Assessing the Business Case for the National Research Universal Reactor (NRU):

The Strategic Context

Canadian Nuclear Association

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Contents

1. OUR MESSAGE

An advanced engineering and manufacturing economy – particularly one that values national autonomy and security – derives good value from having a nuclear research capability. The core of such a capability is a research reactor. Canada's government must evaluate the ongoing operation of the NRU in the context of the country's economic structure and global influence. The discussion around whether or not Canada will have a national research reactor affects Canada's status as an advanced economy and a diplomatic power for the indefinite future.

Industry is far from the only beneficiary of the NRU or of the Atomic Energy of Canada Limited (AECL) nuclear laboratories. These facilities also benefit the federal government, Canadian society, and our international partners.

If we believe that private sector business can make better resource management decisions, we must give the GoCo the opportunity to assess for itself the value of NRU's continued operation.

At the same time, industry understands that the government is reluctant to undertake any commitment to continued or future NRU operations. Such a commitment would require: (a) a clear and acceptable rationale for doing so; (b) assurance that any government funding would be limited in amount and with limited additional financial liability to the government; (c) a role for industry, including the development of a business case for an industry-driven innovation agenda.

Decisions have not yet been taken by the government on whether the government-owned, contractor-operated (GoCo) procurement process would involve operating, and/or possible future investment in, the NRU. If we believe that private sector business can make better management decisions, we must give the GoCo the opportunity to assess for itself the value of NRU's continued operation.

While we believe that the gap between total post-2016 operating costs and what industry will pay can be made predictable and reasonably low, in our view there will be a gap (or "delta") and it must be compared with the overall benefits – strategic, security, economic, diplomatic – of having a national nuclear research capability. Industry is willing to work with others to assess options for Canada's future in nuclear research and to develop a realistic plan. We are prepared to pay our share on a cost-recovery basis. But we do not represent all of the stakeholders in Canada's future. Industry alone cannot capture, nor finance, the full strategic value of a national research reactor, in any country. Industry is willing to play its role but it cannot support such an institution by itself.

Industry is subjecting its role in funding NRU to serious analysis. At the same time, clarifying or changing that role likely requires the government-owned, contractor-operated (GoCo) process to advance further than it has to date. Industry is looking forward to discussing all possibilities with the Site Operator, including those requiring NRU access and availability, once the procurement process is decided.

This submission is an attempt to identify elements of strategic value and advantage that are gained for Canada, at home and abroad, via a robust nuclear R&D infrastructure with the NRU (or a replacement research reactor) as its core.

2. THE STRATEGIC VALUE OF THE NRU

Canada has been, and still is, a leader in nuclear technology.

This leadership has given us strategic advantage in a number of areas befitting an advanced manufacturing and engineering economy. Some areas are more obvious to the eye, such as CANDU nuclear technology. Applications extend deeply into medicine, other life sciences, and materials sciences in fields such as automotive and aerospace. Other advantages of our leadership are less obvious, yet are still of strategic value to Canada, such as our influence in global security issues. Both the obvious and less obvious share one thing, however: the National Research Universal reactor – the NRU – as a core asset behind this advantage.

What is this strategic advantage?

It is best looked at from the perspective of shifting geo-political and security realities which confront Canada today but which will pose even greater challenge in the years ahead. These realities are related directly to Canada's status as an advanced economy in the twenty-first century and to our national security. They reflect trends in the acquisition of nuclear technology, especially in Asia, and in the manipulation of energy supplies for political purposes.

The NRU is a high-capability research reactor that is the core element in a Canada-wide nuclear research and development infrastructure. It underpins the CANDU reactor technology and many life-enhancing applications outside of power generation, for the betterment of Canada and Canadians, such as medicine, crop science, and food safety. But the NRU also has a role, practically as well as symbolically, for the success of Canada's foreign policy, national security, and global markets action plan.

Canada owns the CANDU reactor technology that is currently used by seven countries. We have recognized expertise in all areas of the nuclear fuel cycle, from the mining and milling of uranium to the fabrication of advanced fuels to decommissioning and waste management. We bring high safety and security norms to the world. We have a proliferation-resistant reactor design based on natural uranium, not enriched fuel.

China can be expected to exploit dependency relationships. On which end of such dependency relationships do we want to find ourselves for the rest of the twenty-first century?

What does that get us? More than just royalties from our intellectual property, but also a place at the table. National security. Independence. Influence.

We have influence in international negotiations on nuclear non-proliferation, safety and security – because we own an impressive nuclear technology, underpinned by key strategic assets such as the NRU. This allows Canada to promote non-proliferation and other national security objectives in our foreign policy.

The trend lines are becoming clearer. Asian powers are embarking on indigenous nuclear technology development. China will soon be exporting its own nuclear reactors, based on U.S. design and technology transfers. China will eventually gain an upper hand in global nuclear energy diplomacy – and if more countries in the world rely on its nuclear technologies than on those from the U.S., France or Canada, then China will use that to its strategic advantage.

The question we must ask ourselves is: do we, Canada, want to stay the owner of this strategic energy asset that our nuclear technology gives us? Or will we only be a buyer of a few applications?

Without the NRU or a similar large research reactor, we send the world a signal that Canada's nuclear industry is in decline. We reduce our ability to control the sensitive materials or impose conditions on buyers that protect Canada's non-proliferation interests. As a second- rather than first-tier nuclear country, our ability to influence behaviours that challenge our safety and security would be lessened, our voice and impact less noticed.

The NRU is an essential component of a federal nuclear research laboratory. Every country with a nuclear energy program based on its own technology – as Canada has – has a federal laboratory. Few government-owned, contractor-operated (GoCo) models for operating national nuclear laboratories function without a research reactor.

Now, when the world is being reordered by emerging economic powers, is no time to signal our retreat.

Rather, our partners – and they are many – want signals that Canada is in the game to stay.

Shutting down the NRU would weaken the strategic advantage our nuclear technology gives us – an advantage that cannot be regained later.

