RISKS OF OPERATING CANDU 6 NUCLEAR POWER PLANTS: Gentilly Unit 2 Refurbishment and its Global Implications

BY GORDON R. THOMPSON
Institute for Resource and Security Studies

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Greenpeace Canada

GREENPEACE CANADA
33 Cecil St.
Toronto, Ontario
M5T 1N1

www.greenpeace.ca

1 800 320-7183

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INSTITUTE FOR RESOURCE AND SECURITY STUDIES
27 Ellsworth Avenue, Cambridge, Massachusetts 02139, USA
Phone: 617-491-5177 Fax: 617-491-6904
Email: info@irss-usa.org

ABSTRACT

Operation of any nuclear power plant creates risks. CANDU 6 plants pose additional risks arising from their use of natural uranium as fuel and heavy water as moderator. A CANDU 6 reactor could experience a violent power excursion, potentially leading to containment failure and a release of radioactive material to the environment. Spent fuel discharged from a CANDU 6 could be diverted and used to produce plutonium for nuclear weapons. Those risks are examined here with special attention to Hydro-Quebec's plan for refurbishment and continued operation of the Gentilly 2 plant. That action would lead to continued radiological risk in Quebec and could promote sales of CANDU 6 plants in other countries, thereby contributing to an enhanced risk of nuclear-weapon proliferation. Hydro-Quebec's plan also faces regulatory risks. Safety issues could increase the cost of refurbishing Gentilly 2, weakening an already marginal economic case for refurbishment. This report proposes an approach for systematic, public assessment of the risks associated with Gentilly 2.

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ABOUT THE AUTHOR

Gordon R. Thompson is the executive director of IRSS and a research professor at Clark University, Worcester, Massachusetts. He studied and practiced engineering in Australia, and received a doctorate in applied mathematics from Oxford University in 1973, for analyses of plasma undergoing thermonuclear fusion. Dr. Thompson has been based in the USA since 1979. His professional interests encompass a range of technical and policy issues related to sustainability and global human security. He has conducted numerous studies on the environmental and security impacts of nuclear facilities, and on options for reducing those impacts. For example, Dr. Thompson prepared a report in 2000 for the Standing Committee on Energy, Environment and Natural Resources of the Canadian Senate, discussing the accident risk posed by the Pickering A nuclear generating station.

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Executive Summary

Hydro-Quebec plans to refurbish the Gentilly Unit 2 nuclear power plant to extend its operating life to about 2040. The plan involves three categories of risk that have not been properly assessed. One is the risk of an unplanned release of radioactive material, through accident or malevolence. The second is the risk that spent nuclear fuel will be diverted and used to produce plutonium for nuclear weapons. The third is the risk of regulatory actions that would increase the costs of refurbishing Gentilly 2. This report discusses all three categories of risk, and proposes an approach for systematic, public assessments of the risks associated with Gentilly 2. Those assessments could provide important information to citizens in Quebec, across Canada, and around the world.

BACKGROUND

Gentilly 2 is the only nuclear power plant operating in Quebec, providing about 3 percent of the province's electricity. It was commissioned in 1983, and was built to a Canadian design known as the CANDU 6. Hydro-Quebec plans to refurbish Gentilly 2 at a currently estimated cost of about Can$1.9 billion. The economic case for refurbishment and continued operation is weak, according to Hydro-Quebec. Operation of the plant, after its refurbishment, must be approved by the Canadian Nuclear Safety Commission (CNSC).

Atomic Energy of Canada Limited (AECL), a Crown corporation, has built two CANDU 6 plants in Canada – Gentilly 2, and the Point Lepreau plant in New Brunswick. In addition, nine CANDU 6 plants supplied by AECL are operating in Argentina, China, Romania and South Korea. AECL hopes to build new CANDU 6 plants around the world, and is pursuing opportunities in Argentina, Jordan, Romania, Turkey and elsewhere.

RISKS ASSOCIATED WITH THE CANDU 6 DESIGN

The concept of "risk" encompasses the probability and magnitude of an adverse impact on humans and the environment. Operation of any nuclear power plant creates risks. Plants of the CANDU 6 design pose additional risks that arise from basic features of the design, especially the use of natural uranium as fuel and heavy water as moderator and coolant. Those features create additional risks in two respects. First, a CANDU 6 reactor could experience a violent power excursion, potentially leading to containment failure and a release of radioactive material to the environment. Second, at a CANDU 6 plant it is comparatively easy to divert spent fuel in order to produce plutonium for nuclear weapons.

Continued operation of Gentilly 2 would involve risks specific to that particular plant, the Gentilly site, Hydro-Quebec's management, and Canada's socio-political climate. Risks associated with other CANDU 6 plants would differ in various respects. Nevertheless, the design features of the CANDU 6 plant are a common thread that links the risks associated with every CANDU 6 plant. Canada, as the home of the CANDU 6 design, has a responsibility to assess the influence of that design on the risks associated with CANDU 6 plants worldwide. The Director General of the International Atomic Energy Agency (IAEA) stated in October 2008: "Suppliers of nuclear technology owe a duty of care to the recipients and to the world at large." Hydro-Quebec's plan to refurbish Gentilly 2 provides an opportunity for Canada to carry out that duty in regard to the CANDU 6 design.

