Climate change and nuclear power in Ontario

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Darlington Nuclear Generating Station, 2012-08-01, photo by Milan Ilnyckyj

Spread between the three nuclear generating stations at Pickering, Bruce, and Darlington, Ontario's twenty functioning nuclear reactors have a collective output of over 14,000 megawatts, generating over 50% of the province's electricity. At one time, energy from nuclear fission inspired lofty dreams of pollution-free and inexpensive electricity. More recently, high-profile nuclear accidents and other concerns have deeply undermined nuclear optimism.[1] Globally, the Three Mile Island nuclear accident of 1979 and the Chernobyl accident of 1986 substantially reduced public and elite enthusiasm for nuclear energy. No nuclear power stations have been built in the United States since 1974, and the last reactor at Darlington went online in 1993.[2] As climate change has become a larger concern, the technology's capacity to produce large amounts of baseload energy with low associated carbon dioxide (CO_2) emissions has prompted a measure of re-evaluation.[3][4][5][6] Five new reactors are currently under construction in the United States — all of them at existing power stations. In Ontario, there has been a great deal of discussion about what future, if any, nuclear power should have in the province. The issue splits opinion in unusual ways. Most notably, it divides the environmental movement. While many environmentalists and environmental non-governmental organizations (eNGOs) are deeply skeptical of all things related to fission, others have come to see the technology as valuable (or at least as a necessary evil) in a world that must rapidly transition away from fossil fuel use in order to control anthropogenic climate change.[7][8][9][10][11]

[1] For a fairly comprehensive summary of the major objections to nuclear power — including accidents, waste, expense, and proliferation — see: Cooke, *In Mortal Hands: A Cautionary History of the Nuclear Age*.

[2] Romm, *Hell and High Water: Global Warming — the Solution and the Politics and What We Should Do*, p. 145.

[3] See: Ilnyckyj, "Climate Change, Energy Security, and Nuclear Power", p. 92–112.

[4] Some environmentalists challenge the notion that nuclear energy is a genuinely low-carbon option, pointing to emissions associated with uranium mining, reactor construction, and other related activities. The Fourth Assessment Report of the IPCC concluded: "Total life-cycle GHG emissions per unit of electricity produced from nuclear power are below 40 gCO_2-eq/kWh (10 gC-eq/kWh), similar to those for renewable energy sources." Intergovernmental Panel on Climate Change, *Climate Change 2007: Working Group III: Mitigation of Climate Change*.

[5] See also: MacKay, *Sustainable Energy — Without the Hot Air*, p. 169.

[6] Sovacool, "Valuing the greenhouse gas emissions from nuclear power: A critical survey", p. 2950–2963.

[7] See: Weaver, *Keeping Our Cool: Canada in a Warming World*, p. 3–4.

[8] Stern, *The Global Deal: Climate Change and the Creation of a New Era of Progress and Prosperity*, p. 123.

[9] Monbiot, *Nuked by Friend and Foe*.

[10] Monbiot, *The Fukushima crisis should not spell the end of nuclear power*.

[11] Kharecha and Hansen, "Prevented Mortality and Greenhouse Gas Emissions from Historical and Projected Nuclear Power".

This paper will provide a brief history of Ontario's nuclear industry before moving on to discuss the ethics and politics of the issue. At best, nuclear fission is a transitional energy source. The world has finite amounts of usable uranium and, despite hopes that more-abundant thorium may eventually be extensively used for power generation or that uranium might be viably extracted from seawater, this limit probably means that nuclear fission could only operate on its present or an enlarged scale for several hundreds of years.[12][13][14] This span could conceivably be extended substantially through the use of fast-breeder reactors capable of producing more fissile material than they consume. These could be used either to lengthen the period in which fission can be relied upon or to greatly increase the number of reactors that can be operated for a shorter period, but breeder reactors have proven even more expensive and problematic than more conventional designs.[15] Accepting that nuclear energy cannot supply humanity indefinitely, it is nevertheless the case that achieving the world's objective of avoiding a temperature increase of more than 2˚C above pre-industrial levels requires an amazingly rapid and aggressive transition away from fossil fuels.[16] *Prima facie* evidence suggests that nuclear energy can play a role in this, and the urgency and importance of the climate issue militate in favour of it at least being considered.

Of the many objections to nuclear power, some certainly seem less surmountable than others. There are wide disagreements about the total impact of nuclear accidents like those at Chernobyl and Fukushima Daiichi, but it is undeniable that when these occur they produce massive popular and elite backlashes against nuclear power.[17][18] Given the complexity of nuclear power stations and

[12] MacKay, *Sustainable Energy — Without the Hot Air*, p. 162–3.

[13] A 2007 OECD/IAEA study concluded that uranium reserves are sufficient for half a century of unimpeded growth in generation capacity. See: Massachusetts Institute of Technology, *Update of the MIT 2003 Future of Nuclear Power: An Interdisciplinary Study*, p. 12.

[14] Note that India, which lacks uranium reserves but does possess thorium, hopes to generate 30% of its electricity in this way by 2050. The Economist, *The nuke that might have been*.

[15] A 2009 MIT study concluded that the use of breeder reactors could not be justified on the grounds of economics, uranium availability, or waste management. Massachusetts Institute of Technology, *Update of the MIT 2003 Future of Nuclear Power: An Interdisciplinary Study*, p. 14.

[16] See: The Heads of State, Heads of Government, Ministers, and other heads of delegation present at the United Nations Climate Change Conference 2009 in Copenhagen, *Copenhagen Accord*.

[17] See: Ilnyckyj, "Climate Change, Energy Security, and Nuclear Power", p. 96.

[18] See also: Yergin, *The Quest: Energy, Security, and the Remaking of the Modern World*, p. 414.

the immense amount of energy they seek to control, it is inevitable that more such accidents will occur for as long as nuclear power stations are operated.[19][20][21][22] The financial costs associated with nuclear power are an equally serious impediment to climate-motivated deployment, and difficult to accurately estimate. Costs are extremely hard to determine because of the many forms of visible and hidden subsidy enjoyed by the industry, because of the links between civilian and military nuclear programs, and because of the fundamental difficulty of attributing dollar values to policies like limits on the liability of nuclear plant operators in the event of accidents. Nowhere in the world is the nuclear power industry run as a genuinely private concern; governments are always present — approving, regulating, and financing nuclear power facilities and standing by to absorb most of the costs associated with any serious accident.[23] While the risk of nuclear weapon proliferation probably has little importance in Ontario, it's a factor that must certainly be considered when examining the global viability of fission as a low-carbon power source.[24][25][26] Special consideration must also be given to the disposal of radioactive wastes. In the end, the biggest unanswered questions about nuclear power are probably how much it costs when compared fairly with alternatives like the rapid deployment of renewable energy, as well as how the prospects for the deployment of such alternative technologies look, given the economic and political characteristics of each.[27]

[19] As Daniel Yergin points out, "the core of an operating nuclear reactor has to be constantly supplied with copious amounts of coolant to dissipate the heat produced by fission". As the Fukushima disaster demonstrated, cooling is also essential even when fission has successfully be stopped by emergency shutdown systems. Yergin, *The Quest: Energy, Security, and the Remaking of the Modern World*, p. 371.

