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ECONOMIC GROWTH AND INNOVATION

Canada's Nuclear Crossroads:
Steps to a Viable Nuclear Energy Industry

Bruce Doern
Robert Morrison

In this issue...

Nuclear energy has a role to play in Canada's electrical generation mix, based on cost and environmental grounds.

The Study in Brief

Canada is at an energy and environmental crossroad. Fossil fuels cause environmental damage and the growth potential of large-scale hydroelectricity is limited. Policymakers are reconsidering the merits of nuclear power as both a low-carbon emitting and low-cost base load electricity source.

While nuclear power may look like an attractive option, nuclear power must overcome problems such as the high and uncertain cost of construction, dealing with nuclear waste, reactor licensing and regulation, and the future of Canada's nuclear reactor builder, Atomic Energy of Canada Limited (AECL), a federal Crown corporation.

We examine three key policy questions facing the nuclear industry: cost, privatization of AECL, and regulation.

First, nuclear power is likely cost competitive with fossil fuels once the social costs of all energy are accounted for. Nuclear power already internalizes far more of its social costs and potential liabilities than fossil fuels and the introduction of a carbon price will place the two on a level playing field.

Second, AECL should be partially privatized to bring stable funding, new international partnerships, and market capacity and discipline. However, a privatization deal should include continuing support, public or private, for pure research and development at the Chalk River, Ontario laboratories.

Third, Ottawa should review the array of nuclear regulatory regimes across different nuclear risks, from isotope manufacturing to reactor licensing to long-term waste storage. The commercial nuclear reactor licensing process will also need revision if a nuclear electricity renaissance is to occur in Canada.

The future of nuclear power in Canada is positive – if policymakers can resolve these key issues.

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INDEPENDENT • REASONED • RELEVANT

Canada faces a unique set of nuclear issues in the context of its broader energy and environmental policy.

The country has ample supplies of fossil fuels, but they contribute to a less-than-stellar record on climate change (see, for example, Jaccard 2007; Eberlein and Doern forthcoming).

It is, however, the world's leading producer and exporter of uranium, and it has developed its own unique reactor design, the CANDU, in the hands of a federal Crown corporation, Atomic Energy of Canada Limited (AECL). CANDU reactors already supply 52 percent of the electricity in Ontario, and the federal and Ontario governments now face important policy decisions about the future of the nuclear industry and, more specifically, about the funding and organization of AECL, including its laboratories at Chalk River, Ontario.

In this *Commentary*, we examine three questions and the appropriate policy responses to those questions. First, given the need to meet rising electricity demand while reducing greenhouse gas (GHG) and other emissions, is nuclear power a competitive option in the current policy framework? We conclude that nuclear energy is amply justified as a part of Canada's future electricity energy mix on both energy and environmental grounds. This is based partly on nuclear energy's advantage of low GHG and other emissions, and partly on the ability of nuclear power to provide base load power, in tandem with a range of alternative energy sources for variable intermediate and peak power needs. We also argue that policymakers should ensure that the environmental costs of fossil fuel energy sources are internalized in energy prices to the same extent as they already are for nuclear energy. Fossil-fuel-based energies currently do not need to pay for emitting their CO_2 waste, while nuclear facilities pay for most of the direct and contingency costs of dealing with radioactive waste.

Second, should AECL be privatized? We argue that it should be, at least partially. Partial privatization would bring the needed funding, ownership and partnership structures, and capacities required for the corporation to compete globally. Federal support for Chalk River and other related investments would still be needed, so full privatization likely is not a viable option. However, any approach to partial privatization – whether through the establishment of a new mixed enterprise corporation or through the sale of AECL's commercial assets and activity to a private company or companies – would have to deal effectively with the needed public goods research and development (R&D) functions of the Chalk River laboratories. Indeed, any final partial privatization package should include Chalk River's development and restructuring as a joint publicly and privately funded national laboratory.

Third, is there a need for new approaches to nuclear regulation? We argue that federal policymakers should establish regulatory review mechanisms across the array of nuclear regulatory bodies and agencies and the complete range of nuclear risks. These mechanisms should assess periodically the changing relative risks and ways to manage them, including funding needs related to regulatory capacity. The *Nuclear Safety and Control Act* also needs to be amended to ensure public safety while recognizing the obligations of both the regulator and the federal government for effective and efficient reactor licensing. In addition, policymakers need to demonstrate concrete progress, including with respect to the regulatory and approval process, on site selection for a nuclear waste management facility, since this is an important factor in public approval and would remain a crucial and continuing federal policy need even if the nuclear industry were to be closed down.

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Electricity Supply, Climate Change, and Costs

Given Canada's rising demand for electricity and the need to reduce GHG and other emissions, is nuclear power a competitive option in the current policy framework? We argue that the use of nuclear energy is amply justified as part of Canada's future electricity energy mix on both environmental grounds (its low-to-zero GHG and other emissions) and energy grounds (its ability to provide base load power, in tandem with alternative energy sources for variable intermediate and peak power needs). We begin with the situation in Ontario and, briefly, in other provinces. We then deal with the environmental, climate change, and related cost and subsidy factors of nuclear energy compared with other sources of electricity supply.

Ontario's Demand for Nuclear Energy as a Source of Base Load Power

Whatever the merits of nuclear energy, its future in Canada will be decided by actual orders, both foreign and domestic, for AECL's new advanced CANDU reactor (ACR). Ontario has been and will continue to be Canada's major domestic market for nuclear power, although the annual growth of demand for energy in the province has been negative for the past several years due to slow economic growth, restructuring toward less electricity-intensive activities, and improvements in efficiency. With the current economic crisis, moreover, demand is forecast to continue to decline over the next few years (IESO 2009).