THE RISK OF AN UNPLANNED RELEASE OF RADIOACTIVE MATERIAL

In the context of an unplanned, radioactive release, a CANDU 6 plant has many characteristics in common with other nuclear power plants now operating worldwide. Almost all of those plants are in the "Generation II" category, and most (80 percent) are light-water reactors (LWRs) that are moderated and cooled by light water. Plants constructed during the next few decades would be in the Generation III category.

Any of the nuclear power plants now operating could experience an unplanned release of radioactive material as a result of an accident or a malevolent act. There are plant-specific aspects of the potential for such a release, but also broad similarities. For example, each Generation II plant has a comparatively modest capability to resist attack by a well-informed, well-resourced, sub-national group.

CANDU 6 plants are, in many respects, representative of Generation II plants. There is one respect, however, in which CANDU plants, including the CANDU 6, differ significantly from most Generation II plants. CANDU plants use natural (un-enriched) uranium as fuel, and heavy water as moderator and coolant. As a result, a CANDU reactor has a positive void coefficient of reactivity. Thus, if the flow of cooling water to its core were interrupted and shutdown systems were ineffective, the reactor would experience a violent power excursion, challenging the integrity of the containment structure. Such an event occurred at Chernobyl Unit 4 in 1986, with a large release of radioactive material to the atmosphere. Chernobyl 4 was an RBMK plant, not a CANDU, but it also had a positive void coefficient of reactivity.

AECL is currently offering a new version of the CANDU design concept, known as the ACR-1000. No ACR-1000 plant has been built to date. Design changes incorporated in the ACR-1000 include the use of light water as primary coolant, and low-enriched uranium fuel. As a result of those changes, AECL expects that the void coefficient of reactivity for the ACR-1000 would be slightly negative. That design feature, if achieved by AECL, might allow the ACR-1000 to be licensed in countries that would not accept a positive void coefficient. There are indications that the CNSC would refuse to license a new Canadian plant with a positive void coefficient. Concern about that licensing issue may have influenced the Ontario government to exclude the CANDU 6 from the list of designs for which it has invited bids for construction of new nuclear power plants in Ontario. The list now consists of the ACR-1000, the EPR design offered by AREVA, and the AP1000 design offered by Westinghouse. The latter two designs are LWRs.

In 2000, the IAEA established international standards for the design of new nuclear power plants. Those standards are, in many respects, the "lowest common denominator" of standards set by national regulators. Nevertheless, the IAEA recommends that plants have "inherently safe" behavior. The CANDU 6 design does not meet that standard, because it has a positive void coefficient of reactivity. Moreover, national regulators, including the CNSC, are beginning to require that new nuclear power plants have some capability to resist malevolent acts. The CANDU 6 design has limited capability in that regard. Thus, new CANDU 6 plants will become increasingly difficult to license as safety and security standards rise around the world. The IAEA is encouraging a trend toward standards that are more stringent and more uniform across national regulators.

THE RISK OF DIVERSION OF SPENT FUEL

AECL hopes to sell the CANDU 6 to a number of countries. Presumably, those countries would see advantages to the CANDU 6 that would offset risk issues such as a positive void coefficient and vulnerability to malevolent acts. It appears that the Turkish government sees such advantages. In soliciting bids for construction of new nuclear power plants in Turkey, the Turkish government has stated that it will consider the construction of CANDU-type plants only if they are fueled by natural uranium. The ACR-1000 is excluded by that requirement, but the CANDU 6 is allowed.

One reason for a government to favor a plant design that uses natural-uranium fuel would be the lack of need to purchase uranium-enrichment services for that plant. Moreover, if uranium could be mined within the country, the nuclear fuel cycle could become entirely indigenous. A government might choose that arrangement from the perspective of economics and/or energy security. There is also another consideration that a government would be unlikely to discuss in public. Deployment of an indigenous nuclear fuel cycle, featuring reactors that employ on-line refueling, would provide the country with a reserve capability to produce plutonium sufficient for a substantial arsenal of nuclear weapons. The country's government could draw upon that capability at some future date, depending on the government's assessment of the net benefit of establishing a nuclear arsenal.

The CANDU 6 design employs natural-uranium fuel and on-line refueling. Thus, CANDU 6 could be a preferred plant choice for a government that contemplates the possibility of deploying a nuclear arsenal. Canadians must, therefore, consider the risk that AECL's marketing of the CANDU 6 could contribute to the proliferation of nuclear weapons, albeit inadvertently. In contemplating that risk, it should be noted that growth in the number of nuclear-weapon states could increase the probability of nuclear war, in part by expanding the number of decision centers. Canada has experience in inadvertently contributing to nuclear-weapon proliferation, having supplied the CIRUS research reactor to India in the 1950s, with the condition that the reactor be used only for peaceful purposes. In fact, India produced plutonium in CIRUS for its 1974 test of a nuclear weapon, and for subsequent nuclear weapons.