[20] See also: ibid., p. 372–3.

[21] Strickland, *24 Hours at Fukushima: A blow-by-blow account of the worst nuclear accident since Chernobyl*.

[22] Institute of Nuclear Power Operations, *Special Report on the Nuclear Accident at the Fukushima Daiichi Nuclear Power Station*.

[23] See: Kageyama, *Japan to spend $12.5B bailing out and taking over operator of tsunami-devastated nuclear power plant*.

[24] In a 2003 MIT study where they considered a threefold increase in global nuclear capacity by 2050, the authors concluded that: "The current international safeguards regime is inadequate to meet the security challenges of the expanded nuclear deployment contemplated in the global growth scenario." Massachusetts Institute of Technology, *The Future of Nuclear Power: An Interdisciplinary MIT Study*, p. ix.

[25] See also: Massachusetts Institute of Technology, *Update of the MIT 2003 Future of Nuclear Power: An Interdisciplinary Study*, p. 15–6.

[26] Yergin, *The Quest: Energy, Security, and the Remaking of the Modern World*, p. 409.

[27] One substantial advantage of nuclear energy over renewables concerns total land use. To generate the power output of a nuclear station using energy sources like wind or solar power, dramatically more total land is required, though it can sometimes be used for other purposes simultaneously. Whereas building enough new nuclear power stations in the

So many forms of significant uncertainty overlap in the case of nuclear power that it may be impossible to make credible predictions about its future in Ontario, Canada, or around the world.[28] The development of Ontario's nuclear industry was largely a province- and nation-building project sustained by optimistic projections about cost and energy demand. The political impulses of future Ontario and Canadian governments will determine the future of Ontario's existing nuclear stations and the prospects for the construction of new facilities and reactors. In spite of this uncertainty, it remains possible to make some defensible recommendations about policies that should be incorporated into any new plan for nuclear power plant construction, including genuine independence between safety regulators and plant operators, principles for the handling of waste, and correspondence between those who benefit from the availability of nuclear energy and those who bear its risks.

1 | Ontario's nuclear industry

The history of Ontario's nuclear industry is inseparable from Canada's overall ambition to become a capable builder and exporter of nuclear power stations.[29][30][31][32][33] Step by step, the capacity to construct power-generating facilities was developed, with each new generation of prototypes and reactors serving as both a template for further domestic development and an opportunity for potential export. At every stage, government has been involved as a promoter, regulator, and financier.

Established in Deep River in 1942, the laboratories of Atomic Energy of Canada Limited (AECL) operate non-electricity-generating reactors for scientific purposes and the production of

U.K. to match France's capacity would require 0.02% of the country's available land, doing the same with wind farms would require 10% of all the U.K.'s land. MacKay, *Sustainable Energy — Without the Hot Air*, p. 166–7.

[28] An exception may be admitted for states determined to enlarge their nuclear weapon arsenals, for whom the plutonium-breeding capabilities of nuclear reactors are irresistible.

[29] For a more detailed history than the one provided here, see: Eggleston, *Canada's Nuclear Story*.

[30] Bothwell, *Nucleus: The History of Atomic Energy of Canada Limited*.

[31] Hurst, *Canada Enters the Nuclear Age: a technical history of Atomic Energy of Canada Limited as seen from its research laboratories*.

[32] Freeman, *The Politics of Power: Ontario Hydro and Its Government, 1906–1995*.

[33] On exports of CANDU technology, see: Bratt, *The Politics of CANDU Exports*.

medically useful isotopes.[34] In 1944, Chalk River Laboratories (CRL) became the first site outside the United States to host a nuclear reactor. In 1947, the site's NRX research reactor came into operation, with "high neutron flux and a relatively large core" intended for use as a tool for scientific research and the development of materials, technologies, and expertise for eventual nuclear power station construction.[35] The NRU research reactor, designed as a successor to NRX, went critical in 1957. Technical experiments and the training of personnel at CRL both played an important role in the development, deployment, and operation of Ontario's eventual nuclear power fleet. Two of Canada's major nuclear incidents have also taken place at the CRL. In December 1952, the heavy water moderated NRX reactor experienced an autocatalytic reaction that produced 60 to 90 megawatts of total output.[36] The core and calandria of the reactor were damaged beyond repair and 10,000 Curies of long-lived fission products were released into the basement. Clean up of the site was conducted by 150 U.S. Navy personnel, including future president Jimmy Carter. The reactor was repaired and back in operation in slightly more than a year. In 1958, a fuel rupture and fire in the NRU reactor building contaminated the entire building, requiring an extensive cleanup.[37]

Beyond early experiments at CRL, several additional prototypes were necessary before Canada could build commercial nuclear power stations. In addition to three presently-operating nuclear generating stations, there are two important decommissioned reactors in Ontario: the Nuclear Power Demonstration (NPD) at Rolphton and the Douglas Point Nuclear Generating Station at Kincardine. The 22 megawatt NPD was commissioned in 1962 to serve as a proving ground for heavy-water CANDU (CANada Deuterium Uranium) technology. The reactor was built on the Ottawa River, approximately 225 km upstream from the capital. The reactor employed 132 horizontal pressure tubes made of zircaloy within an aluminium calandria, and was capable of emergency shut-

[34]For background on the troubled recent history of Canada's medical isotope production, see: The Economist, *Ending a dream, or nightmare*.

[35]Gray, "Early Decisions in the Development of the CANDU Program".

[36]Los Alamos National Laboratory, *A Review of Criticality Accidents: 2000 Revision*, p. 95.

[37]The NRU reactor was also the subject of a 2007 controversy in which a conflict arose between Canadian Nuclear Safety Commission President Linda Keen and the elected government of the day about whether to operate the reactor for medical isotope production despite safety concerns.

down by dumping its heavy water moderator. The NPD was the first reactor in which fuel changing would take place during reactor operation, with an automated fuelling machine capable of adding fuel bundles from either side. This approach — which eliminates the need for reactor shutdown during fuelling — was later incorporated into all subsequent CANDU designs.[38] The reactor was shut down in 1987.