Current Ontario policy limits the production of nuclear power in the province to its historical maximum of 14,000 megawatts (MW). At present, CANDU reactors supply most of Ontario's base load, with some help from hydro and coal. Current nuclear capacity is 11,300 MW, based on 16 operating CANDU units at the Pickering and Darlington power stations, owned by the Ontario government through its Crown corporation Ontario Power Generation, and at the Bruce power station, which is leased to Bruce Power, a private consortium. When two units at Bruce currently being refurbished are returned to service, nuclear capacity will increase to 13,000 MW.

Ontario's more variable intermediate and peak load requirements for electricity are now supplied mainly by coal and natural gas. Under the Ontario Integrated Power System Plan, however, coal-fired power is to be phased out by 2014, to be replaced by a combination of natural gas and wind and an increase in nuclear power through the refurbishment of current plants and the building of two new nuclear plants at Darlington. Conservation and the use of renewable energy sources will also be strongly encouraged.

Ontario's new reactors will be purchased on a competitive basis. AECL, with its ACR, is competing for this business with new light water reactor (LWR) designs by both Westinghouse-Toshiba and Areva, a reactor and fuel cycle corporation that is majority owned by the French government and already has four projects under construction. In the export market, AECL also faces tough competition from these and other vendors, including a partnership between General Electric and Hitachi. Ontario will base its purchasing decision on the criteria of low lifetime power cost, the ability to meet Ontario's schedules, and the level of investment in Ontario. On this last factor, at least, unless other vendors also use Ontario labour and subcontractors, AECL should have an edge over its competitors, since all of Ontario's current nuclear power comes from CANDU reactors, most of the CANDU suppliers are in Ontario, and AECL itself is Ontario based. Yet, although nuclear energy is important to Ontario, not just for the electricity it supplies but for the jobs in research and development, design, and manufacturing, the province sees the economic benefit of the first two factors, cost and timing, as much greater than the economic benefit gained through investment and local spending (Infrastructure Ontario 2008). Moreover, vendors other than AECL might offer access to new technologies and markets, as well as offset business for Ontario to compensate for the loss of CANDU activities should the province not choose AECL. Clearly, Ontario's purchase decision will have a profound influence on the future of AECL and the nuclear industry in Canada and, hence, on federal nuclear energy policy.

Nuclear Developments in Other Provinces

The future of AECL's ACR reactor program depends to some extent on whether provinces other than Ontario express an interest in it and adopt it as a part of their energy strategy. New Brunswick and Quebec already have one CANDU reactor each; Alberta and Saskatchewan have not used nuclear power to date but are in the very early stages of considering its adoption.

New Brunswick is actively looking for funding for a new reactor to complement the existing CANDU reactor at Point Lepreau, where AECL is carrying out a $1.4 billion refurbishment project. The bid to install an ACR has been put forward by Team CANDU, a consortium of AECL and private firms, which is proposing a merchant model whereby the consortium, rather than the provincial government, would undertake the project risk.[1] Half of the new reactor's output would be exported to the United States. Since New Brunswick does not want to own a one-of-a-kind reactor, it is looking for the federal government either to invest in AECL to ensure that the company can compete globally or privatize it and let investors make it competitive (New Brunswick 2008). A first order from New Brunswick for a new reactor would be a strong endorsement from an old CANDU customer.

Quebec will refurbish its existing CANDU unit, but is not in the market for more reactors. Rather, its electricity policies are centred more on new hydroelectric power, including projects with long-term northeastern US markets in mind.

Alberta's current electricity supply is largely based on coal and natural gas, and the province will need 5,000 MW of new electricity capacity by 2017. It is under pressure, however, to reduce its GHG emissions, especially from the oil sands (Bratt 2008). Bruce Power is considering the possibility of building nuclear reactors to supply power to the oil sands, displacing natural gas. In March 2008, it announced that it had bought an Alberta company active in promoting nuclear power, and filed an application with the Canadian Nuclear Safety Commission (CNSC) for approval to prepare a site that would generate 4,000 MW from two to four reactors. Alberta is also looking at carbon capture and storage (Cattaneo, 2008), which could be seen as the main cost competition for nuclear power in dealing with emissions from the oil sands provided considerable technological obstacles and regulatory uncertainties can be overcome.

Bruce Power is also studying the possibility of building a nuclear power plant in Saskatchewan (Jones 2008), whose premier sees it as a way of adding value to the province's uranium resources (Bratt 2008).

Provincial support for AECL's new reactor model could provide a domestic base for exports, a benefit that would accrue both to the federal government through an increased market value for AECL and to Ontario through additional jobs in the nuclear industry. Without provincial support, however, the federal government would have less motivation to maintain the technology and the market value of AECL would decline.

Nuclear Energy's Role in Climate Change and Improved Air Quality

Central to governmental decisions about future nuclear power use in Canada is whether the low level of GHG and other emissions from nuclear power can tip the balance in favour of its increased role in the electricity supply mix. A reduction of emissions also would have direct implications for nuclear energy's costs vis-à-vis those of its competitors.

