SASKATCHEWAN IN THE NUCLEAR RENAISSANCE

Richard Florizone

THE PROVINCES
SASKATCHEWAN
LES PROVINCES

Concerns about global warming and increasing energy demands are creating renewed interest in nuclear power. As the world's leading producer of uranium, what should Saskatchewan's role be in this potential "nuclear renaissance"? As Richard Florizone says here, in the near term, opportunities include increasing Saskatchewan's position in uranium exploration and mining, and building on its existing strengths to lead in nuclear R&D — including possibly helping to address the global medical isotope crisis. Generating nuclear power to serve western Canadian electricity markets may also be attractive, although the halting of Ontario's new reactor build suggests that capital costs are a challenge.

Le réchauffement planétaire et la demande croissante d'énergie ont ravivé l'intérêt pour l'énergie nucléaire. En tant que premier producteur mondial d'uranium, quel rôle devrait jouer la Saskatchewan dans cette éventuelle renaissance du nucléaire ?
À court terme, croit Richard Florizone, elle pourrait accroître ses capacités de prospection et d'exploitation minières tout en misant sur ses forces pour prendre la tête de la recherche-développement nucléaire, y compris, possiblement, en aidant à résoudre la crise mondiale des isotopes médicaux. Elle pourrait aussi produire de l'énergie nucléaire pour le marché de l'Ouest canadien, même si la construction interrompue d'un nouveau réacteur en Ontario indique que les coûts d'investissement en seraient très élevés.

The idea of a "nuclear renaissance" has received a lot of press lately. There is indeed a renewed interest in nuclear power, with nations around the world planning for a total of over 200 new reactors in the next decade. This interest is driven by a number of factors including increasing energy demands, concerns about energy security and supply, and the growing urgency around global warming, specifically the need to cut carbon emissions.

Canada is uniquely situated in this new environment. We are one of the highest carbon-emitting countries in the world, and many of our provinces are heavily reliant on fossil fuels for their electricity production. At the same time, our provinces of Ontario and New Brunswick draw a significant portion of their electricity needs from nuclear power. In Atomic Energy of Canada Ltd. (AECL), although its future is the subject of much speculation, we have our own homegrown nuclear technology, the CANDU reactor, which is employed around the world. Moreover, Saskatchewan is currently the world's number one producer of uranium.

Although Saskatchewan has been mining uranium for decades, the decision to move further along the value chain has been the subject of intense, and contentious, political and public debate ever since the first shovel went in the ground. Given a potential nuclear renaissance and our current position as the world's leading producer of uranium, it is time to ask these questions anew: What should be Saskatchewan's uranium strategy and how can we best steward development of these resources? How can we contribute to the world's energy and environmental sustainability, as well as the prosperity and well-being of our province and our nation?

To answer these questions, the Saskatchewan government convened the Uranium Development Partnership (UDP) in the fall of 2008 with a mandate to "identify, evaluate, and make recommendations on Saskatchewan-based value added opportunities to further develop our uranium industry." It is hard to imagine a more difficult and potentially thorny public policy issue.

The way we approached it was threefold. First we convened a panel that could identify and represent the broad range of issues inherent in the question at hand: technical, economic, environmental and social. Our partnership included representatives from industry, academe and affected communities including environmentalists, First Nations and urban and rural municipalities. Second, we enlisted the support of a consulting firm that could extract, challenge and synthesize those views, and compile and analyze the evidence and data. And finally we produced a comprehensive report, with specific recommendations, that could form the basis for public consultation and debate.

The findings of the UDP are that Saskatchewan can and should expand its role across the uranium value chain. But the opportunities to do so are somewhat counterintuitive, with few immediate opportunities for upgrading our raw uranium resources and more opportunity further along the value chain in areas including power production and research and development. More significantly, however, our analysis of each aspect of the value chain produced some key lessons for policy-makers.

In order to extract and summarize those lessons, we need to go step by step through the uranium value chain, as indeed the UDP did in its process. The value chain can be conceptualized in five distinct segments, which extend from the mining of natural uranium through to the management of used fuel from nuclear reactors.

- Exploration and mining includes the discovery, extraction and milling of ore to produce uranium oxide powder (U_3O_8), also known as yellowcake.
- Upgrading is conversion, enrichment and fuel fabrication to turn yellowcake into fuel bundles to be used in a reactor.
- Power generation is the use of controlled fission to generate electricity. Although there are different reactor designs (such as AECL's CANDU), all operate on similar principles of using fission to heat water in a reactor core, which produces steam to drive a turbine and generate electricity.
- Used-fuel management includes the long-term storage of used nuclear fuel, as well as its potential reprocessing to extract further energy and reduce waste.
- Research, development and training spans the entire uranium value chain, with opportunities such as improved mining techniques, new reactor design and the training of operators for nuclear power plants. It also includes medical applications, such as the production and use of medical isotopes, as well as the use of neutron beams for materials science and basic research.