Canada gains other strategic advantages from NRU:

Canada's energy advantage at home – The NRU supports operating power reactors in Canada, particularly in life extension. It provides the special conditions that allow testing, experimentation and problem-solving, essential in dealing with aging reactor components. High radioactive environments are necessary to replicate reactor conditions. The NRU provides these, but not just for Canadian-based CANDU reactors.

Key bilateral relations and energy partnerships – Six countries (China, India, South Korea, Romania, Argentina, Pakistan) use Canadian nuclear technology and have invested in it. They too are looking to life extensions to their Canadian reactors and in some cases are contemplating additional purchases. Should the NRU be shut down, they will assuredly raise strong concerns with the government, given their considerable long-term investments in our technology. It would be a signal of Canada's retreat from the nuclear energy market. Our reliability as a technology and investment partner would be less credible. Bilateral relations with these CANDU-owning countries would suffer.

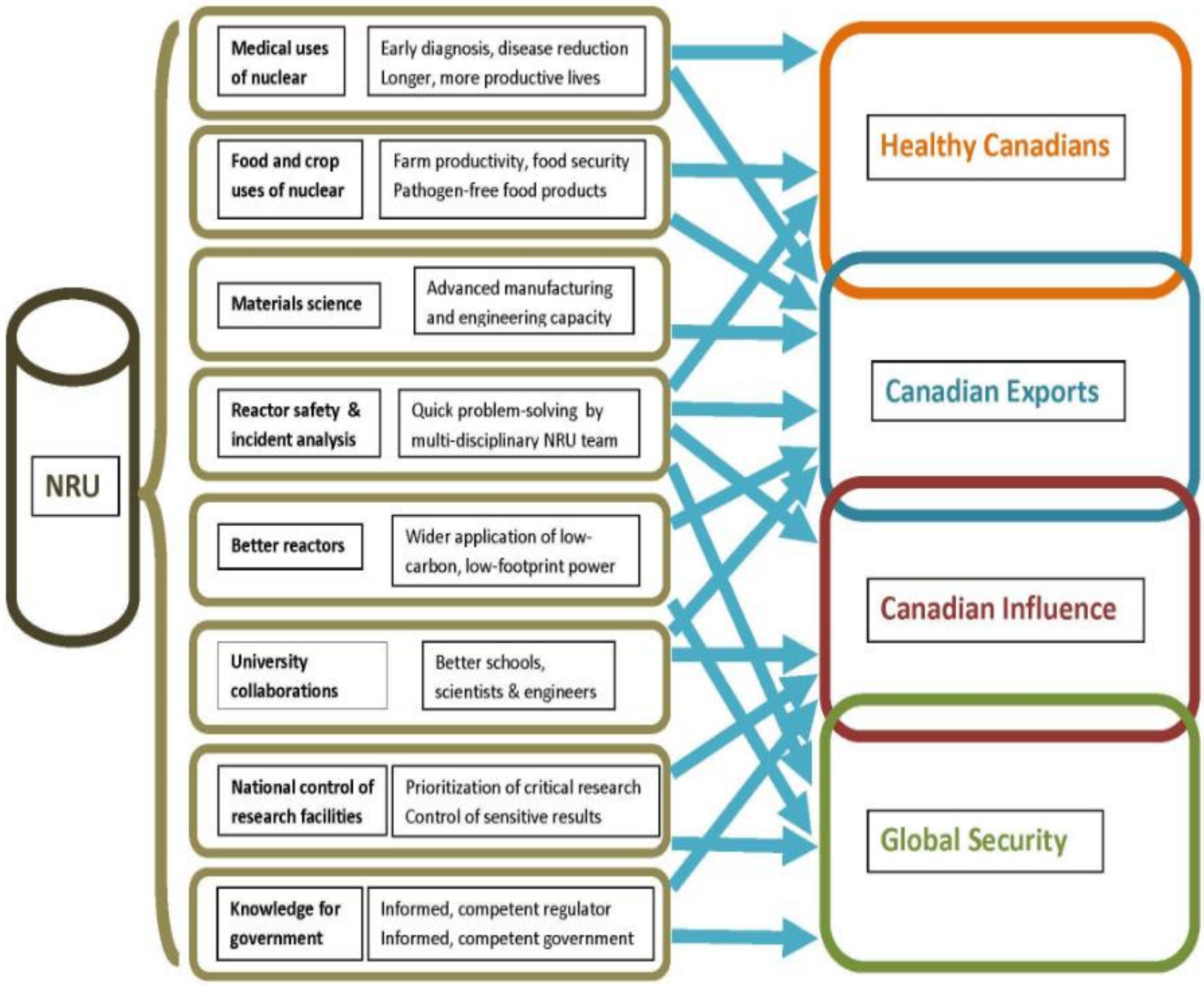
Strengthening nuclear security – More proliferation-resistant reactor fuels are currently under development in Canada with NRU support. Such fuels will strengthen nuclear security in Canada and elsewhere.

Increased safety – Nuclear safety is in Canada's national interest, whether at home or abroad. Canada is at the forefront of efforts to push safety standards higher and higher, thereby reducing the risk of nuclear accidents. The NRU has facilitated the design, testing and quality assurances needed for safety advances to move from concept to use. The NRU also enables a multi-disciplinary team that, when needed, can urgently analyze complex issues in reactor operations. As long as reactors are operating in Canada, whether or not utilities regularly use it for safety-related research, NRU enables a capacity for urgent problem analysis that provides Canadians with a valuable safety resource.

Reducing greenhouse gas (GHG) emissions – Nuclear energy produces very low GHG emissions. Canada's nuclear power plants make a significant contribution to reducing carbon emissions and off-sets those of other Canadian resources sectors. What is more, this form of energy keeps our air clean (an estimated 89 million tonnes of CO_2 <u>not</u> released into the atmosphere annually).