Canada's current GHG emissions total 721 megatonnes per year of CO_2-equivalent, of which fossil-fired electricity, mainly coal, contributes 115 megatonnes per year, or 16 percent of the total (Canadian Electricity Association 2006, 8). To meet its commitments under the Kyoto Protocol, which clearly will not happen on schedule, Canada would need to reduce its emissions by about 160 megatonnes of CO_2-equivalent per year from current levels (Environment Canada 2006). A 1,000 MW CANDU reactor running 80 percent of

1 See "Team Candu ready to proceed with second Point Lepreau reactor without government funding," Daily Commercial News and Construction Record, February 12, 2008.

Table 1: Greenhouse Gas Emissions by Power Source, 2007

	Power Source			
Emissions source	**Coal**	**Natural Gas Boiler**	**Nuclear**	**Hydro**
Subtotal from combustion *(grams of CO_2 per gigajoule)*	90,333	50,112	1,947	3,586
Upstream fuel cycle emissions *(grams of CO_2 per gigajoule)*	3,001	6,260	582	0
Grams of CO_2 per gigajoule of energy	93,334	56,372	2,529	3,586
Grams of CO_2 per kWh delivered	**1078.3**	**616.7**	**13.2**	**17.3**

Note: Emissions from nuclear are estimated from standby generators and auxiliary boilers; other upstream and downstream emissions are not accounted for.
Source: Author's interpretation of GHGenius 3.11, Natural Resources Canada, 2007.

the time would avoid about 6 megatonnes of CO_2-equivalent per year if the alternative were coal and half that much if the alternative were natural gas. Canada's currently active nuclear capacity of 13,000 MW offsets about 80 megatonnes of CO_2-equivalent per year compared to coal, so nuclear energy is already making a big contribution to limiting Canada's GHG emissions.

The Limitations of Environmental NGO Analyses

Most environmental nongovernmental organizations (NGOs) in Canada are strongly opposed to nuclear energy (for example, see Winfield et al. 2006). For example, one argument with respect to GHG emissions of nuclear power is "while the GHG emission profile of nuclear power looks attractive when compared with conventional fossil fuel sources, it is far from zero" (Pembina Institute 2007). The dispute with the nuclear industry's claims of zero GHG emissions is based on a life-cycle analysis that takes into account GHG emissions from activities such as uranium mining, fuel processing, and waste processing, which the NGO estimates suggests amounts to about 12 grams of GHG for every kilowatt hour (kWh) of electricity produced from nuclear energy (Winfield et al. 2006). In contrast, coal power produces over 1,000 grams of GHG emissions per kWh, natural gas 616 grams per kWh, and hydroelectricity 17.3 grams per kWh (Table 1). Even when taking into account the most comprehensive look at GHG emissions from nuclear power, they are about one percent of the equivalent emissions from coal. Therefore, despite the claim that nuclear power's GHG emissions are "far from zero," they are much closer to zero than those from fossil fuels.[2]

Overall, however, the environmental case against nuclear power is based on other arguments: that nuclear waste creates serious long-term environmental problems; that nuclear power is one of the most expensive options; that nuclear power impedes the development of more sustainable options; and that the unreliability of nuclear power, as evidenced by the prolonged shutdown of eight CANDU units in Ontario, has led to increased GHG emissions in that province (Burda and Peters 2008). In fact, rather than nuclear power's impeding of other options, nuclear and renewable energy options are complementary, in that nuclear

2 Another life-cycle study gives a similar result; see Andseta et al. (1998).

Table 2: Estimates of Electricity Costs, by Energy Type

	Cost Estimate	
Energy Type	Low Range	High Range
	(cents per kWh)	
New nuclear	5.3	7.3
Old nuclear	6.3	8.9
Coal	4.7	5.9
Gas	7.2	8.5

Sources: Canadian Energy Research Institute 2004, 2006.

energy supplies base load power whereas renewables tend to be intermittent. The increase in emissions due to the use of coal-fired power when nuclear plants were shut down in Ontario is a reason for better management of the nuclear plants, not for doing away with them.

Costs of Nuclear Energy Relative to Other Energy Sources

Cost estimates for electricity, whether from nuclear energy or from other sources, depend on assumptions about the costs of construction, fuel, decommissioning and waste management, carbon emissions, capacity factors, time horizons, and the discount rate. They also depend on the site and the jurisdiction in which it is located, and on whether it is taxpayers or investors that take on the risks when it comes to financing.

Although the process of reducing GHG emissions represents a political challenge, most economists favour putting a value on emissions as an essential means of achieving that goal (see, for example, Simpson, Jaccard, and Rivers 2007). This can be done through either a carbon tax or a cap-and-trade system. Either way, it would help to ensure that fossil-powered generation of electricity is fully costed. Another approach, favoured by many current governments, is to subsidize alternative energy sources directly by funding development costs or by paying more for electricity from those sources.

Studies that compare unit energy costs levelled across the lifetime of a power plant indicate that nuclear, coal, and natural gas are broadly competitive with one another under a reasonable range of assumptions (World Nuclear Association 2008a, 2008b, 2008c). Other studies suggest that electricity costs per kWh from nuclear energy are about 10 to 25 percent higher for new nuclear power plants than for coal and natural gas power plants in the absence of any cost for GHG emissions (Canadian Energy Research Institute 2004, 2006; see also Table 2).

A review of recent cost estimates of nuclear electricity in the United States by the Nuclear Energy Institute (2008) provides another indication of trends. Its study of a Connecticut utility shows the base case for nuclear at 8.3 cents per kWh and for natural gas combined cycle without carbon capture at 7.6 cents. The Institute's own modelling shows that, with a carbon value of $30 per tonne of CO_2, the price of electricity from natural gas would increase by 1.3 cents per kWh and that from coal by 2.5 cents. Under most scenarios, then, electricity from nuclear energy seems competitive with that from natural gas and coal-fired plants.