The 200 megawatt reactor at Douglas Point was another major step toward commercial CANDU designs, operating from 1968 to 1984. It was built with a stainless steel calandria manufactured by the Dominion Bridge Company of Montreal. The reactor featured key elements of the general CANDU design, including "short-bundle fuel fed from each end of the reactor — on power, bi-directional fuelling" allowing "adequate fuel burnup... with natural uranium".[39] The reactor experienced many problems, including leaks of costly heavy water, and was offline for large portions of its operating life. In part due to these problems, a second planned reactor for the site was never built. The facility was intended to be Canada's first commercially viable nuclear facility.[40] The plant was also designed with an early eye to export possibilities, and a duplicate power station at Rajasthan, India was committed in 1963.[41] Ultimately, two power stations modelled on Douglas Point were built in India, with another in Pakistan.[42] Located on the Bruce Peninsula, the decommissioned reactor building is now located in between the massive Bruce A and Bruce B nuclear power stations.

Canada's nuclear power reactors are of a unique design, employing heavy water as a moderator and capable of operating with unenriched uranium. "Heavy water" is a form of water that includes more hydrogen atoms of the deuterium isotope than is found in normal water. Heavy water was first produced in Canada in 1943 by the Consolidated Mining and Smelting Company plant at Trail, B.C.[43] In the CANDU design, heavy water is used both to cool the reactor core and as a modera-

[38] Canadian Nuclear Society, *Nuclear Power Demonstration Reactor*.
[39] Gray, "Early Decisions in the Development of the CANDU Program".
[40] Whitlock, *The Historical Significance of the Douglas Point Nuclear Power Plant*.
[41] Atomic Energy of Canada Limited CANDU Operations, *The Douglas Point Story*.
[42] Whitlock, *The Historical Significance of the Douglas Point Nuclear Power Plant*.
[43] Gray, "Early Decisions in the Development of the CANDU Program".

tor: slowing down neutrons generated by the chain reactor of uranium fission in order to increase the probability that each neutron will successfully induce fission in another uranium atom. The need for large quantities of heavy water constitutes a significant part of the total cost of a CANDU power station. Out of the total $5.117 billion dollar capital cost of the Darlington Nuclear Generating Station, $1.528 billion was spent acquiring heavy water.[44] The unusual pressure tube design of the CANDU system was chosen because of limitations in Canada's industrial manufacturing capacity, which precluded the possibility of building large single pressure vessels of the sort used in the pressurized- and boiling-water reactors mostly used around the world.[45] Operating CANDU power stations feature 380–480 of these pressure tubes. Because of the efficient use of neutrons in a heavy water design, CANDU reactors can operate on a range of fuels including natural uranium, reprocessed uranium, thorium, plutonium, and used fuel from light water reactors. AECL's proposed 'Advanced' CANDU reactor would make significantly less use of heavy water — employing it as a neutron moderator only, and using conventional 'light' water as primary loop coolant.

Three major power stations at Pickering, Bruce, and Darlington provide Ontario's current nuclear generating capacity. The Pickering Nuclear Generating Station is the oldest of these, with four reactors that went into service in 1971 and four more that began operating in 1983.[46] Since opening, two reactors at Pickering A have been shut down. The construction and operation of Pickering was used to develop the CANDU 6 power station design, which was subsequently installed at Gentilly-2 in Quebec and the Point Lepreau Nuclear Generating Station in New Brunswick. CANDU 6 reactors were also exported to Argentina, Romania, China, and South Korea. Spent nuclear fuel from the Pickering reactors is currently stored on site in the Pickering Waste Management Facility.[47] Used nuclear fuel is kept in cooling ponds for at least ten years after leaving the reactors, and is later moved into dry storage containers. According to Ontario's 2013 Long-Term Energy Plan, Pickering is expected to be shut down in 2020, and may be shut down early if demand lev-

[44] Ontario Power Generation, *Final and Total Capital Cost of the Darlington Nuclear Generating Station*.
[45] This is also one factor that makes CANDU designs appealing for export to states with limited industrial capabilities.
[46] See: Ontario Power Generation, *Pickering Nuclear*.
[47] Ontario Power Generation, *Pickering Waste Management Facility*.

els and refurbishment progress elsewhere permit it.[48] On the Bruce Peninsula, between Georgian Bay and the main body of Lake Huron, sits Canada's largest nuclear complex — second largest in the world after TEPCO's 7-reactor Kashiwazaki-Kariwa complex in Japan.[49] Between the two operating nuclear generating stations at the site, over 6,300 megawatts of electricity is produced, accounting for over a quarter of Ontario's total supply. Construction on Bruce A began in 1969, followed by Bruce B in 1977. In 2009, the Canadian Nuclear Safety Commission renewed Bruce Power's operating licence for Bruce A and Bruce B for another five years.[50] The Bruce design was adapted into the CANDU 9 design, intended for export, but none were ever sold. At present, the oldest reactors at Bruce are slated to be retired in 2043. Built in stages between 1981 and 1993, the Darlington Nuclear Generating Station is Ontario's newest and most modern nuclear power facility.[51] With four reactors, the station produces 3,512 megawatts of output. As discussed later, reactor refurbishments at both Bruce and Darlington, intended to extend the operating lives of the plants, have been announced by the government of Ontario.

In 1983 and 1986, loss of cooling accidents took place in reactor 2 of the Pickering and Bruce power stations, respectively. Each involved the catastrophic failure of one of the pressure tubes in the calandria at the core of the reactor.[52] In August 1983, pressure tube G16 in unit 2 of Pickering A developed a 2 m split. This led to all the pressure tubes in Pickering A eventually being replaced, at a cost estimated at $2.455 billion by the Pembina Institute.[53] In 1986, a fuel channel fire occurred inside one of the Bruce Power reactors, leading to fuel elements being swept into the calandria.[54][55]

In addition to power generation, Ontario has a significant nuclear fuel industry. In Port Hope,

[48] Ontario Ministry of Energy, *Achieving Balance: Ontario's Long-Term Energy Plan*, p. 5.
[49] See: Bruce Power, *A Guide to Bruce Power*.
[50] Heiser, *Bruce Power Gets Five-Year Operating Licenses*.
[51] See: Ontario Power Generation, *Darlington Nuclear*.
[52] For more on fuel channel issues in CANDU reactors, see: Winfield, Horne, and Peters, *Power for the Future: Towards A Sustainable Electricity System for Ontario — Appendix 2 Ontario's Nuclear Generating Facilities: A History and Estimate of Unit Lifetimes and Refurbishment Costs*, p. 123.
[53] Ibid., p. 127.
[54] Brown, *Canada's Nuclear History*.
[55] See also: Ontario Nuclear Safety Review, *The Safety of Ontario's Nuclear Power Reactors: A Scientific and Technical Review*.

