW) data from Ontario Power Authority's (OPA) submission to the Ontario Energy Board (IPSP EB 2007-0707 Exhibit I, Tab 43, Schedule 2) with emission factors provided by the OPA and OPG greenhouse gas emissions were used to determine above-baseline emissions in the Integrated Power Supply Plan.

Imports were assumed to be 10% clean-energy and 90% coal-fired generation, based on the OPA's submission EB 2007-0707 Exhibit I, Tab 43, Schedule 3, which states "The dotted lines include emissions associated with both Ontario generators and imports, assuming that 90% of the imports come from non-renewable resources, largely from coal-fired generation resources."

The following table summarizes the comparison between baseline greenhouse gas emissions and projected additional greenhouse gas emissions due to lower nuclear performance.

Table B1:
Comparison of Baseline and Projected Additional Greenhouse Gas (GHG) Emissions

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
GHG Emissions under IPSP	39.18	37.60	32.32	25.94	23.00	24.05	11.41	15.16	15.55	14.30	15.50	12.71	12.09	7.44
Additional Emissions due to Nuclear Historical Performance	6.17	4.88	13.69	23.70	28.37	23.96	24.41	18.96	18.96	22.22	13.06	16.65	10.58	13.22
Increase in GHG from Baseline	116%	113%	142%	191%	223%	200%	314%	225%	222%	255%	184%	231%	187%	278%

Assumptions in Table 8: Potential Greenhouse Gas Emissions from New-Build Delays

The potential greenhouse gas emissions due to delays in the construction of new nuclear reactors was calculated by converting lost megawatt (MW) capacity into terawatt hours (TWh) per year (assuming a capacity factor of 83%). The "best-case" scenario is based on replacement by domestic combined-cycle gas turbine generation. The worst-case scenario is based on replacement by 90% coal imports.

Table B2: Lost Capacity

NEW-BUILD DELAY	2018	2019	2020	2021
Lost MW	700	1400	2400	3400
Lost TWh	5.09	10.18	17.45	24.72

Table B3
Potential Emissions

GHG EMISSIONS (MT CO_2E)	2018	2019	2020	2021	Total
Increased Emissions from Domestic Gas	1.56	3.13	5.36	7.59	17.64
Increased Emissions from 90% Coal Imports	5.01	10.01	17.16	24.32	56.50

Assumptions in Section 4.1: Unacceptable Choice 1: Increased Greenhouse Gas Emissions

The probable greenhouse gas emissions produced during the outages to extend the life of the Pickering B nuclear station was calculated by converting the OPA's projected lost megawatts between 2013 and 2019 to terawatt hours, assuming an 83% capacity factor.

Table B4
OPA's Proposed Refurbishment Schedule for Pickering B

	2012	2013	2014	2015	2016	2017	2018	2019	2020
Pickering B Unit 1	516	0	0	516	516	516	516	516	516
Pickering B Unit 2	516	516	516	0	0	516	516	516	516
Pickering B Unit 3	516	516	516	516	0	0	516	516	516
Pickering B Unit 4	516	516	516	516	516	0	0	516	516
Total megawatts	2064	1548	1548	1548	1032	1032	1548	2064	2064

Table B5
Lost Production, in Megawatts and Terrawatts

	2012	2013	2014	2015	2016	2017	2018	2019	2020
Lost megawatts	0	516	516	516	1032	1032	516	0	0
Lost Terrawatts	0.00	3.75	3.75	3.75	7.50	7.50	3.75	0.00	0.00

Greenhouse gas emissions were then calculated based on the "best-case" scenario, using replacement energy from domestic, combined-cycle gas turbine (CCGT) generation, and the worst-case scenario, using 90% coal imports.

Table B6
Range of Potential Greenhouse Gas Emission Increases during Pickering B Life Extension Repairs

SCENARIO	2013	2014	2015	2016	2017	2018	2019	TOTAL
Pickering B - Replaced by CCGT	1.15	1.15	1.15	2.30	2.30	1.15	0.00	9.22
Pickering B - Replaced by 90% Coal Imports	2.92	2.92	2.92	5.85	5.85	2.92	0.00	23.38

Assumptions in Table 10: Implications of Waiting for New Nuclear to Replace Pickering B: Greenhouse Gas Emissions

Table B7

MISSING PRODUCTION

SCENARIO	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
MW	0	0	0	0	516	516	1032	1548	2064	2064	2064	1064
TWh	0.00	0.00	0.00	0.00	3.75	3.75	7.50	11.26	15.01	15.01	15.01	7.74

GREENHOUSE GAS EMISSIONS	2013	2014	2015	2016	2017	2018	2019	2020	TOTAL
Pickering B Replaced by CCGT	1.15	1.15	2.30	3.46	4.61	4.61	4.61	2.38	21.89
Pickering B Replaced by 90% Coal Imports	2.92	2.92	5.85	8.77	11.69	11.69	11.69	6.03	55.54

Assumptions in Section 5.1: A Slippery Slope—Nuclear's Decline

The potential increase in greenhouse gas emissions caused by the early shutdown of nuclear stations was calculated by converting the lost megawatts of reactors going offline two years before scheduled in the OPA's plan (see Appendix A). This was then converted to terawatt hours, assuming an 83% capacity factor.

Greenhouse gas emissions were then calculated based on the "best-case" scenario, using replacement by domestic, combined-cycle gas turbine generation and the worst-case scenario, using 90% coal imports. Greenhouse gas emission factors are based on data provided in the OPA's Integrated Power System Supply Plan and by OPG.

Table B8
Pickering A Goes Offline Two Years Early

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	TOTAL
Gas (Mt CO_2e)	0.00	1.15	1.15	0.00	0.00	0.00	0.00	1.15	1.15	0.00	4.60
90% Coal Imports (Mt CO_2e)	0.00	2.92	2.92	0.00	0.00	0.00	0.00	2.92	2.92	0.00	11.67

Table B9
Increased Greenhouse Gas Emissions from Pickering B Going Offline Two Years Early

	2010	2011	2012	2013	2014	2015	2016	Total
Gas (Mt CO_2e)	0.00	1.15	1.15	1.15	2.30	2.30	1.15	9.22
90% Coal Imports (Mt CO_2e)	0.00	2.92	2.92	2.92	5.85	5.85	2.92	23.38

Table B10
Increased Greenhouse Gas Emissions from the Bruce B Reactors Going Offline Two Years Early

	2012	2013	2014	2015	2016	2017	2018	2019	TOTAL
Gas (Mt CO_2e)	0.00	1.78	3.67	1.89	1.79	3.61	1.82	0.00	14.56
90% Coal Imports (Mt CO_2e)	0.00	4.51	9.32	4.80	4.54	9.15	4.61	0.00	36.95

Table B11
Increased Greenhouse Gas Emissions from the Darlington Reactors Going Offline Two Years Early

	2015	2016	2017	2018	2019	2020	2021	TOTAL
Gas (Mt CO_2e)	0.00	1.97	3.93	3.93	3.93	1.97	0.00	15.74
90% Coal Imports (Mt CO_2e)	0.00	4.99	9.98	9.98	9.98	4.99	0.00	39.93

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