AECL expects the capital cost of of its new ACR to be significantly less than those of older CANDU models, but no examples have yet been built and capital costs can be unpredictable. Without factoring in the costs of CO_2 emissions, coal would be favoured slightly over the ACR reactor design; if a cost of $15 per tonne of CO_2 emissions were included, however, electricity from the ACR would cost the same as that from coal – indeed, higher carbon values would tilt the balance in favour of the ACR (Canadian Energy Research Institute 2004, p. 18). On the other hand, merchant financing, the proposed source of funding for a new reactor at Point Lepreau, New Brunswick, has higher financing and tax costs than does public financing, which would add about 40 percent to the cost of nuclear power but only about 20 percent to the cost of coal-fired power.

The effect on plant revenue of placing a value on carbon emissions can be estimated roughly in the following way. A 1,000 MW nuclear plant operating at 80 percent capacity will generate 7 terawatt hours of electricity per year; at 6 cents per kilowatt hour, this represents $420 million of revenue per year. A 1,000 MW coal-fired plant will emit about 6 million tonnes of CO_2-equivalent per year, while a comparable nuclear plant will have negligible emissions. At a modest value of $30 per tonne of CO_2, emissions would cost the coal-fired plant $180 million in annual revenue, a significant share of total revenue. The clear conclusion is that nuclear power becomes a very cost competitive option once modest costs on carbon are imposed.

Subsidization Issues

Nuclear energy has also been criticized for the level of subsidization it receives from government. In Canada, several funding elements of nuclear energy have been characterized as subsidies:

- some of the costs of supporting R&D at the Chalk River laboratories – about $120 million per year – plus additional funding of $300 million in the 2008 federal budget for refurbishment and infrastructure expenses (AECL 2008) and $351 million in the 2009 budget for similar expenses and for the ACR design, plus $100 million in emergency funding for refurbishing older CANDU reactors (McCarthy 2009);
- support for new CANDU and other reactor designs, amounting to several hundred million dollars over several years – the federal government has paid for about half of the $400 million spent on the ACR to date (AECL 2008);
- legacy wastes and liabilities, amounting to $520 million over five years (2006-11), with significant expenses beyond that period and a present value (the current value expected future costs when discounted by the interest rate or some other discount rate) of about $3 billion (AECL 2008);
- limits on nuclear liability for insurance purposes beyond about $650 million in the proposed new legislation, Bill C-5, which was intended to replace the *Nuclear Liability Act*;
- support for CANDU exports in terms of, for example, loans and loan guarantees, amounting to several billions of dollars – here, the subsidy would be the difference, if any, between the government-backed financing rate and the normal commercial rate; and
- the costs of reactor cost overruns, shutdowns, restarts, and refurbishments in Ontario in the 1990s that were borne by provincial taxpayers and ratepayers, amounting to several billions of dollars.

On reflection, however, many of these costs are not "subsidies" *per se*. Some – such as for R&D and new reactor design – could also be seen as investments, while some of the R&D costs at Chalk River are for fundamental science and for the production of radioisotopes for medical purposes, not just for the support of CANDU business. The legacy liabilities were incurred for a variety of policy reasons going back a long way, including defence in the 1950s, and fundamental science and medical goals. As well, there is a low likelihood of invoking loan guarantees for CANDU exports because the national governments of importing countries are likely to fully support investments there, as nuclear plants are a vital part of a country's infrastructure. There are, moreover, international guidelines for government support of nuclear plant exports. The limits on nuclear liability would be relevant only in the unlikely event of a serious accident. In any case, companies cannot pay more than they are worth, so ultimate responsibility beyond that limit would devolve on governments regardless. Finally, to the extent that nuclear costs are built into the price of electricity and paid by ratepayers, one could argue they are not subsidies, while the costs of shutdowns and startups in Ontario were due much more to utility management than to the CANDU technology.[3] In short, while it is clearly difficult to make precise assignments, we suggest that direct subsidies to the CANDU business are likely to be less than $200 million per year on a continuing basis, mainly for R&D and for the ACR design.

Thus, to answer the question of whether nuclear power is competitive relative to the alternatives, federal and provincial policymakers need to look at broader analyses and comparative systematic data and information on all these energy sources. And they should keep in mind that, although nuclear energy does not completely incorporate the costs of its environmental externalities into the price of the electricity it produces, it does so to a much greater extent than do fossil fuels.

Accordingly, any full comparison of subsidies to various energy sources should take into account:

- major federal government support for oil and gas energy research and development via tax breaks and the direct spending of federal labs and agencies;
- similar support by provinces as resource owners;
- subsidies for highways and infrastructure that underpin oil and gas use in vehicles and buildings;
- the failure to price the emissions of fossil fuels, which constitutes a "subsidy" that is not aggregated into comparative subsidy estimate summaries; and
- federal and some provincial subsidization of carbon capture and storage technology, costs which are likely to grow significantly.

The value of such subsidization to these other energy industries is, of course, difficult to assess, although figures for the value of carbon emissions are indicative. On a national scale, the 80 million tonnes of CO_2-equivalent offset annually by nuclear power relative to coal would be worth about $2.4 billion per year at a value of $30 per tonne of emissions – a significant amount when compared with any estimated value of subsidies provided to nuclear energy in Canada.