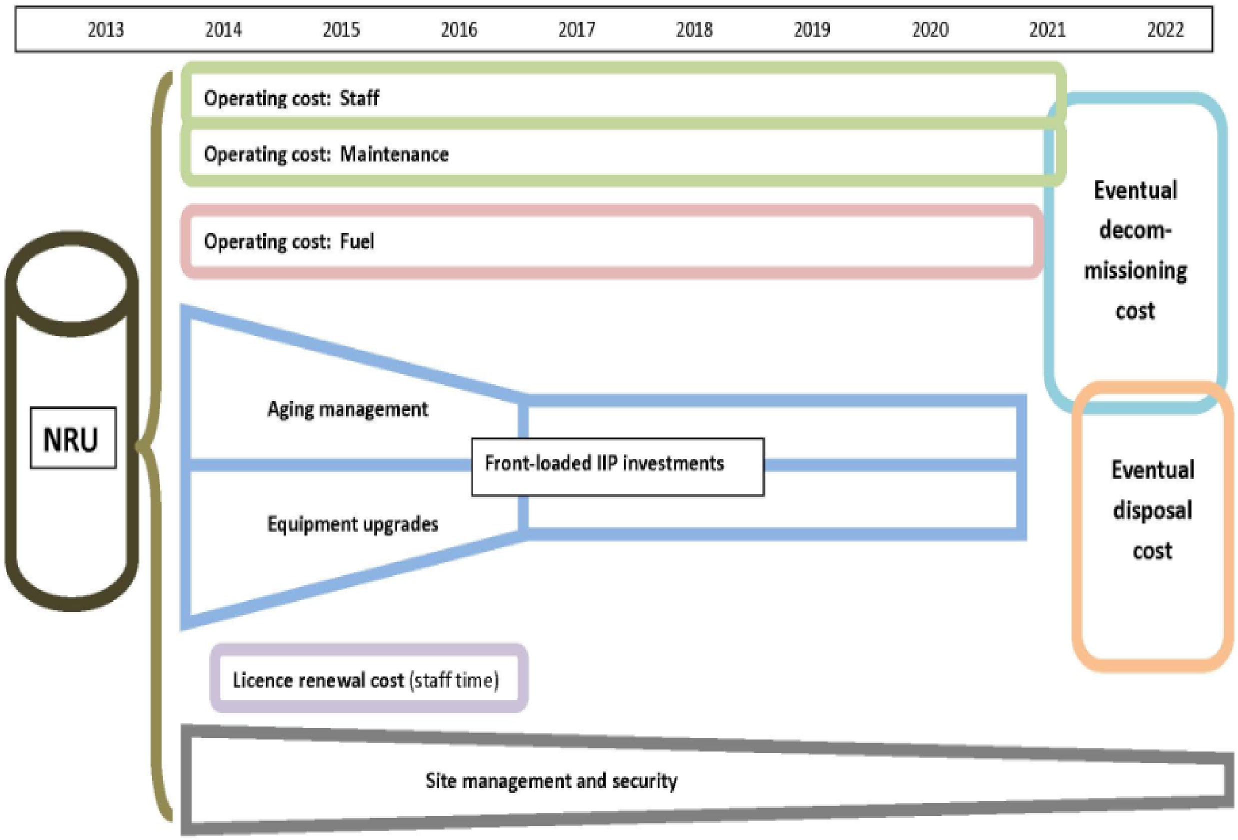
Global market opportunities – The strategic advantage of Canada's nuclear R&D infrastructure could be leveraged in new nuclear energy markets. All forecasts show burgeoning demand for energy and electricity in the developing world, especially in India and China, two huge market opportunities for those with technology and resources such as Canada.

The alternative to nuclear energy is other forms of electricity generation – the most available and cheapest being fossil fuels. The environmental impact of this will be huge, with soaring GHG emissions and air pollution (as China is now realizing). Canadian technology is already mitigating this impact. Moreover, that technology, plus the extremely ambitious targets set by China and India for building new power plants, will create and consolidate long-term additional demand for Western Canada's uranium, helping to support uranium prices.



Graphic: An illustration of NRU's benefits to Canada

Highly qualified personnel in the knowledge economy – The NRU is a strategic training infrastructure. It develops the human capital Canada needs to maintain its international credibility on nuclear energy, non-proliferation, safety and security policies. This expertise includes having the means to regulate nuclear activities and provide for the safety and security of our citizens.



Graphic: An illustration of NRU's cost structure

Canadian influence in key international organizations – A quick look at the top personnel in international nuclear organizations (e.g. IAEA, WNA, WANO) shows Canadians in key positions. How did they get there? Because of their skill, knowledge, practical experience, and credibility. Without the high-level reputation of the research establishment of which NRU is the anchor, this influence would be lessened on topics of importance to our national security, whether it concerns non-proliferation and Iran, nuclear safety after Fukushima, or securing nuclear sources worldwide from terrorist and criminal elements.

Weakening Canada's power to lead on these issues would be a strategic mistake.

3. THE NRU IS SAFE TO RE-LICENSE

The NRU has come a long way since the shutdowns of 2007 and 2009. An Integrated Safety Review (ISR) of NRU was completed in 2010 and accepted by the CNSC. A 10-year Integrated Implementation Plan (IIP) to address ISR findings became the basis for licence renewal in 2011.

IIP activities are heavily front-end loaded, with most deliverables in the first 3 years, meaning much of this effort has been completed or is in progress as of 2014. NRU's future operating risks are being addressed by completing these activities, and safety has been enhanced. Importantly for the Government of Canada, this adds confidence to estimates of the cost of future operations.

AECL joined the World Association of Nuclear Operators (WANO) in 2011 and is leveraging WANO expertise and support to drive improvements to meet the nuclear industry's benchmarks for operational excellence. Review by an expert third party (such as WANO) can be used to verify that activities at a reactor are meeting best industry practice, and such verification would help provide assurance to the Canadian government of the reactor's fitness going forward.

The Isotope Supply Reliability Program (ISRP) has been the source of IIP funding for 2011-2016. AECL has a provision for IIP funding for 2016-2021 in its 2014-15 Corporate Plan. IIP execution is on schedule. Execution is subjected to regular review by the CNSC. Successful execution will be a critical determinant for licence renewal. There have been no findings that would suggest a marked decline in licenseability (a "cliff edge" for licence renewal) beyond 2016.