We now turn to each of these steps in the value chain, identifying the lessons for policy-makers and implications for Saskatchewan in each.

In Atomic Energy of Canada Ltd. (AECL), although its future is the subject of much speculation, we have our own homegrown nuclear technology, the CANDU reactor, which is employed around the world. Moreover, Saskatchewan is currently the world's number one producer of uranium.

Jurisdictions with significant natural resources are always looking for opportunities to add value to those resources to fuel economic development. But a key lesson for policymakers from the UDP analysis of uranium mining and exploration in Saskatchewan is this: In your rush to add value, don't forget about your core industries. You can create significant value by addressing the obstacles and opportunities to existing industries, versus growing new ones.

For example, uranium mining has been a good business for Saskatchewan. It contributes approximately 3,000 jobs — 80 percent in the northern regions of the province — and over $200 million in royalties and taxes to the provincial and federal governments. World demand for uranium is strong and growing, with forecasted growth of 80 percent by 2015. This projected growth is due to the expectation that Russia will stop down-blending its stockpiles of highly enriched weapons-grade uranium by 2013, dramatically increasing the demand for "primary" uranium.

Although Saskatchewan is currently the world's number one producer of uranium, we are likely to lose this leadership position to Kazakhstan in the next year or two. To maintain global competitiveness, Saskatchewan needs to review its royalty framework and evaluate its system of exploration incentives. The province should also work with the federal government to establish more efficient regulatory approvals, and to clarify the parameters and accountabilities for the duty to consult with First Nations and Métis communities.

In short, there are a number of steps that could be taken to support a strong and growing industry before looking at further value added, such as upgrading.

Given that Saskatchewan is the global leader in uranium mining, the natural assumption is that there is an opportunity to "add value" to our exports through upgrading. However, policy-makers, like anyone else, can't escape economic realities.

For each step in the value chain, the UDP asked the tough economic questions at the outset: Is there an attractive market, and do we have a sustainable advantage to compete in that market? In the case of the potential for upgrading uranium in Saskatchewan, the short and somewhat surprising answer is no — at least not in the immediate future.

Conversion and fuel fabrication markets are oversupplied today and we project they will continue to be through 2020. Enrichment presents a somewhat different story. New supply is potentially required to meet demand in the next decade. Enrichment is also undergoing a technological shift, with newer centrifuge plants being built and laser enrichment technology on the horizon. Entering the enrichment sector would present significant challenges for Saskatchewan, including the requirement for Canada to receive approval from the Nuclear Suppliers Group to become an enriching nation.

In summary, the UDP recommended that Saskatchewan should not proactively pursue conversion or fuel fabrication given current market conditions. However, Saskatchewan should enter into discussions with the federal government and with the next generation of enrichment technology developers to determine the conditions under which a commercial-scale enrichment facility could be attractive to the province within 10 to 15 years.

While the idea of upgrading uranium was a driving force behind the formation of the UDP and its mandate, a focus on economic realities produced a very different policy recommendation than anticipated. The cold hard truths of economics can also help illuminate the heated debate on power generation.

Governments around the world are going to face increasingly difficult decisions on electricity generation. Concerns over carbon emissions are creating pressures to phase out the use of fossil fuels. The lesson for policy-makers from the UDP study of power generation is that, contrary to what others might say, there is no single technology or "silver bullet" to fill the gap.

Of all the opportunities considered by the UDP, nuclear power generation has generated the most controversy. Nevertheless, the fact remains that Saskatchewan will require significant new generating capacity in the next decade. We will likely need an additional 1,200 to 1,750 megawatts, which represents over half of our current generating capacity.

Saskatchewan is presently among the most coal-dependent provinces in Canada: 45 percent of Saskatchewan's installed capacity is generated by coal, the most CO_2-intensive power source available. Not only is this environmentally undesirable, but with the imminent advent of carbon pricing it is also becoming less economically desirable. However, all of the available electricity-generating alternatives present a different set of advantages and disadvantages.