International comparisons are also instructive. The governments of the leading exporters of nuclear power technology, such as the United States, France, and Japan, all fund much larger national R&D programs to support their nuclear industry than does Canada, even after taking into account the differences in the scale of their programs. They also support nuclear export projects. In the United States, the *Energy Policy Act* of 2005 provides up to US$2 billion for the first six new domestic nuclear plants to cover the cost of overruns due to delays, and a production tax credit of up to US$125 million per year per reactor. These are substantial offsets for the capital costs of new nuclear plants.

It is true that AECL will have significant ongoing costs that will be covered by the federal government. Some of these, such as the legacy wastes and the need to maintain a licensed site at Chalk River, will be required no matter what happens to AECL. Other costs will depend on how much Ottawa chooses to invest in maintaining the CANDU design as a nuclear option for Canada, as well as the role it sees for medical radioisotopes and for fundamental nuclear science. It might wish to transfer some of the costs and risks of the CANDU to the private sector, although private sector firms have also been known to ask for government subsidies.

In conclusion, when one factors in the full costs of health and environmental effects, including air-quality issues, nuclear power is less expensive than the alternative sources of base load electricity. Moreover, those health and environmental costs are likely to increase in the future. As well, the tangible monetary subsidies given to nuclear power are not very different in kind, although somewhat smaller,

3 Carl Andognini, a U.S. consultant who examined Ontario's nuclear plant performance in the 1990s and then became the chief nuclear executive at Ontario Hydro, said that the poor performance of Ontario Hydro's CANDUs was "…not a technology problem. It's a managerial problem." See Greg Crone and Richard Brennan. 1997. "Ontario's nuclear strategy bombed." *Montreal Gazette.* August 14.

than the implicit subsidies to other types of energy for the right to emit CO_2 at no cost. Finally, if the provinces, especially Ontario, were willing to make a commitment to purchase the new ACR design, this could justify some ongoing federal subsidies for its research and development.

The Privatization Option: Looking for Serious Money

The second question we pose – and it is closely linked to the first – is whether AECL should be privatized.

AECL's Mandate and its Investment and Competitive Realities

As Canada's national nuclear reactor designer and vendor, AECL sells the CANDU reactor, manages most new CANDU projects, and contracts to a range of private suppliers and consultants for components and engineering. As we have seen, it also carries out nuclear R&D and radioisotope production at its Chalk River laboratories in Ontario. It can be characterized as a mid-sized engineering company, with annual commercial revenues of around $500 million.

AECL has reasonable prospects of making some CANDU sales over the next decade, as well as refurbishing existing CANDU reactors. In the export market, AECL has a good track record of building CANDUs in developing and emerging countries, having been effectively shut out of developed country markets by the early widespread adoption of the LWR. The company needs money, however, to refurbish the Chalk River labs, to complete the ACR design, and, possibly, to support ACR sales abroad, in addition to the ongoing need to fund its legacy waste liabilities at Chalk River. A partial privatization of AECL would help to resolve some of these issues.

The federal decision on support for AECL and Ontario's decision on what technology and vendor to choose for its new reactors are intertwined (Purchase 2008). As emphasized above, if Ontario opts for the CANDU, it would be a big boost for AECL. If it does not, and if no other domestic CANDU orders emerge, AECL probably would be consigned to refurbishing existing CANDUs, as foreign customers likely would not buy a new reactor from AECL that had not been purchased in Canada. Refurbishing is a good business in its own right, but it does not provide the same stream of long-term business as the design and building of new reactors. A decision by Ontario to go with the CANDU would allow the Canadian nuclear industry to carry on with much the same roles and structure, although privatization of AECL's CANDU business could bring changes. If Ontario opts for another vendor, AECL would look for benefits from access to new technologies and markets, but it could also face the loss of much of the business from new CANDU sales.

A 2007 report by the auditor general suggested that AECL faces certain critical challenges, particularly the development and licensability of the ACR in time to meet market requirements and the replacement of aging facilities at its Chalk River Laboratories (Auditor General of Canada 2007, 2).[4] Despite AECL's receipt of an additional $34 million from the federal government to address urgent health and safety issues at Chalk River, the report noted that "a source of funding for the other significant costs had not yet been identified." The challenge for AECL is that its mandate is not defined in an act of Parliament; rather, it functions through an annual corporate plan approved by the federal government. Moreover, AECL does not have borrowing powers, and must have government approval for key decisions such as investment in capital assets. Most government ministers, however, see few political positives to nuclear power issues but many negatives, and have not made nuclear energy a budgetary or political priority until recently. Thus, the costs and subsidy aspects of our first question are entwined with the partial privatization question.

4 The reports also noted the challenge of completing and licensing a Dedicated Isotope Facility (DIF), consisting of two MAPLE isotope production reactors and a new isotope processing facility. The DIF facility has since been cancelled.

Privatization Options

The federal government is currently reviewing AECL's situation, and has indicated the likelihood of the company's full or partial privatization and to different ways of managing the Chalk River site. Should AECL succeed in obtaining contracts for new ACRs in Ontario and New Brunswick, its value to the federal government would be enhanced, making it a more attractive target. Likely private investors would be Areva, as well as Canadian firms such as SNC-Lavalin and Bruce Power. For Areva, the main attraction would be to acquire new intellectual property linked to reactor design, R&D, waste storage, and fuel recycling, not to mention the important assets of highly qualified nuclear engineering and research personnel and possibly some of the facilities and capabilities at Chalk River.