NRU is conducting life extension work similar to that recently performed at nuclear power plants in Ontario and New Brunswick, including condition assessments. The integrated implementation plan (IIP) was written and accepted by the CNSC as part of NRU's licence renewal in 2011. The IIP is a 10-year plan, and NRU management has been meeting deliverables.

4. RISKS TO CANADA IN CLOSING THE NRU

To illustrate what industry believes are real-world risks to Canada in ending NRU operations, this section sketches out some of the possible impacts. The purpose is not to suggest that all of these will happen, but rather to clarify for the reader how we see some actual repercussions playing out in the international context.

Canada is perceived internationally to be losing its advanced engineering and manufacturing capacity, and thus retreating from advanced-economy, G7 status.

The Government of Canada loses a strategic asset that underpins its international security policies in the areas of nuclear non-proliferation, nuclear safety and nuclear security. We retreat from first-tier to second-tier nuclear country status.

Canada loses a core element of its energy self-sufficiency and independence, because the NRU is essential to CANDU reactor technology, which Canada owns. A major means for reducing Canada's overall GHG emissions – and a potential means for producing GHG-free power to the oil sands industry – is compromised by reducing or preventing growth in Canada's nuclear power production. To the extent that a nuclear power industry survives, leadership and ownership may be ceded to non-Canadians. Royalty revenues from the use of our technology may be indefinitely foregone.

A key objective of the Government's AECL restructuring policy – to strengthen Canada's nuclear industry through innovation and commercialization – is difficult to achieve without a national research reactor.

The safety of Canadians is reduced without the NRU research and testing facilities, as the NRU and its connections to multi-disciplinary engineering and scientific resources are no longer available to utilities for investigating complex reactor problems under emergency circumstances.

Anticipating the end of NRU's operating licence, highly qualified personnel increasingly quit Chalk River in 2014-15, dropping the NRU's staff below the minimum complement required. This accelerates NRU's closure, ending isotope production capacity earlier than expected.

A key objective of the Government's AECL restructuring policy – to strengthen Canada's nuclear industry through innovation and commercialization – is difficult to achieve without a national research reactor.

In the absence of NRU support, Canada's nuclear supply chain clusters and knowledge skills are eroded when they are needed for licensing, commissioning, operation, refurbishment and decommissioning of nuclear facilities. Highly qualified jobs and skills are lost with a declining nuclear industry, thereby reducing the productivity gains on which income growth is based.

Canada loses some of its capability to address growing international challenges through nuclear technology applications – such as desalination, medical diagnostics and treatment for cancer, maternal and child health in developing countries, and finding desert aquifers.

Without the NRU, the strategic objectives of the Government's Global Markets Action Plan – to secure access for Canadian industries abroad – are less attainable and opportunities are lost in the growing new nuclear energy markets.

Major commercial opportunities are missed, notably in the UK, China and India, since Canada loses much of its capacity to test MOX or thorium fuels. The promise of the 2013 Canada-India Nuclear Cooperation Agreement goes unfulfilled. International customers, who expect their international nuclear partners to have long-term research capabilities and sustained government backing, no longer believe that Canadian partners in nuclear technology meet this requirement.

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5. THE FEDERAL GOVERNMENT'S CHALLENGE

In the ongoing AECL restructuring process, the federal government must decide whether or not the Site Operator will run the NRU and who would fund such operations. Putting the NRU on a track to shut down before the Site Operator takes over must reduce the value of the operator's role -- by precluding a large and important set of options associated with NRU's continued operation.

If the NRU continues to operate (or is replaced) then the Government of Canada will presumably have a funding role. The magnitude of funding will be determined by the business case for NRU operations following the end of Molybdenum-99 isotope production in or around 2016.

The U.S. Department of Energy laboratories provide successful examples, including the Oak Ridge, Sandia and Idaho National Laboratories. At the INL, for example, the operating contractor (Battelle) is incentivized to find other sources of funding than the government. It uses entrepreneurial talents to find additional revenue streams, and management expertise to reduce operating costs.

> *Putting the NRU on a track to shut down before the Site Operator takes over must reduce the value of the operator's role -- by precluding a large and important set of options associated with NRU's continued operation.*

Even so, national research reactors are generally not self-financing. It is unlikely that current and foreseeable revenue streams from NRU operations and commercialization of research performed on the NRU will fully cover operating costs. Therefore, there will be a "delta" between operating cost share and real/anticipated revenue streams.

The government's concern is to ensure that its operating cost share (the delta) has guaranteed limits, both in funding dollars and financial liability. Any agreed cost-share formula must have such assurances ironclad.

The value of the delta must be assessed from a strategic, as well as a risk-based perspective, and must include non-market benefits. The delta value may be seen as both manageable and justified when such important measures as the role and contribution of Canada's nuclear technology and industry to Canada's wider economic and international interests are taken into account.

If they are taken into account, then there is a public policy rationale for funding support of the NRU – a rationale best situated in a national nuclear strategy.

GoCo timeline		NRU timeline
May : Consult with qualified respondents **Fall :** RFP release	2014	**Government engaged in considering Nuclear Innovation Agenda** **March :** AECL applies to CNSC for 1-year extension of Licence Condition 16.3 **June 30 :** Deadline for Licence Condition 16.3 (AECL to submit post-2016 plan for NRU – whether continued operation or shutdown)
Spring : Select preferred bidder	First half 2015	**June 30 :** AECL's proposed new deadline for Licence Condition 16.3
Summer/fall : Finalize contract GoCo takes over operations just a few months after AECL has submitted post-2016 plan for NRU	Second half 2015	
GoCo forced to end NRU operations OR If NRU relicensing has occurred and operations continue, GoCo has up to 4 years to evaluate NRU, while still retaining option to end operations before 2021	2016	**October 31:** Current end of operating licence
	2019-2020	Decisions on future NRU operation
	2021	**October 31 :** End of extended operating licence (if extended from 2016 to 2021)

6. THE WAY FORWARD

Here is industry's view of a viable, cost-controlled path forward for NRU.

1. Continue and complete the GoCo procurement process, having clarified that the successful bidder will have the opportunity to consider future business potential of the NRU. This raises the value of the GoCo opportunity (versus the alternative: presenting the successful bidder with a NRU that is on track to close down).

