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A BOLD IDEA TO LAUNCH CANADA'S ENERGY FUTURE

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Solo Flight

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A BOLD IDEA TO LAUNCH CANADA'S ENERGY FUTURE

Humanity searches for a solution to climate change while attempting to balance and combat the cultural and political pressures of our existing systems and collective experiences. The world will continue to need energy, and the pragmatic solution of the near future will continue to balance renewables with other more polluting sources of energy. The innovation required of a future energy system will need "human imagination, motivation and collaboration."[1]

Introduction

Access to energy has been the catalyst for each human industrial revolution[2], from organised human labor, to steam, to the electric motor, these have all marked a period of change and a period of bounty for the human race. This paper will describe a bold and innovative idea that has the potential to position Canada as a security and energy leader on the international stage for generations to come. Today, the energy race is looking for a clean energy source that will prevent our current generations from indebting the next one and move our society to a sustainable and safe supply of energy.

This work will explore why Canada should leverage its military capacity and nuclear industrial capabilities in order to develop and build a new generation of small and safe nuclear reactors. In contrast to a purely academic paper, this paper will follow the outlines of a policy paper describing the strategic considerations and implications of such an idea. In Canada at the federal level, ideas for projects need to demonstrate expected results along the lines of value-for-money,

[1] Rosabeth Moss Kanter, "How Great Companies Think Differently?," *NHRD Network Journal* 5, no. 1 (January 2012): 69, doi:10.1177/0974173920120101.
[2] Vaclav Smil, "World History and Energy," in *Encyclopedia of Energy* (Elsevier, 2004), 549–61, doi:10.1016/B0-12-176480-X/00025-5.

sound stewardship and an expectation of return[3] before those ideas can become funded projects. To demonstrate these, this work will follow the government of Canada's standardised business case process and inform the reader of the strategic context around this bold idea. First this paper will describe where we are now and the circumstances surrounding the next generation of nuclear reactors. Then it will discuss the current strategic environment, the innovation outcomes and drivers, and why the Department of National Defence (DND) is a strategic fit for the development of this technology. Finally we will discuss the main friction points slowing the development of this new technology.

Where Are we Now?

Today, Canada is a leader in nuclear energy and stands alongside other countries such as the US, France, UK, China and Russia with a "full spectrum of nuclear capabilities"[4]. Worldwide, nuclear power accounts for 11% of all electricity and the number of large plants is decreasing due to the significant costs associated with their construction. In Canada, nuclear energy accounts for 15% of total electricity generated and is in use in Ontario and New Brunswick. Although new generations of plants are under design, none are currently slated for construction in Canada.[5]

Nuclear power sees its fair share of opposition; however, that negative publicity is mostly ill founded. The world has recognised the need to reduce carbon emissions and nuclear power has

[3] Treasury Board of Canada Secretariat, "Business Case Guide," guidance, *Aem*, (July 22, 2009), https://www.canada.ca/en/treasury-board-secretariat/services/information-technology-project-management/project-management/business-case-guide.html.
[4] Canadian Small Modular Reactor Roadmap Steering Committee and others, *A Call to Action: A Canadian Roadmap for Small Modular Reactors* (Ottawa, 2018), 1.
[5] "NEB - Nuclear Energy in Canada: Energy Market Assessment - Index," accessed March 30, 2020, https://www.cer-rec.gc.ca/nrg/sttstc/lctrct/rprt/2018nclrnrg/index-eng.html.

the potential to assist industries and countries to reduce and limit emissions to agreed targets. According to the Intergovernmental Panel on Climate Change, nuclear power produces less waste and less carbon emissions than recognised low emission systems such as solar, hydropower or geothermal[6]. This fact has swayed more pragmatic environmentalist which now see nuclear power as part of the solution to climate change and have begun a pro-nuclear environmentalism movement.[7,8] To combat climate change and reduce carbon emission, nuclear power will be required alongside renewables to deliver on international targets such as the Paris Accord.[9]

From a health perspective, nuclear power has been demonstrated to have "one of the smallest levels of direct health effects[10]" among all of the power generating systems. This is due to its relative safety for the workers at the stations, the communities around them and the lack of pollutants emitted into the air. Simply to challenge our misunderstanding of the situation and to provide a comparison, the incident at Chernobyl will have caused less deaths from the accident itself and the radiological effects of the release over 20 years[11,12] than from Christmas trees in US