Private investors could bring renewed drive and discipline, along with new ideas about developing and marketing the CANDU system, fuel cycle work, and extracting better value from Chalk River.

The goal of the current privatization review appears to be to establish a strategic partnership that would be linked to Ontario's reactor decision. Privatization could help to clarify roles and contribute to funding nuclear R&D and design work, although maintenance and legacy costs would remain. At the same time, the federal government will want to protect Canadian high-technology jobs at AECL and in the nuclear supply companies as much as possible. Keeping the CANDU design capability would maintain jobs in that critical area and help to ensure business for Canadian companies that have experience with the CANDU supply chain. Private investors could bring renewed drive and discipline, along with new ideas about developing and marketing the CANDU system, fuel cycle work, and extracting better value from Chalk River.

Although the federal-Ontario relationship is crucial, strategic partnerships are also possible with other provinces. If Alberta and Saskatchewan became serious about investing in nuclear energy, the federal-provincial dynamics would become more complex, as these provinces would want some say in nuclear development. Such input likely would be handled through normal federal-provincial energy relations, however, rather than through some kind of ownership role in a partially privatized AECL.

Privatization discussions and debate inevitably raise policy concerns about what constitutes the nuclear "industry" now and in the future. Should policy focus on the nuclear industry "in Canada," with a related concern for jobs, or on the "Canadian nuclear industry," a broader definition with an emphasis on investment and exports?

Privatization also raises the concern that, while there are advantages to being part of a larger and perhaps more efficient organization, there are also risks. In time, a large, new private owner could decide simply to shut down AECL's facilities and product lines and offer key staff jobs elsewhere, with deleterious effects on the CANDU supply industry. On the other hand, a private owner of AECL would very likely include significant Canadian content in new reactors that it supplied, even if they were not CANDUs.

The Ontario government's view of privatization is centred on its stated preference to select the right nuclear reactor technology at the right price and in a competitive market, rather than being pressured to "buy Canadian" and "buy Ontario" by purchasing CANDU reactors from AECL. But advantages would accrue to AECL as an Ontario-centred company and to the Ontario and federal governments if a partially privatized AECL had a partnership in a second kind of reactor product with access to the global market for reactor contracts in the United Kingdom, the United States, and China. Moreover, should privatization of AECL lead to lower costs for customers, Ontario would be the direct beneficiary.

The search for privatization and related partnership options has arisen not just because of AECL's serious funding needs, but also because

AECL is a relatively small company and the owner of a minority technology competing in a global nuclear reactor market in which it accounts for only about 6 percent of the 439 reactors operating in the world (Nuclear Energy Agency 2008, 50). Moreover, Canada did not participate in the consolidation of the nuclear reactor industry in the 1980s and 1990s that led to the shedding of unprofitable nuclear divisions of large companies (Secor 2007, 24). Today, the Canadian nuclear industry's competitors follow business models ranging from Areva's vertical-integration approach across the nuclear power generation supply chain to the focus of GE and Westinghouse on reactor design, building, and servicing in the context of a larger organization.

Privatization of AECL, however, raises issues of its possible adverse effects on nuclear proliferation, regulatory concerns, and a lessened Canadian nuclear identity and science capacity. Nuclear proliferation and regulatory concerns are unlikely to be harmed by a partial privatization option – indeed, the federal government might become more vigilant because it would no longer, in a sense, be regulating itself but, rather, a private firm. As for nuclear identity and science capacity, depending on which option was chosen, privatization in fact might preserve and enhance both by more clearly delineating the public goods and private roles in nuclear energy matters. When AECL's privatization has been contemplated in the past, potential private investors naturally have supposed that they would assume the company's commercial operations while the federal government would maintain the public goods of research costs. From the government's perspective, however, that would mean absorbing all such costs with no offsetting revenues. Thus, any attempt at partial privatization would have to find a way to obtain the needed commercial investment and entrepreneurial expertise and capacity while allowing the federal government to defend its actions against the charge that it is selling a public asset without public benefit.

Partial privatization would involve choosing among at least three options: creating a new mixed enterprise; selling the commercial assets to a private firm or firms; or devising a new national public-private government laboratory model for Chalk River. The first option could involve the sale of AECL to a new, mixed-enterprise corporate entity with shares owned by the federal government and by another private nuclear firm or firms in some agreed proportion. In addition, there would have to be public agreements or statutory provisions regarding ongoing federal or joint funding of financial obligations for the financing of the public goods aspects of AECL's role at Chalk River. The new entity's governing board of directors would have to be appointed in a manner that reflected the balance of joint ownership. Canada has had some experience with such formal mixed enterprises – for example, the case of Telesat Canada.

The second partial privatization option would be to sell the CANDU commercial-related assets but leave the Chalk River assets with a reconstituted AECL (whose reduced mandate would need a new statutory basis). It is likely that the reactor refurbishment business would also be a part of the private entity rather than stay with AECL. The reconstituted AECL could be given a more definitive funding structure from the federal government since it would not be able to self-finance to the same extent that AECL previously had.

A third model or element of a privatization package, Chalk River as a restructured national laboratory, is inherent in the first two options but would be made much more explicit. It would also address more frontally the federal government's need for a new way to maintain and build the public goods R&D function. Under this option, Chalk River, as a part of the remaining noncommercial AECL, could be converted into a public-private national laboratory. Federal funding for the laboratory could be provided, but withdrawn or reduced over ten years or so, to be replaced by new partnership funding and/or contracting arrangements. Federal laboratories already have varied structures and funding, so a restructured national nuclear research lab could join other energy labs such as the Natural Resources Canada's Devon lab, near Edmonton, which supports the Alberta oil sands through partnered funding (see Doern and Kinder 2007). In fact, the federal government has already received a contract study from the National Bank that, though not yet public, reportedly recommends that Ottawa sell at least 51 percent of AECL but retain ownership of Chalk River (Howlett and McCarthy 2009).