2. Consider engaging an independent third party to verify the condition of the NRU and its fitness for continued operation through 2021, so as to increase confidence in the projected costs of that operation.

3. Set conditions for enhanced revenue streams from NRU under the new operator.

4. Re-licence the NRU to 2021. The condition of the asset is well understood by CNSC and stakeholders, having been upgraded by investments made since 2010. This five-year investment program was front-loaded (concentrated in 2010-13). The safety case is made and future operating risks are being addressed by these expenditures. Third party verification (see step 2) can help confirm this.

5. Undertake a pilot program for 3 years following the GoCo procurement decision, under which the new Site Operator can take detailed stock of the CRL facilities and their operational potential, including the potential for continued NRU operations as part of the SO's commitment.

6. Ensure through contractual means that any financial commitments or liabilities on the part of the government associated with operating the NRU during the pilot program are strictly limited.

7. Ensure openness in principle to medical and industrial isotope production at CRL by non-government entities using the NRU, keeping in mind that the NRU produces not only Moly-99 but also a number of other isotopes: http://www.aecl.ca/en/home/facilities-and-expertise/nru/isotopes.aspx

8. Provide continued capabilities to utilities, on a cost-recovery basis, during the GoCo transition period and beyond.

9. Consider making the case to Ontario (with due sensitivity to the role of the provincially owned power utility) that that province should partner in supporting NRU operations, because of the importance of the nuclear industry cluster to the province, both as a source of durable, high-skilled jobs and engineering, and as the source of more than half of the province's electric power supply.

7. A NUCLEAR SCIENCE STRATEGY FOR CANADA

A degree of energy independence – or a relative absence of dependence on too small a number of suppliers – gives a country, an economy, strategic security. Recent events in Russia and Ukraine show how these relationships, if imbalanced, can be used.

The distribution of power in the world is shifting, led in part by the ownership of, and demand for, energy resources and technologies. Both of these are moving inexorably away from the G7 countries toward faster-growing regions. With that comes increasing economic power and geo-political clout.

While oil and gas developments currently favour North America, especially the shale revolution in the U.S., the energy technology accumulation by China and India will grow. Politically they will find supporters in countries such as Brazil, South Africa, Iran, Russia, and Indonesia.

How do we counter or at least protect ourselves from disadvantage or dependencies from this shift? Our international reputation as a nuclear nation and as an advanced G7 economy is an asset built through decades of investment and performance. Now, when the world economy is being reordered by emerging economic powers, is no time to depreciate that asset and signal our retreat. Rather, our partners – and they are many – want signals that Canada is in the game to stay.

A Canadian nuclear science strategy would consolidate the roles of the GoCo, the federal nuclear R&D infrastructure and the nuclear industry in obtaining advantage and benefits for Canada. It would give direction to the government's policies and action plans, while strengthening our national security.

Nuclear research capabilities are an integral part of an advanced manufacturing and engineering capability in the twenty-first century. If Canada is to remain an advanced economy, quite apart from the question of whether we are to continue to have a nuclear industry, then Canada's scientists, engineers, product designers and manufacturers need access to high-quality, cutting-edge R&D infrastructure.

The NRU provides that an essential element of that infrastructure to the nuclear industry and thus a strategic advantage to Canada and its knowledge economy.

Canada is an influential G7 country in part because it is one of only a relatively few countries with a full spectrum of nuclear technologies.

Within the nuclear industry, power reactor operators, in Canada and abroad, rely on continuous technological improvements and innovations. For safe and reliable operation, they depending on a testing and experimentation environment that only such a research reactor can provide. This capability, in the form of the NRU, benefits both Canadians and our international CANDU-technology partners whether in reliable electric power supply, nuclear security or nuclear safety.

8. NRU: FOUNDATION OF A STRATEGY

A nuclear science strategy does not require federal government funding of all aspects of nuclear science and technology. Nor do nuclear R&D facilities have to be fully operated by the government. A government-owned, contractor-operated model can work effectively, as one finds, for example, at the USA's Idaho National Laboratory: https://inlportal.inl.gov/portal/server.pt/community/about_inl/259 .

However, such a laboratory is not useful or effective without a reactor, particularly for a country with a nuclear energy industry, which Canada will have for decades to come. Most would also argue that a federal nuclear research laboratory must be owned, if not operated, by the federal government. This is largely because of the inherent national interests at stake in the use of nuclear technology, the need for government to be able to prioritize research and maintain confidentiality, and in the conduct of foreign relations -- influencing of others abroad to use nuclear technology accountably.

Even where a GoCo model has been adopted for the federal nuclear laboratories, therefore, a nuclear science strategy is required as a matter of national security and it requires maintaining a research reactor capability owned by the federal government. Federal funding in part of the research reactor's operations would be expected. However, the Site Operator in the GoCo model would also fund these operations from investments and revenues obtained elsewhere. A nuclear science strategy can envisage both the GoCo model and the continued operation of the research reactor (in this case the NRU), along with a reduction and limitation of the government's share of the funding.

The means by which the strategy achieves its twin objectives of continued safe nuclear power in Canada and a greater role for Canadian technology and expertise abroad is innovation, for which the GoCo model plus the NRU should provide a successful framework.

9. THE NRU AND INNOVATION

Innovation involving the NRU is already occurring in a number of key areas, such as *advanced reactor fuels* – a key selling point for CANDU reactors in countries such as the UK and China; and *improved safety margins* – which is a national security imperative for Canada both at home and abroad.

Government clients of the Canadian Neutron Beam Centre are Natural Resources Canada, Defence Research and Development Canada, Transportation Safety Board, National Research Council, AECL, and the Canadian Nuclear Safety Commission.

Innovation is greatly stimulated where there are crucibles or clusters of research and development, even if small, in a specific geographical area. In the nuclear field there are key R&D clusters around Chalk River Laboratories, the Sylvia Fedoruk Centre for Nuclear Innovation in Saskatoon, and southern Ontario.