In Saskatchewan, as elsewhere, hydroelectricity is economical but has its own environmental and social impacts and, as in most jurisdictions, the prime sites have already been developed. Non-hydro renewable energy sources, like solar and wind, enjoy great public support, but with current technology they cannot economically provide significant amounts of baseload power — that is, reliable power that generally runs at all times. Like renewables, nuclear power is low-carbon and can also provide baseload power (figure 1). Furthermore, assuming capital costs of $3,850 per kilowatt and carbon pricing estimated in the range of $20 to $30 per tonne, nuclear is also cost competitive with coal and gas (figure 2). In short, there is a set of circumstances under which nuclear power can make good environmental and economic sense.

The halting of Ontario's new reactor build, however, suggests that capital costs may be a challenge. If the industry cannot deliver capital costs in the range of $4,000 per kilowatt, the nuclear renaissance may be short-lived. Furthermore, despite an impressive safety record relative to competing technologies (figure 3), some remain cautious in their consideration of nuclear power, particularly in jurisdictions where it doesn't already exist. An emerging challenge for new nuclear projects is the recent drop in natural gas prices, spurred by the global economic downturn. If gas prices persist below US$5 per million BTU, as figure 2 shows, nuclear power would have difficulty competing economically with gas — even if carbon pricing significantly increased beyond $30 per tonne. With gas prices low, it will be difficult for jurisdictions to resist the temptation to build more gas-powered electricity generating capacity — the greenhouse gas footprint of gas is better than that of coal, but significantly worse than that of nuclear power (see figure 1).

The solution for Saskatchewan, as for most other jurisdictions, will likely include a diverse portfolio: expanding hydro where possible, pursuing clean coal and carbon capture, investing in further development of wind and solar potential, and building new nuclear generation capacity where it is feasible and there is public support. The UDP concluded that including nuclear power in Saskatchewan's energy mix is indeed a good option and deserves further consideration. These considerations should include identifying and addressing social acceptance, but also further analyzing technical and economic issues such as the potential for export to Alberta and the need for infrastructure upgrades. Finally, a full environmental assessment would need to be completed before any nuclear power plant could be built.

Although Saskatchewan is currently the world's number one producer of uranium, we are likely to lose this leadership position to Kazakhstan in the next year or two. To maintain global competitiveness, Saskatchewan needs to review its royalty framework and evaluate its system of exploration incentives.

Along with power generation, waste management is a segment of the uranium value chain about which the public remains the most wary and skeptical. The examples of other jurisdictions provide the clear lesson for policy-makers that social acceptance is key to the successful implementation of technology policy. Solutions that rely on overly top-down approaches can lead to some phenomenally expensive failures.

The whole history of repositories for used fuel demonstrates this point. In the United States, the selection of the Yucca Mountain repository was driven by the US Congress. Local opposition to the project continues to be strong, and it now appears that Yucca Mountain will not proceed after many years and billions of dollars of investment. In contrast to the US, Finland actively engaged stakeholders and gave local community councils veto rights throughout the process. The local council in Olkiluoto, Finland, ultimately voted 20-7 in favour of the facility, and the development of the full-scale repository is under way with a target commissioning date of 2020.

Used nuclear fuel is hazardous to humans and the environment, and needs to be safely and securely contained. However, the amount of used fuel produced to generate large amounts of electricity is relatively small. Canada's *total* inventory of used fuel from all operating and decommissioned reactors to date would fill five hockey rinks to approximately the top of the boards.

Canada's approach to used-fuel management is governed by the Nuclear Waste Management Organization (NWMO), which ensures that the costs of long-term used-fuel management will be fully funded by the owners of the used fuel. The NWMO has proposed development of a centralized deep geological repository and is now beginning a site selection process.

Given its favourable geology and current participation in the nuclear fuel cycle, Saskatchewan is one of four provinces the NWMO has identified as a potential host of the Canadian long-term repository. The potential benefits to the province of hosting such a repository would be significant, including early benefits from research and development, peak employment (4,000 to 6,000 direct and indirect jobs) during construction, sustained employment (about 900 jobs) during operations and monitoring, and approximately $2.4 billion in discounted cumulative GDP impact.