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[6] Intergovernmental Panel on Climate Change, *Climate Change 2014 Mitigation of Climate Change: Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge: Cambridge University Press, 2014), 1335, doi:10.1017/CBO9781107415416.
[7] Caroline McCalman and Steve Connelly, "Destabilizing Environmentalism: Epiphanal Change and the Emergence of Pro-Nuclear Environmentalism," *Journal of Environmental Policy & Planning* 21, no. 5 (September 3, 2019): 549–62, doi:10.1080/1523908X.2015.1119675.
[8] Tim McDonnell, "Closing This Nuclear Plant Could Cause an Environmental Disaster," *Mother Jones*, accessed May 3, 2020, https://www.motherjones.com/environment/2016/02/diablo-canyon-nuclear-plant-climate-change/.
[9] International Energy Agency, *Nuclear Power in a Clean Energy System.*, 2019, 3; ibid., 4.
[10] Anil Markandya and Paul Wilkinson, "Electricity Generation and Health," *The Lancet* 370, no. 9591 (September 2007): 979, doi:10.1016/S0140-6736(07)61253-7.
[11] *Sources and Effects of Ionizing Radiation: UNSCEAR 2008 Report to the General Assembly, with Scientific Indexes Vol. 2, Vol. 2,* (New York: United Nations, 2011), 65.
[12] "Survival Rates for Thyroid Cancer," accessed May 3, 2020, https://www.cancer.org/cancer/thyroid-cancer/detection-diagnosis-staging/survival-rates.html.

over those 20 years[13,14.] The majority of the population misunderstands nuclear energy and its adverse effects.

Due to nuclear power's history of large upfront costs, construction risks, delays and overruns, private or commercial investment is very difficult and potentially the main reason why the next generation of nuclear power plants have not been built. According to the International Energy Agency, the investment appetite for the current generation of nuclear plants is collapsing.[15] The private sector has been unable to generate the capital necessary to fund the next generation of nuclear power plants.

From a defence perspective, Canada is under increased pressure from allies to increase defence spending[16] and although an increase in budget is planned under the latest defence policy, *Strong Secure Engage*[17]*,* those expenditures will not reach the 2% goal set out by NATO. Canada and her population have historically been apathetic[18] to its military, which often prevents the military and military issues from becoming the priority during national discussions. Therefore, attaining the 2% goal, by spending on purely military technology is politically difficult. Finally, Canada is uniquely positioned amongst its allies as it requires the control and defence of large swaths of

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[13] Marty Ahrens, *Home Christmas Tree and Holiday Light Fires* (National Fire Protection Association, 2007), i.
[14] US National Fire Protection Association indicates, the from 2004-2008, Christmas trees caused on average 6 deaths per year, while the UN's report indicates there were 28 deaths from acute radiation poisoning and approximately 6000 people who have developed thyroid cancer from the increased radiation exposure which has a 1% death rate.
[15] International Energy Agency, *Nuclear Power in a Clean Energy System.*, 85.
[16] Murray Brewster · CBC News · Posted: Nov 23, 2019 11:58 PM ET | Last Updated: November 24, and 2019, "Canada Facing Renewed Pressure from U.S. to Meet NATO Defence Spending Benchmark | CBC News," *CBC*, November 24, 2019, https://www.cbc.ca/news/politics/canada-pressure-us-defence-spending-1.5371352.
[17] Canada and Department of National Defence, *Strong, Secure, Engaged - Canada's Defence Policy.*, 2017, http://epe.lac-bac.gc.ca/100/201/301/weekly_acquisitions_list-ef/2017/17-23/publications.gc.ca/collections/collection_2017/mdn-dnd/D2-386-2017-eng.pdf.
[18] Full Comment, "Opinion: We Need to Have the Backs of Our Men and Women in Uniform | National Post," November 11, 2019, https://nationalpost.com/opinion/opinion-we-need-to-have-the-backs-of-our-men-and-women-in-uniform.

arctic territory which is sparsely populated and developed. Diesel generating stations are the source of power in remote communities throughout Canada's vast lands and diesel generators also power all military arctic operations.