Regardless of which option might be chosen, further agreements between the federal government and any privatized entity would also have to be negotiated. In negotiating the partial privatization of AECL, the federal government could learn some lessons from the contentious relations between AECL and MDS-Nordion in the wake of the cancellation of the MAPLE isotope production reactors (see footnote 4). The key issue was the desire of MDS-Nordion to have a guaranteed supply of isotopes. MDS-Nordion now seeks $1.6 billion in damages from AECL.

The fundamental contractual problem is one of risk. AECL carried the risk of the MAPLE reactors not being licensable; now, with the ACR design still incomplete, there is a risk that it will not be commercially viable. It thus seems appropriate to differentiate the kinds of risk that governments should take on (such as those that affect public well-being concerning safety and regulatory risks, as well as those involved in basic science R&D) and those that should be passed on to a private corporation (such as market and construction risks, and the risks of applied R&D linked to specific commercial products). Accordingly, it might make sense to consider a partial privatization of AECL only after the ACR is certified but before construction begins.

The federal government should also pay close to attention to guarantees, whether implicit or explicit. For instance, if it were to sell the CANDU business but retain responsibility for Chalk River, Ottawa likely would have to guarantee some level of R&D in basic science relevant to the CANDU design. Conversely, in return, such a guarantee could require from the buyer a minimal level of ongoing applied CANDU R&D business in order to justify further investment in Chalk River. This would also have an impact on the sale price of the CANDU business.

Nuclear Regulatory Challenges

Our third and final question centres on whether there is a need for new approaches to nuclear regulation. In our view, federal energy policymakers should devise explicit mechanisms that assess more systematically and deal with changes in relative risk across the larger nuclear regulatory regime, which consists of several bodies. For instance, the isotope supply crisis of late 2007 was due to a clash between the need for reactor safety and the risk of going without medical isotopes, with different agencies responsible for the different risks. The nuclear regulatory regime also needs modernizing through statutory changes in the mandate of the Canadian Nuclear Safety Commission (CNSC), particularly regarding the licensing of new nuclear reactors.

The nuclear regulatory regime necessarily has to deal with the combined issues of health and safety and relative risk assessments in domains such as nuclear reactors, isotope production, use, and transportation; the timely and efficient licensing of nuclear reactors; and the long-term storage of nuclear wastes (see Doern, Dorman, and Morrison 2001; Stoett 2003). Issues of reactor safety clearly involve assessments of relative risk (for example, reactor safety versus isotope production) and diverse notions of risks versus benefits. Timely licensing issues centre around regulatory efficiency, speed of decisionmaking, and regulatory compliance in an era when the ideas of economic and technological innovation in concert with effective public safety are increasingly important (see Doern 2007).

The nuclear regulatory regime also might have a different central dynamic if AECL were partially privatized, since the federal government would no longer be regulating a Crown corporation but a much larger commercial corporate and business presence with international implications.

The Nuclear Regulatory Regime in Brief

Canada's nuclear regulatory regime is mainly a federal responsibility and consists of several policy and regulatory agencies. Both Natural Resources Canada and Industry Canada promote the industry, while the former initiates energy policy and legislative change with five other organizations concerned with safety, nuclear waste, and health matters.[5]

Natural resources minister Gary Lunn announced in June 2007 that he had accepted the approach recommended by the federal Nuclear Waste Management Organization (NWMO) for managing used nuclear fuel, including the isolation and containment of used fuel deep underground with an option for temporary shallow underground storage. The NWMO recommended going one step at a time and leaving as much flexibility as possible to future policymakers. Site selection will take years and will be a regulatory and management challenge of immense complexity involving the need to manage wastes over a period of hundreds and even thousands of years. There is also a contentious debate about current and future nuclear costs and economics and who should pay for them; the intent is that electricity consumers should pay, but there are many uncertainties about the magnitude of the costs and their profile over time.[6]

In our view, federal policymakers need to ensure that demonstrable progress occurs on the actual site selection for a nuclear waste management facility, since this is an important factor in gaining public approval for nuclear energy, and would remain a federal concern even if the nuclear industry were closed down. Although the next steps reside with the NWMO, the federal government should support steady, visible progress in this area, and have a comprehensive and credible regulatory and approval process in place, with full cooperation among the CNSC, Environment Canada, and the relevant provincial agencies.

The most recent regulatory issue to make headlines was the demotion and later resignation of the head of the CSNC (Calamai 2008), which arose because of serious communication problems between the CNSC and AECL about the safety of the reactor used to produce medical isotopes, coupled with confusion about who in Ottawa was responsible for what risks (see Morrison and Meneley 2008). Although the isotope crisis led to political controversy, it revealed an underlying policy problem of the nuclear regulatory regime's incapacity to deal with changes in relative risks, not just with respect to commercial reactors. Thus, federal policymakers should design review mechanisms across the array of nuclear regulatory bodies and agencies, and across the range of changing relative risks, to assess periodically the relative risk agenda to be addressed and ways to manage it, including funding needs related to regulatory capacity. Annual assessments probably are not practical, but regular assessments certainly should be adopted and made public.