Together these, plus research facilities at more than a dozen universities, and major scientific facilities such as British Columbia's TRIUMF and Saskatchewan's Canadian Light Source (CLS), make up Canada's "nuclear eco-system". In southern Ontario, the cluster includes engineering, manufacturing and construction companies that build and maintain the infrastructure for nuclear power generation as well as nuclear R&D.

Research and innovation lines stretch out from points in the nuclear eco-system back to the NRU. This is illustrated in the CNA's summary of Groupe Secor's 2011 study on Canada's nuclear science and technology capabilities:
http://www.cna.ca/wp-content/uploads/Building-Partnerships-With-Value.pdf

Thirty-five Canadian universities are clients of the Canadian Neutron Beam Centre at the NRU, along with advanced industrial sectors such as aerospace, automotive, biotechnology, electronics, metal production, mining, oil and gas, and nuclear energy. Government clients are Natural Resources Canada, Defence Research and Development Canada, Transportation Safety Board, National Research Council, AECL, and the Canadian Nuclear Safety Commission.

Researchers come to Chalk River from all over Canada and the world to probe materials with neutron beams to find solutions to challenges in health, industry and science. Leading-edge imaging and analytical research opens the potential for innovative commercial applications.

The NRU is Canada's only major neutron source and only major materials testing reactor. Without the NRU, it is impossible to envisage a robust, industry-driven innovation agenda with applications in the advanced industrial sectors, since the latter rely on neutron beam-scattering facilities.

Thirty-five Canadian universities are clients, along with advanced industrial sectors such as aerospace, automotive, biotechnology, electronics, metal production, mining, oil and gas, and nuclear energy.

10. THE NRU, PRODUCTIVITY AND LIVING STANDARDS

The NRU has contributed to quality of life in Canada in three main ways:

- By supporting electric power supply. Electrification is inextricably linked worldwide to better health, greater longevity, and higher living standards.

- By supporting carbon-free nuclear energy. The use of nuclear power plants in Canada, by displacing fossil fuels, prevents an estimated 89 million tonnes of CO2 being released into the atmosphere annually. See Appendix C for more information.

- By providing materials testing and thereby supporting the use of advanced materials in all kinds of manufacturing and engineering in Canada and in the products and services we export to the world.

The following chain shows the linkages from the materials testing done at the NRU to the current and future living standards of Canadians. It is no exaggeration to say that research infrastructure like the NRU is an integral part of an advanced manufacturing and engineering economy – one that delivers real quality of life to Canadians.

MATERIALS TESTING

"Neutron radiography is a powerful tool for **non-destructive testing of materials** and finds numerous applications in industry and in material research . . . Strong neutron sources like **research reactors** and accelerator-based spallation neutron sources can provide intense neutron beams required for efficient and practical . . . examination of nuclear fuels, explosives, electronic components and engine turbine blades. Recently, neutron imaging has been used in new branches: fuel cell research, the study of objects from cultural heritage, geosciences and soil physics . . . and the real-time analysis of systems including fluid flow and/or moving components. With the advent of portable neutron sources, neutron radiography can also be employed away from reactors, opening up applications like checking for drugs and explosives concealed in luggage and cargo containers. . . . **There are only a few [research reactor centres] which are well developed and have advanced facilities . . .** "
("Neutron Imaging: A Non-Destructive Tool for Materials Testing," International Atomic Energy Agency Tecdoc 1604, 2008)

ADVANCED MATERIALS

"Clients from the **aerospace, automotive, energy and environmental sectors supply a material or fully manufactured part to test**, and NRC researchers use the Chalk River reactor to perform neutron scattering, analyze the diffraction and report the data. Such information helps to project the fatigue life of the part. One of the greatest advantages of the program is that NRC can perform tests **under realistic conditions** including high temperature (up to 2000 ºC), high electric or magnetic fields, high tensile or compressive loads, and during operation in hostile environments. NRC can combine a variety of testing conditions, as required. For example, we can apply a load to a sample while heating it to see how it performs in these conditions." ("Applied Neutron Diffraction for Industry," National Research Council Industry Brief, 2008).

MANUFACTURING INNOVATION

“**Manufacturers need to know the tolerances of new materials before using them** to manufacture products - particularly those related to public safety. And the new knowledge we can provide by neutron scattering techniques can also lead to innovative materials or fabrication methods that **enhance competitiveness**.” (“Applied Neutron Diffraction for Industry,” National Research Council Industry Brief, 2008).

“Advanced materials and the manufacturing techniques to make them can give our economy a competitive advantage for job growth. . . . **Materials developments** are invisible to users of technology, but **are at the heart of so many important advances**.” (Materials Research Society)

“A ‘Materials Genome Project” can catalogue the properties of known materials and allow designers to better model potential devices, thus **accelerating product development**.” (“A Manufacturing Renaissance for America?,” Massachusetts Institute of Technology News, 2010).

PRODUCTIVITY GROWTH

Manufacturing is the economic sector that contributes the most to productivity growth. ”Services can propel the economy only so far. **There is no substitute for making tangible, useful products**.” (“A Manufacturing Renaissance for America?,” Massachusetts Institute of Technology News, 2010).

LIVING STANDARDS

Productivity growth is the *only* basis for sustained advances in living standards.

Graphic: How the NRU connects to Canadians’ living standards

11. CAN REPLACEMENT REACTOR SERVICES BE USED?

Other research reactors exist internationally. Some of them provide services to international clients on a customer-supplier basis. Indeed, some Canadian organizations, including AECL, are familiar with this option because they already use these services.

Why could Canadians not become customers of these services if the NRU were decommissioned? The problems would be:

- Reactor size. Among research reactors, the NRU is unusual in being large enough to accommodate fuel experiments. The OECD's Halden research reactor in Norway, for example, can only accommodate one *partial* fuel bundle at a time. Experiments with CANDU reactor fuel would need to be done piecemeal and then assembled by computer model. It is unclear whether regulators would accept this, or whether they would continue to require testing on a complete fuel bundle basis. This testing is important to the viability of the Canadian nuclear supply chain in international markets.