Cameco operates one of the world's four uranium conversion facilities, producing over 12,000 tonnes of uranium hexafluoride per year for enrichment as well as 2,800 tonnes of uranium oxide for use in reactors.[5657] Cameco is the world's largest publicly traded uranium company, and fuel produced at Port Hope is exported around the world. In addition to the Port Hope conversion plant, Cameco also operates a uranium refinery in Blind River.

2 | The politics and ethics of nuclear power

Opposition to nuclear power has long been a central feature of the environmental movement; indeed, it is one of the issues which helped the movement first emerge as a popular and coherent political force. That being said, climate change is altering the perceptions and priorities of the environmentally-minded. As an energy source capable of reliably producing large amounts of electricity with low associated CO_2 emissions, nuclear fission cannot simply be written off. Broecker and Kunzig note:

> It's a measure of how urgent the CO_2 problem has become that some antinuclear environmentalists have lately been willing to reconsider their long-standing opposition. Nuclear power, as its proponents frequently remind us, has killed far fewer people than coal mining, not to mention pollution from coal-fired power plants.[58]

These authors remain skeptical on the basis of radioactive waste, the links between civilian nuclear facilities and the danger of weapons proliferation, and the scale of expansion that would be necessary for fission to make a substantial difference in the degree of climate change the world experiences. Others are much more optimistic, pointing to the possibility that future reactors could be safer than current designs both in terms of accidents and proliferation risk, and highlighting

[56]Cameco, *Port Hope — History / Innovations*.

[57]For more on Canada's history of nuclear fuel production, see: Bothwell, *Eldorado: Canada's National Uranium Company*.

[58]Broecker and Kunzig, *Fixing Climate: What Past Climate Changes Reveal About the Current Threat — and How to Counter It*, p. 194.

how the constant energy output from nuclear plants could provide a useful backstop to intermittent energy from renewable sources.[59][60][61]

Nearly 78% of the electricity used by France's 66 million people comes from nuclear fission — the legacy of an ambitious construction program that led to 59 operating nuclear power stations.[62][63][64] This partly explains why, with nearly twice Canada's population, French CO_2 emissions amounted to 382.9 million tonnes (MT) in 2006, compared with 544.3 MT in Canada.[65] The operation of French nuclear stations over the course of decades has kept vast quantities of CO_2 from being added to the atmosphere, compared with a scenario in which the electricity was provided by coal- or gas-fired power stations. The same is true for the substantial nuclear infrastructure in Japan, China, Germany, the United Kingdom, Russia and the former Soviet republics, South Korea, Sweden, Switzerland, the United States, and elsewhere. In total, nuclear fission produces about 16% of the world's electricity. If the same amount of electricity were generated using coal, it would add between 2.2 and 2.6 billion tonnes of CO_2 pollution per year to world output.[66] At the same time, the amount of new nuclear capacity that would be necessary to significantly reduce global greenhouse gas (GHG) emissions is massive. By one estimate, if the United States wished to replace its current vehicle fleet with one running on hydrogen produced using nuclear power, 387 new reactors would be needed by 2050 to serve this purpose alone.[67] In another estimate, building 700 large new nuclear power stations — which continuing to operate all those that exist currently — would provide one of the eight necessary 'wedges' to stabilize the global concentration of CO_2 at 550 parts

[59] McLean and Love claim that: "If managed correctly, nuclear and renewable generation — far from being the bitter enemies they are presumed to be today — could complement each other in interesting and productive ways". McLean and Love, "Technology and Climate Change", p. 127.

[60] Regarding the possibility of safer designs, see: The Economist, *The nuke that might have been*.

[61] See also: The Economist, *The shape of things to come*.

[62] The Economist, *Pocket World in Figures: 2011 Edition*, p. 57.

[63] Stern, *The Global Deal: Climate Change and the Creation of a New Era of Progress and Prosperity*, p. 43.

[64] It is notable that the development of this industry in France was linked to the French government's desire for nuclear weapons — just as the first British nuclear power station at Calder Hall was intended more for weapon-related plutonium production than for civilian electricity generation.

[65] The Economist, *Pocket World in Figures: 2011 Edition*, p. 104.

[66] Intergovernmental Panel on Climate Change, *Climate Change 2007: Working Group III: Mitigation of Climate Change*.

[67] McLean and Love, "Technology and Climate Change", p. 126.

per million (ppm), which is well above the level many scientists consider "dangerous" and likely to produce more than 2˚C of warming.[68] Given the shutdowns that have taken place in Germany, Japan, and elsewhere since the Fukushima Daiichi disaster, achieving this 'wedge' would be even more difficult.

Nuclear waste is a practical and ethical dimension of fission power which has received a great deal of attention. At present, all of Canada's nuclear waste is in temporary storage facilities of various types, including cooling pools at nuclear power stations and in dry cask storage containers. Over the long term, most experts who have looked into the problem have concluded that a deep geological storage facility located in a seismically stable area is probably the best option for waste disposal.[69] Such a facility would be straightforward to construct and would probably offer a good capacity to contain dangerous radioactivity even across the very long timescales during which many wastes will be dangerous.[70][71] The main challenges in establishing such a facility are the cost and the need to convince any nearby communities to accept it.[72] Ontario Power Generation has a controversial plan to establish a deep geologic repository on the site of the Bruce power station, located 680 m below the surface.[73][74][75] Past experience in Canada and internationally suggests that it is easiest to build new nuclear facilities at the sites of existing ones, possibly because municipalities hosting nuclear facilities become appreciative of the local economic benefits. At the same time, the proximity of the Bruce site to Lake Huron has probably increased the degree of environmen-

[68] Romm, *Hell and High Water: Global Warming — the Solution and the Politics and What We Should Do*, p. 23.

[69] One objection to this approach is that components of radioactive waste could prove desirable in the future — for instance, for breeder reactors — and would be difficult to recover from such a facility. Another objection is that human beings are not capable of building any containment system that can be expected to last long enough to contain all dangerous radioactive by-products we may wish to bury for as long as they will remain dangerous. Others counter that a sufficiently thick and geologically stable rock formation surrounding artificial containment structures would acceptably control any risk of release.

[70] America's Waste Isolation Pilot Plant — used to store wastes associated with nuclear weapon production — demonstrates the feasibility of the basic construction techniques required.

[71] See also: Yergin, *The Quest: Energy, Security, and the Remaking of the Modern World*, p. 406–7.