Finally, we are currently witnessing a shift in nuclear power technology which has the potential to provide clean and safe power at the scale necessary to combat climate change and deliver a sustainable energy source to remote communities and work sites. This new technology is referred to as Small Modular Reactors (SMRs) and Micro Modular Reactors (MMR)[19]. These smaller nuclear power plants create electricity or heat, and are small enough to be assembled in factories, and then transported to their intended destination. This new technology promises to be smaller, simpler, safer and much cheaper and will create a new industrial sector which the first-mover "will lock in significant economic, geopolitical, and social and environmental benefits in this area of high-tech innovation with substantial export potential"[20].

Canada has the opportunity to lead the next generation of nuclear power technology. By developing this technology, Canada will create a new industry in Canada, which will have significant environmental, health and financial benefits for its citizens, a clear value-for-money proposition. The military has a need for a clean, safe and sustainable energy supply to lower its carbon emissions, power Canadian Forces infrastructure and sustain operations in remote areas. By using the military as the lead purchaser, industry will have a guaranteed customer, which will spur investment and reduce commercial investment risks.

[19] The Canadian Nuclear Laboratories considers SMRs to be reactors with electrical output up to 300MW, while a MMR are up to 30MW. For comparison, typical reactor plants are 800MW.
[20] Committee and others, *A Call to Action: A Canadian Roadmap for Small Modular Reactors*, 2.

Strategic Environment and its Drivers

DND is uniquely positioned to deliver on large projects and has a mandate, to implement "Government decisions regarding the defence of Canadian interests at home"[21] whatever those may be. Canada's latest Defence Policy, *Strong Secure Engaged*, directs DND to "Examine alternative energy options and their potential use for operations"[22], and "build the capacity of whole-of-government partners"[23] in Canada's North. DND has proven records of working well with federal, territorial, provincial and local partners, [24] and has a legitimate need for a clean and sustainable electricity source to support operations in remote areas for lengthy periods of time[25].

As Canada's largest department[26], DND has significant project management capacity and has proven experience in delivering complex projects with international, aboriginal and provincial partners. Due to this capacity and capability, DND has an Organizational Project Management Capacity Assessment level of 3[27] which indicates it has an evolutionary capacity to successfully deliver [28] projects. DND uses this capacity to deliver equipment and services to Canada's military and ensure good stewardship of citizen's funds.

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[21] National Defence, "Mandate of National Defence and the Canadian Armed Forces," organizational descriptions, *Aem*, (February 19, 2013), https://www.canada.ca/en/department-national-defence/corporate/mandate.html.
[22] Canada and Department of National Defence, *Strong, Secure, Engaged - Canada's Defence Policy.*, 76.
[23] Ibid.,79.
[24] Ibid.,79.
[25] News and Canada, "Frostbite and Fuel Shortages: The Logistical Challenges of a Military Operation in Canada's Arctic | National Post," March 22, 2018, https://nationalpost.com/news/canada/frostbite-fuel-shortages-and-atvs-frozen-in-the-mud-the-logistical-challenges-of-a-military-operation-in-canadas-arctic.
[26] Defence, "Mandate of National Defence and the Canadian Armed Forces."
[27] Kevin Sorenson, "Report 7, Operating and Maintenance Support for Military Equipment – National Defence, of the Fall 2016 Reports of the Auditor General of Canada." Canada, House of Commons, (June 2017). http://publications.gc.ca/collections/collection_2017/parl/xc16-1/XC16-1-1-421-29-eng.pdf
[28] Treasury Board of Canada Government of Canada, "Guide to Using the Organizational Project Management Capacity Assessment Tool 5 / 9," October 30, 2009, https://www.tbs-sct.gc.ca/pm-gp/doc/ompcag-ecogpg/ompcag-ecogpg05-eng.asp#a2.

Today, fuel for arctic operations, for Canada's military arctic training center and for all residential communities in Nunavut must be barged in by sea annually[29], there is no backup to the diesel generator stations in remote communities and there is no significant reserve of fuel to supply unexpected missions such as an arctic search and rescue operations. Canada has a clear need for a clean and sustainable energy source to support military and industrial operations in Canada's north and ensure Canadian remote communities enjoy access to clean and reliable electricity.