- Complementary experiments. The NRU's size and flexibility makes possible sets of complementary experiments, notably in simulating the aging of materials by exposing them to fast (high energy) neutron beams. While France's Osiris reactor is open to international clients and can do certain experiments of this kind, it cannot do the full range of complementary experiments that is essential to completely model reactor aging.

- Priority of access. The organizations governing reactors outside Canada have closer links to other countries' reactor suppliers and supply chains (and other manufacturing and engineering interests and governments) than they would to Canada's. When choices arose, they would not prioritize Canadian organizations' needs.

- National security. Cases will arise where Canadians want to safeguard knowledge of our nuclear knowledge, research capabilities and lines of inquiry.

12. FUNDING MODELS FOR RESEARCH REACTORS AND LABS

One of the deepest discussions of research funding (and of its national benefits) has taken place in the United States in recent years around federal government funding for advanced computing (e.g. through the Accelerated Strategic Computing Initiative, later called Advanced Simulation and Computing), as part of a mix of government, academic, international, and private funding.

Key conclusions in this discussion can be summarized in this way:

- The labs succeed in their mission, which is to stay ahead of very fast market-driven advances in computing power.

- This in turn keeps the U.S. as a country at the forefront of computing, to the benefit of industries and to national power and prosperity. "ASC has significantly contributed to the advancement of high performance computing technology used by other federal agencies [in addition to Energy and Defense] and some commercial sectors [with] an increasing role in national security (e.g. in nuclear forensics); energy and environmental science (e.g. global climate); and the commercial world (e.g. exploration for natural resources)."[1]

- This success also attracts the best international researchers, and these partners "not only do great science, but leave the facility better for the general user."

- This funding pays off directly to agencies of government (particularly Defense and Energy in the modelling of nuclear phenomena).

- University researchers benefit greatly from the existence of government research, notably because the latter is collaborative and team-based, while university research tends to reward single principal investigators. "Facilities at the [DOE multi-program] labs [e.g. Argonne, Oak Ridge] are viewed as extremely important resources for academics, often providing opportunities to conduct key scientific experiments that cannot be conducted anywhere else."[2]

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[1] Defense Science Board Report on Advanced Computing, 2009.
[2] National Laboratories and Universities: Building New Ways to Work Together. National Academies Press, 2005.

At the USA's Idaho National Lab (INL), the operating contractor (Battelle) is incentivized to find other sources of funding than the federal government and uses entrepreneurial talents to find additional revenue streams and its management expertise to reduce operating costs and find efficiencies. On the other hand, it should be noted that much of what INL identifies as "third party work" is for the military, an income stream that would be very limited for a Canadian facility. Info on the Advanced Test Reactor user facility: https://atrnsuf.inl.gov/documents/ATR%20NSUF%20Fact%20Sheet%20Sept.%202011_web.pdf

Norway's Halden research reactor is funded by a pool of OECD (international) funds for part of its costs. Halden also earns income from bilateral customer-supplier contracts (including with AECL) and receives some funding from the Government of Norway. More info: http://www.ife.no/en/ife/halden/hrp/the-halden-reactor-project?set_language=en

A private entity operating the Chalk River site should not be denied the option of investing capital to continue operation of the NRU, and of receiving the revenue stream from any new activity that such operation allows.

France's Jules Horowitz materials testing reactor is being constructed with 50% of funding from France's national nuclear research body (CEA), 20% from Electricite de France, 10% from Areva and 20% from an international consortium of research institutes. More info: http://www.cad.cea.fr/rjh/index.html

A private entity operating the Chalk River site should not be denied the option of investing capital to continue operation of the NRU, and of receiving the revenue stream from any new activity that such operation allows. The National Research Council might have a potential role in a private-public partnership (P3) model for the NRU. Also, Ontario and/or Saskatchewan could be additional public partners in a P3 funding model.

The Government could consider using its share of the P3 to develop a nuclear Centre of Excellence around the NRU operations (beyond the Canadian Neutron Beam Centre). Such a Centre of Excellence could perform nuclear-related R&D that has clear potential for commercial application.

APPENDIX A: Background on the NRU

The National Research Universal (NRU) reactor is a research reactor that entered service on November 3, 1957 at Chalk River, Ontario. It was built with a power capacity of 200 megawatts thermal (MWth) and for three primary purposes:

- to be a major Canadian facility for neutron physics research;
- to provide engineering support and development work for CANDU power reactors; and
- to supply medical and industrial radioisotopes, of which it has become one of the world's major producers. At the time of its construction, NRU was the largest research reactor in the world, and it is still one of the largest in operation today.

NRU has succeeded in its original mandate, and remains the heart of Canada's nuclear science and technology programme. It was the site of one Nobel Prize for Physics, that of Dr. Bertram Brockhouse in 1994. Thanks in large measure to the work done at NRU, CANDU reactors today are found in Canada, South Korea, China, Argentina, India, Pakistan and Romania. A total of 38 CANDU power reactors have been built and commissioned since 1962, and these reactors continue to lead the world in both electricity production performance and safety of operation.

NRU is the principal technical support for a large number of government and university collaborations on government policy and research programs. It has also been the world's premier producer of medical and industrial radioisotopes.

Appendix B outlines how the Government of Canada depends upon the capabilities of the NRU and Chalk River Labs to support a number of important programme areas.

Safe to 2021

The NRU reactor has already been substantially upgraded prior to 2010 under the NRU Upgrades Project, and since 2010 as a result of the Integrated Safety Review (ISR) and Integrated Implementation Plan (IIP). These investments have increased confidence in estimates of cost of operation to 2021, by materially improving the NRU's fitness to operate for an additional five year period beyond that date.

The following is a general description of the seven major upgrades installed under the NRU Upgrades Project. All the upgrades are required to be seismically-qualified and environmentally-qualified. They are all designed to "modern" codes and standards.

Secondary Trip System: The Secondary Trip System is an independent second trip system that safely shuts down the reactor based on trip units detecting: seismic events, Class 4 power failure, major process water flood, excess neutron power, or excess log rate neutron power. The safety design requirements include separation, redundancy, and signal buffering.