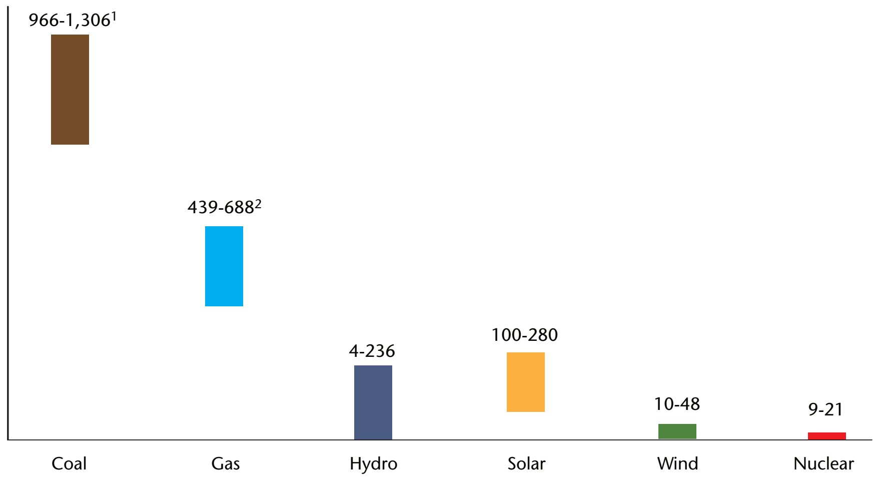
Although the geology and economics are potentially attractive, past experience in other jurisdictions has shown that acceptance of a local host community is the most important factor for the successful siting of a repository in a geologically suitable location. In light of these observations, the UDP recommended that Saskatchewan support the NWMO consultation and siting process, while maintaining flexibility with regard to its ultimate participation. And most importantly, it should support any willing host community that comes forward through this process.

Even with strong technical and economic rationale behind them, complex technology policy initiatives such as used-fuel management risk failure without a broad public mandate and strong local support. But as we will see in the next stage of the value chain, research and development, an initiative with a strong social need and public support can appear to have a weak business case when viewed through a narrow economic lens.

Canada's critical role in the global medical isotope market has been highlighted during recent shutdowns of the NRU reactor at Chalk River. Indeed, in June 2009, Natural Resources Canada called for expressions of interest for new sources of medical isotopes.

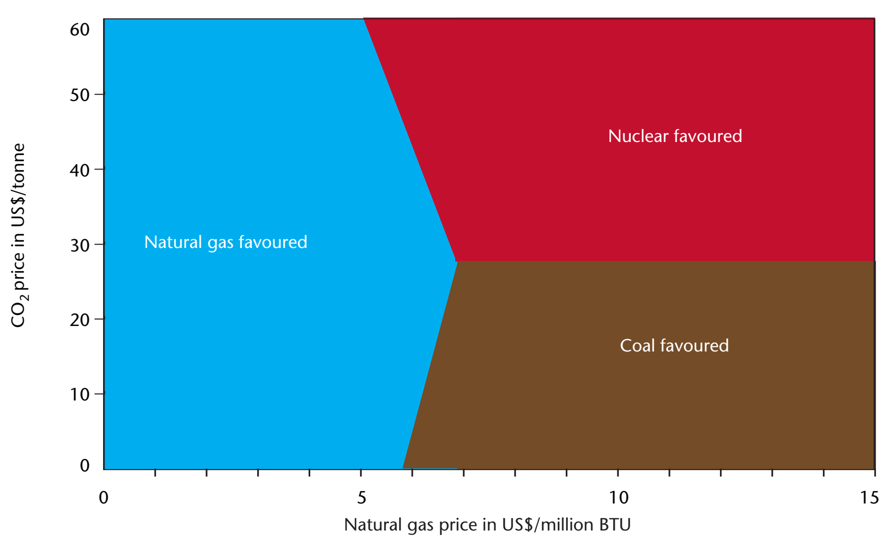
In addition to isotope production, the NRU, which is slated to shut down

FIGURE 1. GREENHOUSE GAS EMISSIONS (GRAMS OF CO_2 EQUIVALENT PER KWH GENERATED)



Source: International Atomic Energy Agency, "Greenhouse Gas Emissions of Electricity Generation Chains," 2000.
[1] Consists of 790-1,017 gCO_2e/kWh direct and 176-289 gCO_2e/kWh indirect.
[2] Consists of 362-575 gCO_2e/kWh direct and 77-113 gCO_2e/kWh indirect.
Note: Life cycle GHG emissions include mining, transportation and processing of fuel; construction and manufacturing of components; and removal and transportation of wastes and by-products.

FIGURE 2. RELATIVE COST COMPETITIVENESS OF VARIOUS POWER GENERATION OPTIONS



Note: Based on $3,850/kW, $2,500/kW and $1,300/kW overnight cost for nuclear, coal and natural gas (combined cycle gas turbine, or CCGT) respectively.
Source: McKinsey Electric Power and Natural Gas Practice levelized unit electricity cost model; Uranium Development Partnership, "Capturing the Full Potential of the Uranium Value Chain in Saskatchewan," March 2009.

permanently in 2016, also enables research and development in nuclear power generation and is a source of neutrons for neutron science. Medical isotopes may be produced in other ways, but if Canada wants to maintain this other research and development associated with the NRU, the country will likely need one or more new research reactors.