LINKAGE BETWEEN RISKS AT GENTILLY 2 AND RISKS AT OTHER CANDU 6 PLANTS

The risk of a violent power excursion at a CANDU 6 plant, and the risk of diversion of spent fuel, both derive from the plant's use of natural uranium as fuel and heavy water as coolant and moderator. The risk of a violent power excursion exists at Gentilly 2 and all CANDU 6 plants, with some local differences. By contrast, the risk of diversion of spent fuel is highly country-specific. At present, there is little prospect of Canada using plutonium from Gentilly 2 in nuclear weapons. The same cannot be said for every country where CANDU 6 plants exist or might be built. AECL would undoubtedly use the refurbishment of Gentilly 2 as an asset in its marketing of the CANDU 6. Thus, in weighing the costs and benefits of refurbishing Gentilly 2, citizens of Quebec and other parts of Canada are obliged to consider not only the risk of an unplanned release, but also the risk of contributing to nuclear-weapon proliferation.

REGULATORY RISK ASSOCIATED WITH REFURBISHMENT OF GENTILLY 2

The CNSC criteria for approving license extensions for Canadian CANDUs are vague. It is difficult to determine the stringency with which the CNSC will apply those criteria to license extensions, and the extent to which all plants seeking license extensions will be treated equally. That uncertainty reflects a current tension within the CNSC between its traditional regulatory approach, which has ad hoc and incestuous qualities, and a more modern and professional approach. If the professional approach gains influence, then any licensee seeking a CANDU license extension will be obliged to conduct lengthy and expensive studies on shutdown-system effectiveness and other matters. The licensee could be required to implement safety-enhancing measures, which could be costly.

In view of these considerations, Hydro-Quebec faces significant regulatory uncertainty regarding the extension of the Gentilly 2 operating license. If the CNSC takes a uniform, professional approach to all license extensions, Hydro-Quebec will be obliged to make substantial expenditures on safety studies that could reveal needs for costly modifications of the plant. Also, delays pursuant to CNSC requirements could arise during the refurbishment of Gentilly 2. Hydro-Quebec has already stated that the economic case for refurbishment and life extension of Gentilly 2 is weak. Accounting for regulatory uncertainty could further weaken that case. Additional weakening could come from consideration of the risk of onsite economic impacts from fuel-damage events.

Hydro-Quebec announced its plan to refurbish Gentilly 2 without waiting to complete studies on safety issues and the potential to improve safety through plant modifications. Presumably, that action reflects Hydro-Quebec's judgment that the regulatory risk is low. In reaching that judgment, Hydro-Quebec was probably encouraged by the example of the Point Lepreau plant. Refurbishment of that plant, which is similar to Gentilly 2, is proceeding. However, ongoing studies on shutdown-system effectiveness and other matters related to CANDU safety could convince the CNSC that safety-enhancing measures – such as the use of low-enriched uranium fuel – should be required. The Point Lepreau plant might escape that requirement because the licensing process has moved further in that case. Taken together, the factors discussed here indicate that Hydro-Quebec's judgment about regulatory risk could be faulty in two respects. First, a trend to professionalism in the CNSC could lead to higher safety standards. Second, ongoing studies could reveal, within the next few years, needs for safety-enhancing measures at existing CANDU plants.

Recommendations

Each of the three categories of risk discussed in this report deserves a thorough assessment before Hydro-Quebec proceeds with its plan to refurbish Gentilly 2. Those assessments should be published, with limited exceptions for sensitive information. Openness and transparency are essential if the findings are to be credible. The assessments should be conducted soon, before substantial expenditures are made on refurbishment of Gentilly 2. Thorough assessments could show that refurbishment is neither cost-effective nor prudent.

The CNSC should require Hydro-Quebec to perform a full-scope probabilistic risk assessment that examines unrestrained reactivity excursions and other fuel-damage scenarios at Gentilly 2. A complementary study should assess the risks of unplanned releases caused by malevolent acts. Both studies should be available for independent review. Hydro-Quebec should be required to identify and characterize a range of risk-reducing options, including the use of low-enriched uranium fuel. Descriptions of the options and their effects on risk should be published.

The government of Canada should direct its relevant agencies, including the CNSC, to assess the risk that international marketing of the CANDU 6 will contribute to the risks of nuclear-weapon proliferation and nuclear war. That assessment should be published.

Hydro-Quebec should support the recommendations set forth above. In addition, Hydro-Quebec should independently assess the regulatory risk associated with refurbishment of Gentilly 2, and the risk of onsite economic impacts from fuel-damage events. Those assessments should inform a review of the costs and benefits of refurbishing Gentilly 2. The risk assessments and the cost-benefit review should be published.

Legislators in Quebec and across Canada should call for open assessments of risks, as described above. If the CNSC, the Canadian government and Hydro-Quebec do not perform thorough assessments, legislators should consider sponsoring alternative actions such as the conduct of independent hearings and studies.

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