[72] The scale of these challenges is not to be underestimated, as the ongoing Yucca Mountain debacle in the United States demonstrates. See: Massachusetts Institute of Technology, *Update of the MIT 2003 Future of Nuclear Power: An Interdisciplinary Study*, p. 11.

[73] Ontario Power Generation, *Deep Geologic Repository*.

[74] Ontario Power Generation, *Nuclear Waste Management*.

[75] Canadian Nuclear Safety Commission, *Status: Ontario Power Generation Deep Geologic Repository*.

talist opposition to the siting of a long-term radioactive waste storage facility there.[76][77] Ontario's nuclear industry would unquestionably be on firmer ethical footing if it were able to establish a safe facility to permanently contain its legacy wastes, as well as those from any newly constructed or refurbished reactors. If the other barriers to new nuclear reactor construction were not so daunting, it might also be appealing to propose that the construction of such a facility be required before any new reactors would be approved.

One of the most ethically troubling issues related to climate change is the disjuncture between who enjoys the benefits of fossil fuel use and who suffers the consequences. The benefits accrue to those alive and using fossil fuels today: disproportionately, the citizens of rich industrial economies. By contrast, since the GHGs produced by using those fuels largely endure for thousands of years, along with the temperature anomaly their accumulation creates, most of the costs and suffering associated will fall on members of future generations who will not have derived a benefit from the initial use of the fuels.[78] Compounding this is the high likelihood that uncontrolled climate change will involve effects which are both harmful and essentially irreversible, such as the long-term disintegration of the Greenland and West Antarctic ice sheets, along with the sea level rise of up to 14 metres that would accompany it. Such sea level rise would permanently eliminate large parts of countries like Bangladesh and the Netherlands; deeply challenge the viability of coastal cities around the world; and inundate much of the geographic, social, and cultural legacy of humanity. In contrast with the risk-benefit split seen with fossil fuel use, the risks and benefits of nuclear energy are largely experienced by the same people.[79] Nuclear power stations are usually constructed close to major urban centres in order to reduce energy losses associated with transmission. The Pickering Nuclear Generating Station, for instance, is located approximately 40 km from Toronto. There is an intuitive ethical case that those who benefit from the use of a technology should be the ones exposed to the risks, or at least that it is questionable for one group to experience the benefits of

[76] See: Henry, *Critics fear dump may contaminate lakes*.
[77] Flesher, *Proposal to bury nuclear waste in Ontario wins local support; sparks U.S. ire*.
[78] Inman, "Carbon is forever".
[79] Weaver, *Keeping Our Cool: Canada in a Warming World*, p. 268.

a technology while maintaining an unlimited ability to impose the risks on absent and defenceless others.[80]

The largest barrier to nuclear fission as a means of controlling climate change is likely to be the expense. The cost of nuclear power stations is enormous and almost certainly rising in rich democracies. A 2009 MIT study concluded that:

> The track record for the construction costs of nuclear plants completed in the U.S. during the 1980s and early 1990s was poor. Actual costs were far higher than had been projected. Construction schedules experienced long delays, which, together with increases in interest rates at the time, resulted in high financing charges. New regulatory requirements also contributed to the cost increases, and in some instances, the public controversy over nuclear power contributed to some of the construction delays and cost overruns. However, while the plants in Korea and Japan continue to be built on schedule, some of the recent construction cost and schedule experience, such as with the plant under construction in Finland, has not been encouraging. Whether the lessons learned from the past have been factored into the construction of future plants has yet to be seen. These factors have a significant impact on the risk facing investors financing a new build.[81]

Yergin estimates that a new nuclear plant in the United States may cost US$6–7 billion, and take "a decade or two to site and build".[82] This perspective is consistent with the extreme cost inflation that accompanied Ontario's construction of the Darlington Nuclear Generating Station between 1981 and 1993.

The most challenging questions associated with nuclear power may be to what degree it produces economic externalities (costs imposed on third parties and not borne by the buyer or seller

[80] For an elaboration of this important ethical argument, see: Shue, "Deadly Delays, Saving Opportunities".

[81] Massachusetts Institute of Technology, *Update of the MIT 2003 Future of Nuclear Power: An Interdisciplinary Study*, p. 8.

[82] Yergin, *The Quest: Energy, Security, and the Remaking of the Modern World*, p. 398.

in a voluntary transaction) and to what degree it is subsidized by taxpayers. At the optimistic end of the scale, McLean and Love assert that: "In Canada, waste disposal and reactor decommissioning costs are included in the price of nuclear electricity. The major externalities of nuclear power are therefore fully internalized — making it the only large-scale generation technology to do so".[83] In at least a couple of ways, this claim is demonstrably wrong. Nuclear plant operators including Ontario Power Generation and Bruce Power are only liable for up to a maximum of $75 million in the event of a nuclear accident. Above this level, the cost will be borne by the federal government.[84] A serious accident at any of Ontario's nuclear generating stations could exceed this liability limit many times over. As a former member of the U.S. Nuclear Regulatory Commission explained to the *New York Times* in 2005, an accident like Three Mile Island "could turn a $2 billion asset into a $1 billion cleanup job in about 90 minutes".[85] In the event of an accident that causes widespread contamination outside the reactor's containment structure, the cleanup costs could be even greater. The liability limit therefore constitutes a significant subsidy to the industry, though there are both practical and methodological problems in estimating how much it is worth. In addition, Canadian taxpayers have provided subsidies of many forms for the development, deployment, and operation of nuclear power stations. AECL is a Crown corporation which developed CANDU technology with taxpayer support and which has significant decommissioning liabilities that are likely to eventually impose costs on taxpayers. Also, when Ontario Hydro was split into Ontario Power Generation and Hydro One in 1998, "stranded debt" of $19.4 billion arising from nuclear construction was passed on to electricity consumers, who now pay a "debt retirement charge" on their bills.[86] Over time, other liabilities related to the Ontario nuclear industry may come to light, and taxpayers may well end up paying for them.

[83] McLean and Love, "Technology and Climate Change", p. 118.

[84] Canadian Nuclear Association, *Nuclear Facts – Are Canadians insured against damage from nuclear plant accidents?*

[85] Romm, *Hell and High Water: Global Warming — the Solution and the Politics and What We Should Do*, p. 175.

[86] Spears, *Ontario Hydro's legacy of debt*.