Real success arises from technology policy that is technically feasible, economically attractive, environmentally positive and socially acceptable. This is challenging to achieve, but history suggests that it is possible. A prime example is the way North America came together to fight acid rain in the last two decades.

Prior to this, the UDP recommended that Saskatchewan would be an attractive location for a replacement to the NRU. The UDP analysis also showed that the business case for isotope production alone can justify only a fraction of the cost of a new reactor. The Saskatchewan government, the University of Saskatchewan and their collaborators therefore together submitted a proposal to the government of Canada for a new world-class research facility to meet Canada's medical isotope and research needs: the Canadian Neutron Source (CNS). The CNS would be a research reactor optimized to serve two purposes: the supply of medical isotopes and the delivery of neutron beams for neutron science.

Saskatchewan has a history and an existing base of nuclear research and development upon which it can build. In 1948, the University of Saskatchewan built the first betatron facility in Canada, and in 1951 the use of cobalt-60 in treating cancer was pioneered by a University of Saskatchewan research team in collaboration with AECL. Today Saskatchewan's nuclear-related R&D capabilities include the Canadian Light Source (CLS) synchrotron and a Slowpoke II reactor.

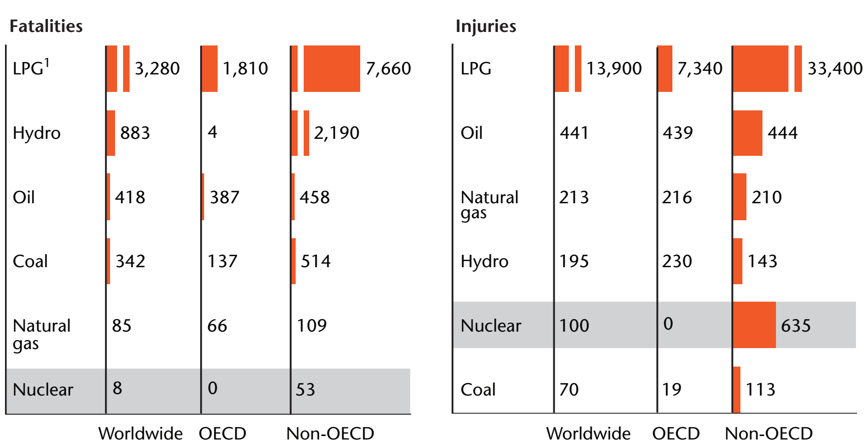
The CLS — which uses photons to study materials — is highly synergistic with a neutron source, which uses neutrons to conduct complementary research. These synergies enhance research through collaboration, but can also deliver financial and operational savings through shared infrastructure and support services. Indeed, the United States, United Kingdom, France, Switzerland and now Sweden have recognized the value of these synergies by co-locating their neutron sources next to their synchrotrons. Furthermore, in successfully delivering the CLS — the largest Canadian science project in a generation — Saskatchewan and the U of S have demonstrated the skills and track record to make a complex project an international success. Additionally, pending the completion of public consultation, the government of Saskatchewan would consider a major financial investment in establishing the CNS.

If Canada wants a new isotope and research reactor, Saskatchewan could be a great place to build it.

Real success arises from technology policy that is technically feasible, economically attractive, environmentally positive and socially acceptable. This is challenging to achieve, but history suggests that it is possible. A prime example is the way North America came together to fight acid rain in the last two decades. The response included the implementation of a cap-and-trade system in the United States that mitigated a very significant environmental problem crossing state and national boundaries, employing a technically and economically efficient solution. A contrasting example is corn-based ethanol, which enjoyed strong social and political support, but which many have argued is, in fact, energy inefficient and has resulted in distortion in global food prices.

The report of the UDP provides specific recommendations for the development of the nuclear industry in Saskatchewan. But the central lesson is this: the successful implementation of technology policy requires the balancing of four factors — technical, economic, environmental and social. Ignore any one of these factors at your peril. Allow one or more to trump the others and you will fail.

FIGURE 3. SEVERE ACCIDENTS AT POWER GENERATION FACILITIES IN OECD AND NON-OECD COUNTRIES (PER TERAWATT YEAR)



Source: "Severe Accident Analysis for Large Energy Systems." Paul Scherrer Institut, 1998.
[1] LPG = liquefied petroleum gases.

Richard Florizone is vice-president (finance and resources) at the University of Saskatchewan, and a policy fellow in the Johnson-Shoyama School of Public Policy. He is past chair of the Uranium Development Partnership and holds a Ph.D. in nuclear physics from MIT.