The CNSC and the Changed Political Economy of Reactor Licensing

While the entire nuclear regulatory regime is crucial to the public's concerns about nuclear safety and risk, the CNSC faces some inherent regulatory challenges, particularly regarding nuclear reactor regulatory licensing.

With the transformation of the Atomic Energy Control Board into the CNSC in 2001, nuclear regulation in Canada has moved from a performance-based system to a more compliance-based or detailed command-and-control approach (see Jackson and de la Mothe 2001, 97-98). The latter had also been the preferred approach of the US nuclear regulatory body for decades, and was reinforced by the Three Mile Island and Chernobyl reactor accidents in the 1970s and 1980s. More recently, however, the US regulator has evolved in the direction of greater flexibility.

Under Canada's earlier regulatory system, control was exercised through a dialogue among experts on both sides, but, under new legislation and with its greatly increased staff, the CNSC has become much more prescriptive and document oriented. Interestingly, a study of the isotope crisis, jointly commissioned by AECL and the CNSC,

5 The five bodies are the CNSC; Health Canada's Radiation Protection Bureau; the Canadian Environmental Assessment Agency; Transport Canada (with respect to the transportation of dangerous or irradiated goods); and the Nuclear Waste Management Organization, which was established by federal legislation but is funded by provincial utilities.

6 While long-term waste storage has been a serious regulatory challenge for nuclear energy for some time, a similar challenge is emerging with respect to long-term carbon storage in underground facilities and locations in many different potential locations across Canada.

recommended that more formal documentation, monitoring, and communication protocols be established even as industry forces were pressing for a more timely and efficient licensing system (Talisman International 2008).

The CNSC's main regulatory experience has been with Canadian-made CANDU reactors operated in Canada. Recently, however, the CNSC has been moving toward international standards for reactor regulation that, in principle, are technology neutral (CNSC 2006, 3). Although national requirements are built into the international regime, some CANDU supporters argue for a made-in-Canada regulatory approach (see, for example, Boyd 2007), on the grounds that international standards might be influenced by the regulatory requirements of the internationally dominant LWR and thus work against the CANDU.

The CNSC's licensing process for new reactors proceeds through four stages: environmental assessment, which can take up to three years, and the granting of licences to prepare a site, to construct, and to operate (CNSC 2006, 13). In fact, however, no new reactors have been licensed for some time, and the CNSC does not have any separate licensing processes for the refurbishment of existing reactors. As a result, it is unknown whether international estimates that it takes about ten years for a new nuclear reactor to be assessed, licensed, and put into operation would apply in Canada.

The CNSC's regulatory role focuses pre-eminently on safety and risk assessment, but increasingly also on efficiency in regulatory licensing. This means that the federal government must continue to give it the budgetary and staffing resources it needs to meet these twin mandates. However, the *Nuclear Safety and Control Act* needs to be amended to make these mandates explicit, since the statute currently contains no explicit economic and procedural efficiency clauses.

The Need for Policy Change

Given rising demand for electricity and the need to reduce GHG and other emissions, nuclear power, along with renewable sources and conservation, can be a much more important source of Canada's overall energy supply. Nuclear energy has clear environmental advantages over fossil fuels with respect to GHG emissions and reliability advantages over renewable energy sources in the provision of base load energy. Moreover, increasing calls for carbon storage on the part of fossil fuel industries suggest that the nuclear industry will no longer be alone in having to deal with the long-term health, environmental, and regulatory effects of its wastes. The fulfilling of nuclear energy's promise, however, is highly conditional on the resolution of concerns raised by the public and NGOs about safety, risks, and costs. Although there is uncertainty about the degree to which the adverse environmental effects of both nuclear energy and fossil fuel energy sources are factored into their prices, the Canadian nuclear industry has made a greater effort, mandated by federal policy and regulation, to contain its wastes and to fund its future management than have the fossil fuel energy industries. Policymakers, therefore, should hold these other energy sources to the same standards that exist for nuclear energy, and ensure that the relative levels of environmentally linked costs and subsidization of all these energy sources become a central and explicit feature of energy policy.

At the same time, policymakers should consider seriously the partial privatization of AECL, which would result in the funding, ownership, and partnership structures and capacities that the Canadian nuclear industry needs to compete globally. The alternative is significantly more taxpayer subsidization of and investment in AECL to permit it to embark on new reactor and fuel cycle designs, a renewal of its research capabilities, and the development of export markets. However, whether partial privatization involves the establishment of a new mixed enterprise corporation or the sale of AECL's commercial assets and activity to private owners, the federal government would need to play an ongoing role in maintaining the public good of the R&D functions of the Chalk River laboratory, perhaps as a joint publicly and privately funded national institution.

Finally, regulatory policy needs to be amended to deal systematically with the full multi-agency nuclear regulatory regime and with a range of changing relative risks, not just one regulator or one regulation or one risk at a time. Policymakers need to devise mechanisms to assess changing relative risks and to give a much higher priority to selecting sites for nuclear wastes, which will remain a continuing federal responsibility even if the nuclear industry were to be closed down. Moreover, the legislation governing the Canadian Nuclear Safety Commission CNSC should be amended to ensure that its obligation to provide effective and efficient licensing processes are added explicitly to its core mandate of safety and risk management, especially considering the changed political economy of nuclear reactor regulatory licensing.

In short, Canada's federal and provincial energy policymakers need to cooperate more fully to assure the public, through support of the long-term safety and efficacy of CANDU reactor technology, that nuclear energy is ready and able to take its rightful place in the national energy mix.

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