While the idea is a non-starter at the federal level under the leadership of Stephen Harper, it is possible that a future Canadian government or government of Ontario will introduce a carbon price, which would alter the relative economics of nuclear versus other forms of electricity generation. Some have predicted that — with a carbon tax that rises to $100 to $150 per tonne by 2050 — Canadian GHG emissions might be half what they would have been under a business-as-usual scenario and that such a tax would likely drive new nuclear construction.[87][88][89] At the same time, the ongoing 'shale gas revolution' enabled through the use of hydraulic fracturing is altering the North American energy market. Economically, power plants fuelled by natural gas are virtually the opposite of nuclear power stations. They can be build comparatively quickly, with low capital costs per unit of output. While the cost per unit of fuel or per unit of energy produced is extremely low for nuclear, it is dominant for gas plants.[90] Further contributing to the complexity of new nuclear power plant economics is the likelihood that — up to a considerable degree — reducing electricity demand may be significantly cheaper than building new generation capacity. Romm estimates that doing so in the United States would begin at less than 1.4 cents per kilowatt-hour, which is well below the cost of electricity in Ontario.[91] On the other hand, the deployment of new low-carbon technologies such as electric vehicles and ground- and air-source heat pumps may cause electricity demand to rise, in order to get emissions to fall.[92][93] Similarly, it is within the realm of possibility that growing output from renewables will bring intermittancy problems that nuclear can help to address, or conversely that new energy storage infrastructure, inter-regional electricity grid

[87] Simpson, Jaccard, and Rivers, *Hot Air: Meeting Canada's Climate Change Challenge*, p. 207, 209.

[88] A 2003 MIT study concluded that: "In deregulated markets, nuclear power is not now cost competitive with coal and natural gas. However, plausible reductions by industry in capital cost, operation and maintenance costs, and construction time could reduce the gap. Carbon emission credits, if enacted by government, can give nuclear power a cost advantage." Massachusetts Institute of Technology, *The Future of Nuclear Power: An Interdisciplinary MIT Study*, p. ix.

[89] This conclusion was re-affirmed in a 2009 re-evaluation: Massachusetts Institute of Technology, *Update of the MIT 2003 Future of Nuclear Power: An Interdisciplinary Study*, p. 6.

[90] Ibid., p. 8.

[91] Romm, *Hell and High Water: Global Warming — the Solution and the Politics and What We Should Do*, p. 163.

[92] See: Massachusetts Institute of Technology, *Update of the MIT 2003 Future of Nuclear Power: An Interdisciplinary Study*, p. 4.

[93] MacKay, *Sustainable Energy — Without the Hot Air*, p. 140–54.

linkages, and demand management will be able to address this issue.

Another substantial uncertainty related to nuclear energy is how quickly it could be deployed, given the general lack of political will to do so. Even building new reactors at existing power stations is a drawn-out and controversial process, as proposals to do so at Darlington have shown. Breaking ground on entirely new power stations would be even more controversial and time-consuming. Even during the period of utmost optimism about nuclear energy, countries including France and the United States spend decades building up the capacity of their nuclear fleets. At the present rate of emissions growth, the world has only 15 years before it has produced enough cumulative GHG emissions to breach the 2˚C threshold designated "dangerous" by the world's major governments.[94] The prospects of any new nuclear reactors coming online in Ontario within that timespan are slim. Still, there are substantial and important differences in the probable outcomes of constraining climate change to higher levels than 2˚C. A 3˚C-hotter world would pose fewer dangers for humanity than a 4˚C- or 5˚C-hotter one. Even if it would take decades to substantially increase the total quantity of deployed nuclear energy infrastructure globally, doing so could play a role in constraining the most extreme warming scenarios.[95]

One major governance issue that affects the nuclear industry is the overlap between regulation and promotion of nuclear energy within the same organizations. In Canada, AECL was established with a mandate to develop and promote nuclear energy. The Canadian Nuclear Safety Commission falls under the authority of the Minister of Natural Resources, who has also headed up efforts to sell CANDU technology internationally. In the United States, the Nuclear Regulatory Commission has been criticized for playing a similar dual role of safety regulator and technological promoter.[96][97][98] Around the world, nuclear operators have frequently failed to provide full information about ac-

[94] McKibben, *Global Warming's Terrifying New Math*.

[95] For an assessment that finds a substantial increase by 2050 technically plausible, see: Massachusetts Institute of Technology, *The Future of Nuclear Power: An Interdisciplinary MIT Study*.

[96] Cooke, *In Mortal Hands: A Cautionary History of the Nuclear Age*, p. 389.

[97] Stilts, *Scientists: NRC fails to protect public*.

[98] See also: Speth, *The Bridge at the Edge of the World: Capitalism, the Environment, and Crossing from Crisis to Sustainability*, p. 83.

cidents and incidents, sometimes enjoying the assistance of national regulators in concealing their failings.[99] After Chernobyl, the U.S. Department of Energy and Nuclear Regulatory Commission issued gag orders to their staff about the accident.[100] The French government provided radiation exposure estimates after the disaster that were between one third and half of what would be credible, and the British Ministry of Agriculture, Fisheries, and Food failed for months to inform the public that radiation levels had exceeded its "trigger levels".[101] [102] The motivation for such misdirection has been twofold: the desire to protect the massive investment made in nuclear infrastructure from public criticism, and the desire to maintain demand for export sales. The nuclear industries of major western democracies have also failed to effectively prevent the knowledge and technology that they have transferred to other states from being used for nuclear weapon development.[103] [104] [105] [106] [107] The plutonium used in India's first (1974) nuclear test was bred in a reactor with a design derived from a Canada-provided CIRUS research reactor.[108] A 40 megawatt light-water reactor provided to Iraq by France was at the core of the Saddam Hussein's nuclear weapon program before it was destroyed by an Israeli airstrike in 1981.[109] Israel's illicit production of nuclear weapons at its Dimona facility in the Negev desert was similarly dependent on a French-provided reactor.[110] Certainly, the ethical position of the nuclear industry would be strengthened if a relationship of true independence were established between safety authorities and nuclear operators and promoters. Similarly, much more

[99] Cooke, *In Mortal Hands: A Cautionary History of the Nuclear Age*.

[100] Ibid., p. 318.

[101] Ibid., p. 320–1.

[102] The British government also failed to properly inform the public during and immediately after the serious 1957 fire at their Windscale plutonium production facility.

[103] A detailed public history of the development of nuclear weapons around the world, for which journalist Richard Rhodes received a Pulitzer Prize, can be found in: Rhodes, *The Making of the Atomic Bomb*.

[104] Rhodes, *Dark Sun: The Making of the Hydrogen Bomb*.

[105] Rhodes, *Arsenals of Folly: The Making of the Nuclear Arms Race*.

[106] Rhodes, *The Twilight of the Bombs: Recent Challenges, New Dangers, and the Prospects for a World Without Nuclear Weapons*.