The development of this safe and sustainable power source has multiple drivers which together highlight the need for such an investment. Some of these drivers are normal evolution of markets or technology, are international in nature, or are temporary opportunities. Today, Canada is potentially in the lead of SMR development and according to the Honourable Amarjeet Sohi, Canada's Minister of Natural Resources, Canada also recognises the importance of this innovative technology and the opportunity it presents for Canada "both at home and on the world stage"[30]. Due to these benefits, a consortium has been created which includes provincial and territorial governments, nuclear industry, energy utilities and Indigenous organisations, and they have developed a clear roadmap to the development of commercially viable SMR and MMRs.[31]

There currently exists multiple viable SMR and MMR designs from different competing companies which are at different stages in the licensing process in Canada and around the world. Some designs are more mature than others and the more mature ones are currently under review

[29] News and Canada, "Frostbite and Fuel Shortages."
[30] Natural Resources Canada, "Canada Poised to Lead the Deployment of Next-Generation Nuclear Technology," news releases, *Gcnws*, (November 7, 2018), https://www.canada.ca/en/natural-resources-canada/news/2018/11/canada-poised-to-lead-the-deployment-of-next-generation-nuclear-technology.html.
[31] Committee and others, *A Call to Action: A Canadian Roadmap for Small Modular Reactors*.

by the Canadian Nuclear Safety Commission[32], an independent federal government agency[33], in an attempt to complete the initial licensing steps.

This licensing process eventually leads to building demonstration plants and the Crown corporation, Atomic Energy of Canada Limited (AECL), is in the process of building a MMR at Chalk River to demonstrate various technologies. This leading position shouldn't be squandered as both the US, China and Russia have similar projects[34] and due to the necessary upfront capital and investments required of such a project, one of the first commercially viable plants is likely to become the global market favorite.[35]

Because of the global market potential, multiple countries are attempting to develop SMRs in order to supply the technology. Nations, especially developing ones, need clean, safe and affordable energy, and the first to commercialise this technology will be greeted with significant demand for the technology. Given the design philosophies and priorities of other nations around the world who are willing to export such technology, it's vitally important that Canada with its safe record and high standards, be in a position to offer SMRs to developing nations. The only two SMRs to have been built recently are the Akademik Lomonosov 1 and 2, both built by Russia based on 1970s technology,[36] to supply power to remote communities. They cannot be described as cutting edge or meeting the latest safety expectations and they have received a

[32] "More SMR Vendor Design Reviews for CNSC - World Nuclear News," accessed March 24, 2020, https://www.world-nuclear-news.org/NN-More-SMR-vendor-design-reviews-for-CNSC-2002187.html.
[33] Canadian Nuclear Safety Commission, "New Reactor Facility Projects," March 6, 2020, https://www.cnsc-ccsn.gc.ca/eng/reactors/power-plants/new-reactor-facilities/index.cfm.
[34] International Energy Agency, *Nuclear Power in a Clean Energy System.*, 87.
[35] Robin Cowan, "Nuclear Power Reactors: A Study in Technological Lock-In," *The Journal of Economic History* 50, no. 3 (1990): 541–67.
[36] "Bellona Releases New Report on the Russian Drive for Floating Nuclear Power Plants," *Bellona.Org*, February 2, 2011, 37, https://bellona.org/news/nuclear-issues/nuclear-russia/2011-02-bellona-releases-new-report-on-the-russian-drive-for-floating-nuclear-power-plants.

significant amount of criticism[37]. Given the current rate of development, it is predicted that newer generations of SMRs could be ready for export to developing countries by the mid-late 2020s.[38]

Although nuclear power from the previous technologies has been beset with cost overruns, it continues to provide a lower marginal cost than any other conventional source[39] and when used to supply the electrical baseload, nuclear power is capable of guaranteeing the supply of electricity which prevents blackouts and brownouts. The energy system of the future will require a guaranteed supply of clean energy but this future system cannot be built using our current nuclear technology. The huge initial costs have stalled the investment necessary for the construction of new nuclear power plants. Nuclear professionals have re-attacked the problem and will need the opportunity to demonstrate what a modern nuclear reactor could be. SMRs are different, their smaller size, modern designs and construction methods lead to much lower costs. The first SMRs, the first version of the technology will be more expensive; however, their benefits outweighs that initial costs which is why SMRs are seen by the Premiers of multiple provinces as a technology that has the "opportunity to reduce emissions while providing an economic opportunity."[40]