Qualified Emergency Response Centre: The Qualified Emergency Response Centre is an all hazards-qualified alternative location to ensure the reactor can be placed in a stable shutdown state with adequate fuel cooling. It provides initiation and monitoring of all engineered safety features in the event that the main control room is unavailable. It houses equipment used for the other safety upgrades, which are also hazards-qualified, thereby providing separation of these systems from the other process and safety related systems in NRU.

New Emergency Core Cooling: The New Emergency Core Cooling system upgrade ensures that water is automatically made available to the primary cooling pumps of the emergency cooling circuits in the event of a Loss of Coolant Accident. Combined with the Liquid Confinement/ Vented Confinement upgrade, it provides for collection and recirculation of heavy water discharged from a break.

Emergency Power System: The Emergency Power System supplies electrical power independently and separately from the original electrical distribution system, providing Class 1, 2 and 3 electrical power to the upgrades components. It also provides back-up Class 1 power to existing DC motor starters, for emergency cooling Main Heavy Water Pump motors #4 and #5.

Qualified Emergency Water System: The Qualified Emergency Water System incorporates an independent water reservoir and redundant pumping system for post-shutdown heat removal via emergency cooling circuits 4 & 5. The cool qualified emergency water system water is pumped through the secondary sides of the Main Heat Exchangers, absorbing the primary coolant heat load and returning to the reservoir.

Main Pump Flood Protection: The Main Pump Flood Protection is principally a passive system designed to divert water from major leaks in process piping. It ensures the proper operation of the main primary coolant pumps, including the emergency DC drive system, in the event of a major failure of the process water piping within the NRU building. The flood level detectors associated with this system are designed to trip the reactor and trigger an automatic shutdown of all four large process water supply pumps at the powerhouse.

Liquid Confinement/Vented Confinement: The Liquid Confinement/Vented Confinement provides a confinement boundary surrounding the reactor and a variety of rooms in the immediate area. It confines gaseous fission products, tritiated vapor, and released light and heavy water.

APPENDIX B: Government Program Areas Supported

Foreign Affairs: The Department of Foreign Affairs, Trade and Development benefits from subject matter expertise related to nuclear non-proliferation and safeguards, for its mission to the International Atomic Energy Agency (IAEA), and for the Government's participation in the Nuclear Suppliers Group (NSG). Knowledge gained from NRU also supports the Government in the negotiation of bilateral nuclear co-operation agreements, and has supported DFAIT's Global Nuclear Partnership Programme, specifically aimed at co-operating with Russia and Ukraine institutions in securing nuclear sites and materials.

CNSC: Many of the CRL research activities underway inform nuclear regulation. For example, CRL provides key data and experimental evidence that enable industry to respond the needs of the CNSC (e.g. closure of Generic Action Items). CRL also interacts directly with the regulator in areas such as safeguards.

National Defence: Using expertise gained from the NRU, CRL provides technical advice and support to Department of National Defence in areas such as the assessment of the risk of exposure to soldiers exposed to depleted uranium.

Health Canada: Health Canada has collaborated with AECL on a number of projects using the unique CRL Biological Research Facility and provides funding for specific projects. Some of the collaborations are multilateral involving DRDC, Ottawa Heart Institute and Canadian universities including McMaster and RMC. The European Commission supports research at CRL (in which Health Canada also participates) on the effects of low-level radiation as part of a wider European collaborative project. AECL is the only non-European partner that is funded, recognising its unique facilities for biological research.

Others: Public Safety Canada; Canadian Border Services Agency; Royal Canadian Mounted Police; Defence Research and Development Canada.

APPENDIX C: Nuclear Power and Greenhouse Gases (GHGs)

Nuclear energy produces very low greenhouse gas (GHG) emissions. The use of nuclear power plants in Canada, by displacing fossil fuels, prevents an estimated 89 million tonnes of CO_2 being released into the atmosphere annually. This is a great contribution to reducing carbon emissions, offsetting the GHG emissions of other Canadian resource sectors. What is more, the nuclear technology that Canada has provided and supported through the NRU has contributed to reducing GHG emissions worldwide, including in the countries using such technology. It is therefore a strategic asset in Canada's international position with respect to GHG emissions.

The strategic advantage of Canada's nuclear R&D infrastructure could potentially be extended if the opportunities in new nuclear energy markets are taken up. Unless nuclear energy is embraced, other forms of electricity generation will be used – the most available and cheapest being coal. The impact of this on the environment will be huge, with GHG emission and air pollution set to soar (as China is now realizing). Canadian technology could be part of mitigating the severe environmental impact of relentless energy production fuelled by carbon-intensive resources. The potential for this role will expand as carbon emissions become constrained, as they presumably will, by treaties, regulations and the pricing of carbon.

Growth in the world nuclear power industry, manifested for example in the extremely ambitious targets set by China and India for building new power plants, will create and consolidate long-term additional demand for Western Canada's uranium, giving a lift to uranium prices and to this important resource industry.

APPENDIX D: Small Modular Reactors

Much discussion, design, research and development is taking place in the area of *small reactors* that are modular in construction, operate at lower power and maintenance levels, and could have broader applications (such as direct heat for resource processing, or seawater desalination). Several designs of small modular reactors (SMRs) are already in use for marine vessel propulsion and other applications around the world, and many more are proposed by more than a dozen international ventures.

Several Canadian firms are working on SMR applications, and SMRs have particular applicability to Canada.

- In remote communities which suffer from lack of inexpensive, reliable power for electricity and heating.
- To replace existing fossil-fuel power plants of modest generating capacity, so that carbon-free power can be installed easily without additional investments in power transmission.
- In new resource extraction projects (such as Alberta's oil sands, Saskatchewan's northern mines, Ontario's Ring of Fire mineral region).

The NRU currently has very limited links to SMR development mainly because the SMR opportunity in Canada has not yet reached the appropriate stage. Rather, the focus currently is on preparing the regulatory ground, since current regulatory structures have grown up around larger reactor designs built on-site. But it is easy to foresee a role for the NRU in testing before an SMR is deployed in Canada. Closing the NRU would close off opportunities that are likely to arise when SMRs come closer to being installed in Canadian locations.

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