[107] Also of interest in this regard (including in terms of nuclear technology's vulnerability to cascading failures) is: Schlosser, *Command and Control: Nuclear Weapons, the Damascus Accident, and the Illusion of Safety*.

[108] Cooke, *In Mortal Hands: A Cautionary History of the Nuclear Age*, p. 114.

[109] Rhodes, *The Twilight of the Bombs: Recent Challenges, New Dangers, and the Prospects for a World Without Nuclear Weapons*, p. 14–15.

[110] Cooke, *In Mortal Hands: A Cautionary History of the Nuclear Age*, p. 151.

substantial measures to prevent the global nuclear power industry from contributing, directly or indirectly, to nuclear weapon proliferation are desirable.

Most Ontario eNGOs are actively opposed to nuclear power — so much so that anti-nuclear protestors are a frequent sight at events held by Toronto environmental groups. A number of eNGOs wrote to the Canadian Nuclear Safety Commission in 2001 to express their concern about ongoing refurbishment of reactors at Pickering, Darlington, and Bruce.[111] These groups included Citizens For Renewable Energy, the Energy Action Council of Toronto, Energy Probe, and the Sierra Club of Canada. In 2006, Energy Probe estimated that total subsidies to AECL since 1952 have added up to $74.9 billion, including interest payments, making AECL responsible for 12% of Canada's total national debt at the time.[112] Greenpeace Canada argues that "nuclear energy undermines our clean energy future" and states that Canadians should "stop Darlington".[113] They claim to fight nuclear energy by "challenging industry claims", "pressuring politicians", and "informing the public". In 2008, Greenpeace issued a report entitled "Better Never Than Late: The Climate Fall-Out of Ontario's Nuclear Electricity Plan", in which they argued that new reactors would be risky and expensive and that Ontario's CANDU reactors should be shut down.[114] The report also argues that nuclear power "stands in the way of green energy" and that renewable energy, energy conservation, and "efficient local generation" present superior alternatives to nuclear.[115] The Sierra Club Canada has a "Nuclear-Free Canada" campaign which, among other things, opposes the construction of new reactors at Darlington. In their submission to the Darlington New Nuclear Power Plant Project Joint Panel, they specifically argue that new reactors would be "no help against climate change" because "[a]pproximately 240,000 to 366,000 tonnes of carbon dioxide are produced every year in Canada from nuclear plant construction, uranium mining, milling uranium ore, road

[111] Kleinau et al., *Submission to the Canadian Nuclear Safety Commission*.
[112] Adams, *Federal Government Subsidies to Atomic Energy of Canada Limited*, p. 2.
[113] Greenpeace, *Nuclear | Greenpeace Canada*.
[114] Greenpeace Canada, *Better Never Than Late: The Climate Fall-Out of Ontario's Nuclear Electricity Plan*.
[115] Ibid., p. 35–7.

transportation, fuel fabrication, conversion and refining activities".[116] Given the difference in scale between these GHG emissions and those that would be produced with fossil fuel power plants with output equivalent to Canada's nuclear fleet, this argument may serve more to undermine than to bolster the Sierra Club's credibility on this matter. At present, the David Suzuki Foundation's web-site is somewhat less critical of nuclear energy, though it does describe concern about cost, waste, and accidents.[117] In 2011, the Green Budget Coalition called for an end to subsidies for nuclear operators and AECL, an increase in minimum accident insurance, and the removal of the cap on reactor operator liability.[118]

3 | The future of the industry in Ontario

According to the Canadian Nuclear Association, Canada's nuclear industry has annual revenues of $5 billion per year and directly employs 21,000 people.[119] They argue that reactor "refurbish-ment is essential" if output from power stations is not to fall away across the 2020s, to well below projected demand.[120] Furthermore, they argue that refurbishments alone will not be sufficient to keep up with projected growth in demand, and that "[n]uclear energy is the only large, base-load emissions-free source available to Ontario".[121] On a slide entitled "Canada and the Kyoto Protocol", they argue that Canada's nuclear reactors have avoided 1.6 billion tonnes of emissions since 1972 and that each CANDU reactor avoids five million tonnes of CO_2 per year.[122] On their website, they promote a link to a video of James Lovelock, with text reading "a pro-nuclear environmentalist".[123]

In 1997, Ontario Hydro adopted a Nuclear Asset Optimization Plan, under which seven reactors would be taken offline for repair and overhaul at a cost of between $5 and $8 billion over four

[116] Sierra Club Canada, *Sierra Club Canada Submission to the Darlington New Nuclear Power Plant Project Joint Panel*, p. 12.
[117] David Suzuki Foundation, *Nuclear energy*.
[118] Green Budget Coalition, *Green Budget Coalition's Recommendations for Budget 2011*, p. iii, 22–23.
[119] Coupland, *Clean Air and Dependable Electricity Generation - The Nuclear Option*, p. 2.
[120] Ibid., p. 8.
[121] Ibid., p. 9.
[122] Ibid., p. 12.
[123] See: `http://www.cna.ca/studies_reports/`

years.[124][125] [126] The plan relied on coal-fired generation to make up the difference in power output, substantially increasing problems with smog, acid rain precursors, heavy metals, and GHGs.[127][128] The first reactor to resume service at Pickering did so only in 2003, at a cost of $1.25 billion — compared with an initial estimate of $780 million for four reactors and an originally projected restart date of 2000.[129] The refurbishments at Bruce were also significantly behind schedule and over-budget.[130] These experiences likely contributed to subsequent lack of enthusiasm about reactor refurbishment and the construction of new generating facilities.

A 2004 study conducted by the Pembina Institute argued that "grid demand could be reduced by nearly 50% relative to business as usual projections through a combination of energy efficiency and demand response programs, fuel switching, and increased cogeneration" at a cost of $18 billion and that "more than 95% of this amount would be recovered by energy consumers through energy cost savings".[131] By comparison, providing that generation capacity with nuclear reactors would cost $32 billion in capital expenses. The report recommends that the Ontario government adopt improved energy efficiency standards and a tightened building code; that municipalities be allowed to establish energy efficiency requirements as a condition of new development; that net metering be more widely deployed; that financing be provided to utilities, municipalities, and other bodies for energy efficiency improvements; and that various other measures be implemented to encourage efficiency and the expansion of renewable generation capacity.[132]

In 2006, the province of Ontario directed Ontario Power Generation to begin the process of proposing up to four new reactors at the Darlington site.[133] Bids were solicited from Areva NP,

[124] Winfield, *Blue-Green Province: The Environment and the Political Economy of Ontario*, p. 111.
[125] See also: Kleinau et al., *Submission to the Canadian Nuclear Safety Commission*.
[126] The NAOP was later renamed the Integrated Improvement Program (IIP).
[127] Winfield, *Blue-Green Province: The Environment and the Political Economy of Ontario*, p. 136.
[128] See also: The Conference Board of Canada, *Greenhouse Gas Mitigation in Canada: Energy, Environment and Transportation Policy*, p. 8, 35.
[129] Winfield, *Blue-Green Province: The Environment and the Political Economy of Ontario*, p. 140.
[130] Ibid., p. 140.
[131] Winfield, Horne, and Peters, *Power for the Future: Towards A Sustainable Electricity System for Ontario*, p. 1.
[132] Ibid., p. 7–8.
[133] Ontario Power Generation, *Darlington New Build: Project Overview*.