[37] "Bellona Releases New Report on the Russian Drive for Floating Nuclear Power Plants."
[38] Ioannis N. Kessides and Vladimir Kuznetsov, "Small Modular Reactors for Enhancing Energy Security in Developing Countries," *Sustainability* 4, no. 8 (August 2012): 1826, doi:10.3390/su4081806.
[39] "The Future of the Global Power Sector | Deloitte | Challenges, Power Companies, Transform, Cost Reductions," 15, accessed March 30, 2020, https://www2.deloitte.com/global/en/pages/energy-and-resources/articles/future-of-global-power-sector.html.
[40] News and Canada, "What Are Small Modular Nuclear Reactors, and Why Are Three Provinces Uniting to Build Them? | National Post," December 3, 2019, https://nationalpost.com/news/canada/what-are-small-modular-nuclear-reactors-and-why-are-three-provinces-uniting-to-build-them.

Innovation Outcomes

While the third and fourth order effects of innovation are more difficult to quantify, the first and second order ones are much easier. For Canada, there would be three main benefits in developing SMRs, an economic benefit by creating a new technology, an environmental benefit by creating an energy source which has little to no carbon emissions, and the creation of a clean and reliable source of energy for remote communities or military operations.

According to the roadmap, the domestic market in Canada is 19$ billion per year and would impacts at least 6000 jobs, while there is the potential for a 150$ billion per year global export market[41]. Canada has had good success exporting nuclear technology having successfully built a nuclear reactor on time and under budget in China[42]. This success lead Canada and China to continue their relationship on nuclear technology and opens a door to another market who is both looking for energy production and pollution reduction.

In addition to nuclear electricity being one of the lowest carbon emitters, smaller SMRs or MMRs could be designed to generate power and industrial heat for heavy industry applications. Recent studies indicate that given the current trend in development of SMRs they can play a crucial role in limiting oil sands emissions[43]. However, studies of SMRs for oil sands extraction indicate SMR costs are currently very uncertain due to their unproven design and this uncertainty make SMRs uncompetitive with natural gas power and heat generation[44]. This uncertainty and costs is currently preventing private investment and the necessary breakthroughs.

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[41] Committee and others, *A Call to Action: A Canadian Roadmap for Small Modular Reactors*, 32,37.
[42] M.V. Ramana and Eri Saikawa, "Choosing a Standard Reactor: International Competition and Domestic Politics in Chinese Nuclear Policy," *Energy* 36, no. 12 (December 2011): 8, doi:10.1016/j.energy.2011.10.022.
[43] BE Schmitt, *Deployability of Small Modular Nuclear Reactors for Alberta Applications* (Alberta Innovates - Energy and Environment Solutions, 2018), 75.
[44] Schmitt, *Deployability of Small Modular Nuclear Reactors for Alberta Applications*.

In addition to the clean heat and electricity they produce, some new SMR designs can run on used nuclear waste[45] thus slowly reducing the amount of radioactive waste stored around the world. Although, detractors of nuclear energy continue to highlight the waste generated by older generations of power plants, few among them could genuinely and honestly argue against a system which generates clean power from nuclear waste. The only current alternative to managing the waste is to archaically bury it somewhere deep, far from curious people.

Developing and more importantly, building SMRs for remote communities will "support all four pillars of the Government of Canada's four-tiered "Northern Strategy": sovereignty, environment, economic development, and self-governance." [46] The military has also been identified by the Canadian Nuclear Laboratories at Chalk River as a potential customer for such innovation where it could be used to supply power to remote locations and support arctic sovereignty.[47] This uniquely Canadian situation (among our allies) creates the need for much smaller reactors and due to the size of their own market, northern communities are unlikely to fund the development of this new technology[48]. The smaller reactors necessary for remote communities, or MMRs, would have the added benefit of being somewhat portable and although the first versions of MMRs are unlikely to be moved often, future versions could be deployable on short time frames. This much smaller portable scale of power would be uniquely useful to