Westinghouse, and AECL.[134] The matter was considered by a Joint Review Panel mandated by the federal Minister of the Environment and President of the Canadian Nuclear Safety Commission. While the panel concluded that "[n]o significant adverse environmental effects [were] predicted, given proposed design and mitigation measures", in 2013 the Ontario government announced that it would not build new reactors at Darlington.[135][136][137] Energy Minister Bob Chiarelli announced that the proposed reactors could cost up to $26 billion and that the electricity they would provide would not be required.[138] The decision was criticized by Progressive Conservative energy critic Lisa MacLeod, on the basis of protecting jobs in the nuclear industry and being able to provide more energy in the event of faster-than-expected economic growth. NDP energy critic Peter Tabuns was supportive of the decision not to go forward with the new build. Generally speaking, the Liberal Party in Ontario has shown itself to be open to refurbishment of existing reactors in some cases, but not inclined to favour new construction. The provincial NDP has been more critical of nuclear power generally, while the Progressive Conservatives have sometimes expressed more overt support for the industry, including in terms of new construction.[139][140]

In 2013, the government of Ontario released "Achieving Balance" a long-term energy plan which aims to "balance five principles that will guide future decisions": "cost-effectiveness, reliability, clean energy, community engagement, and an emphasis on conservation and demand management before building new generation".[141] The plan calls nuclear generation "the backbone of Ontario's supply" and includes: "[m]oving ahead with nuclear refurbishment at both Darlington and Bruce Generating Stations, beginning in 2016".[142] The plan also claims that the province will

[134] Howlett and McCarthy, *AECL favoured to build Ontario reactors: sources*.
[135] Ontario Power Generation, *Summary of the Environmental Impact Statement for the New Nuclear at Darlington Project*.
[136] Leslie, *Ontario nixes building two nuclear reactors; will rebuild existing reactors*.
[137] The province's Long-Term Energy Plan claims the decision to defer new nuclear will lead to "significant ratepayer savings". Ontario Ministry of Energy, *Achieving Balance: Ontario's Long-Term Energy Plan*, p. 6.
[138] Hamilton, *$26B cost killed nuclear bid*.
[139] Benzie, *NDP vows to wean Ontario off nuclear power*.
[140] Radwanski, *Ontario Tories' nuclear promises could short-circuit their election platform*.
[141] Ontario Ministry of Energy, *Ontario Releases Long-Term Energy Plan: Province Presents Strategy for Clean, Affordable Energy*.
[142] Ontario Ministry of Energy, *Achieving Balance: Ontario's Long-Term Energy Plan*, p. 3.

"support the export of our home-grown nuclear industry expertise, products and services to international markets".[143] At present, Ontario's Ministry of Energy expects nuclear power to shrink as a percentage of total electricity generation — down to 42% by 2025.[144] Compared with many other Canadian jurisdictions, Ontario has been energetic in the promotion of renewable forms of energy, notably through its feed-in tariff program. Ontario has also been moving forward with the phase-out of coal-fired electricity generation, justified with reference to both climate change and toxic air pollution.

In recent years, AECL has experienced substantial problems with profitability. In 2009, the federal government allocated $651 million to the Crown corporation for cost overruns on ongoing CANDU refurbishments, repairs at Chalk River, and continued design work on the Advanced CANDU reactor.[145] In 2011, the federal government sold the CANDU design and marketing business of AECL to the Montreal-based engineering firm SNC-Lavalin for $15 million plus 15 years worth of royalties.[146][147] The year before, AECL's reactor division posted losses of $104 million on total revenues of $428 million.[148] This history raises questions about the plausibility of any further AECL-designed or CANDU reactors being built, even if Ontario does decide at some point that building new nuclear reactors is appropriate.

While there seems to be little immediate prospect of building new nuclear reactors in Ontario, the longer-term outlook is uncertain. So many independent forms of uncertainty overlap when trying to evaluate the future prospects for nuclear power that it becomes difficult to make any definite prediction, particularly since many of the issues affecting the future of Ontario's nuclear industry are much more political than technical. The 2011 Fukushima Daiichi nuclear disaster has bolstered public opposition to fission around the world, and the legacy of major cost overruns at Ontario nuclear facilities is sure to give pause to future decision-makers. Predictions of rapidly

[143] Ontario Ministry of Energy, *Achieving Balance: Ontario's Long-Term Energy Plan*, p. 5.
[144] Ontario Ministry of Energy, *Backgrounder: Ontario's Supply Mix*.
[145] Hamilton, *Atomic 'Challenges' prompt Ottawa to shell out another $200 million*.
[146] CBC News, *AECL sold for $15M to SNC-Lavalin*.
[147] Weston, *Ottawa basically paying SNC to take AECL*.
[148] Reuters, *Canada set to sell AECL unit to SNC-Lavalin: report*.

increasing energy use have also not materialized and, if there is to be success in the fight to control climate change, the trend in future energy use probably needs to be downward. At the same time, factors like the prospect for exports are difficult to incorporate, and an enormous sum of money has already been invested in nuclear facilities and expertise. If some global event succeeds in producing much greater seriousness in efforts to control climate change, the prospects for nuclear power may also be boosted.

At the same time, the rate at which climate change will affect human and natural systems is unpredictable. This uncertainty is magnified because, over and above the warming that occurs directly because of anthropogenically-induced increases in GHG concentrations, there is the likelihood that existing carbon sinks will become net sources of CO_2 and other GHGs as the planet warms. In particular, there is the possibility of truly massive emissions from the melting of arctic permafrost, which would magnify the effects of directly-induced warming. In the event of rapidly ongoing global climatic destabilization, it is especially challenging to predict that responses governments may choose: whether they might band together and finally make a serious attempt to control emissions, or whether cooperation would further break down as states sought to protect their short-term interests. In a sufficiently severe climate change scenario, or with a very different government in power, the possibility of new nuclear power plant construction in Ontario cannot be excluded. For the moment, however, the prospect does not seem likely.

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