[45] Giorgio Locatelli, Chris Bingham, and Mauro Mancini, "Small Modular Reactors: A Comprehensive Overview of Their Economics and Strategic Aspects," *Progress in Nuclear Energy* 73 (May 2014): 75–85, doi:10.1016/j.pnucene.2014.01.010.
[46] J Whitlock and J Sprinkle, "Proliferation Resistance Considerations for Remote Small Modular Reactors," *Nuclear Review* 1, no. 2 (2014): 10.
[47] M Moore et al., "A Review of Small Modular Reactors: The Canadian Applications and Impacts" (Atomic Energy of Canada Limited, 2015).
[48] C. Waters and R. Didsbury, "Small Modular Reactors - A Solution for Canada's North?," *AECL Nuclear Review* 1, no. 2 (December 1, 2012): 3–7, doi:10.12943/ANR.2012.00012.

remote communities and the military[49] and could conceivably be used in support of disaster relief when areas are affected by natural disasters[50].

Strategic Fit for DND

At first glance, DND is not the organisation one would imagine should support the development of the next generation of nuclear energy for Canada and this idea has its detractors. However, the Canadian military is uniquely positioned for this endeavour as it has both the capacity and capability to support such a large project for the Federal, Provincial and Territorial governments. Although this may look like an awkward and unconventional fit, national level innovation programs often partner with the military to take advantage of their capacity. Historically, military research and development programs, or innovation programs, have had three paths to success. One of those paths involves using the military as the "lead purchaser" because it could absorb the risk of unproven technology and enable suppliers to both reduce their costs and increase their reliability.[51]

Canada and DND have multiple needs which this innovative idea would support and therefore are an excellent fit to be the lead purchaser of this technology. Canada is under pressure from allies to increase defence spending, has a requirement to decrease the carbon footprint of DND and requires a sustainable source of clean power in order to increase capacity and capabilities in remote areas, all legitimate DND business needs. By developing small modular reactors through

[49] "56 MW Power Plant at Bagram Airfield | WSP," accessed March 24, 2020, https://www.wsp.com/en-US/projects/bagram-airfield.
[50] "What Is a Nuclear Microreactor?," *Energy.Gov*, accessed March 24, 2020, https://www.energy.gov/ne/articles/what-nuclear-microreactor.
[51] David C. Mowery, "National Security and National Innovation Systems," *Journal of Technology Transfer; Indianapolis* 34, no. 5 (October 2009): 455–73, doi:http://dx.doi.org.cfc.idm.oclc.org/10.1007/s10961-008-9100-4., 457.

DND, Canada would increase relative defence spending on a dual use technology, generate significant income potential for Canada and its industries, and create a clean and sustainable power generation capability it could use in remote regions in support of other government departments or local communities.

Military departments have historically been used to great success[52] as the lead, or first purchaser of innovation. This coupled with the military's requirements for performance, quality and safety over costs drives suppliers towards a different version of the technology. This version would be different than the one generated by a consortium of investors who would prioritise costs over other design features. With the military acting as the lead purchaser, suppliers would also have an assured market for their product and could therefore "reduce costs of their products and improve their reliability and functionality."[53]

To be clear, this paper is not advocating DND should design or lead the technology development. DND should support the development of the next generation by steering a SMR project through the bureaucratic process and being one of the first SMR or MMR customers. This would create a market for the industry and would lower future investment risks at which point private companies would be more comfortable investing. Although developing the First of a Kind (FOAK) is more expensive, the economic benefits on the longer time scales are

[52] Kenji E. Kushida, "The Politics of Commoditization in Global ICT Industries: A Political Economy Explanation of the Rise of Apple, Google, and Industry Disruptors," *Journal of Industry, Competition and Trade* 15, no. 1 (March 1, 2015): 49–67, doi:10.1007/s10842-014-0191-3, 62.
[53] David C. Mowery, "National Security and National Innovation Systems," *Journal of Technology Transfer; Indianapolis* 34, no. 5 (October 2009): 455–73, doi:http://dx.doi.org.cfc.idm.oclc.org/10.1007/s10961-008-9100-4, 457.

significant[54] and there is confidence in a return on the initial investment for the Government of Canada.

By following such a path, Canada would find itself in a position where it uses small modular reactors to power operations and communities in remote regions and exports nuclear technology and equipment built in Canada to other countries. If conditions in local populations abroad are agreeable, Canada could also supply clean sustainable power to international organisations or allied military infrastructure around the world.

With DND in support of such an endeavor and with the right diplomatic clearances, staff could potentially access some of the US DoD studies about SMRs which have been conducted by DARPA and the Center for Naval Analyses[55]. Access to this information would assist in developing the knowledge base required to avoid pitfalls and would further reduce the risks associated with such a project.

DND and its public servants and Canadian Forces members are for the most part a-political and therefore would be able to unbiasedly support a project which has interest from Ontario, New Brunswick, Saskatchewan, Alberta, Nunavut and the North West Territories. Canada is presented with an opportunity for collaboration which could cut across political and geographic lines and provide the country with an economic boom. Using large government departments to lead such innovative endeavors has been successful because the project and the risks associated with it

[54] 5 billion in Canada and over $150 billion between 2025 and 2040 around the world
[55] Bret Strogen, "Small-Scale Nuclear Reactors for Remote Military Operations: Opportunities and Challenges" (NATIONAL DEFENSE INDUSTRIAL ASSOCIATION ARLINGTON VA ARLINGTON, 2015).

were underwritten by the government,[56] which is why a private sector only approach is unlikely to succeed in this case. In no way is this the only step government can take, they have multiple options available to them, most of which have already been undertaken and are bearing fruit. Canada and other allies have been "conducting or funding research and development, stimulating private investment, and demonstrating technology."[57] This paper suggest that the next step, the step of building a commercially viable SMR will require a robust customer, one capable of surviving delays, overruns and can weather political storms. This technique is proven and "has often played a decisive role in technology development and is likely to be the catalyst for the U.S. small reactor industry"[58].

Unlike the US, Canada has a recognised simple licensing process[59] compared to other countries for the building of nuclear plants. Although it is not easy or less rigorous, the process is a singular one vice a dual license system such as the one in France or one with multiple steps and stakeholders all of which can delay or even end the project. Although DND and the military have not built nuclear stations, the licensing steps and process would be familiar to DND project managers who routinely follow complicated bureaucratic processes for other projects which have environmental, social and economic impacts. In any case, like all large projects, DND would be partnering with industry and other government agencies to deliver government decisions and ensure value for money and sound stewardship.

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[56] Marty Hoffert, "Governments Must Pay for Clean-Energy Innovation," *Nature* 472, no. 7342 (April 2011): 137–137, doi:10.1038/472137a.
[57] Richard B Andres and Hanna L Breetz, "Small Nuclear Reactors for Military Installations: Capabilities, Costs, and Technological Implications" (NATIONAL DEFENSE UNIV WASHINGTON DC INST FOR NATIONAL STRATEGIC STUDIES, 2011), 11.
[58] Ibid.
[59] Alexandre Bredimas, William J Nuttall, and others, "A Comparison of International Regulatory Organizations and Licensing Procedures for New Nuclear Power Plants," *REVUE GENERALE NUCLEAIRE* 5 (2007): 68, 12.

Using DND and the military to innovate in this field has other key benefits, in Canada, the process for building a nuclear plant involves engagement with the public and in Canada this engagement is more significant than other countries such as the US and UK[60]. A project lead by the military would benefit from the military's good public relation capabilities and respect by the Canadian public.

In addition to the good relationship with the general public, the military has bases on federal lands throughout the country where the population in the area have positive outlooks about the military. Due to the size and location of the base, the population may largely consist of military family members or friends, a military service provider, or at the very least, with people who are familiar with the military. As an example, CFB Gagetown next to Fredericton is the third largest employer of personnel in New Brunswick and military members consists of approximately 16 percent of the population, in this area the military provides 200$ million into the local Fredericton economy and 700$ million in the province of New Brunswick[61]. All this, while being 80 kms from New Brunswick's own nuclear generating station. A location, filled with a military community who have lived close to a safe nuclear station is a location where the government can have rational and honest discussions about the building of the next generation of nuclear plants. A constructive discussion with an open minded population is significantly more appealing for a project than one challenged with "not-in-my-backyard" campaigns and would be very beneficial in improving public perception which has been identified as a drawback[62] for the installation of nuclear power.

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[60] Ibid., 21.
[61] "City of Fredericton," *The Canadian Business Journal*, April 2, 2018, https://www.cbj.ca/city-of-fredericton-nb/.
[62] Lauren Boldon et al., "Sustainability Development Platform for Nuclear-Renewable Energy Integration: Environmental Impacts, Economics, and Socio-Political Implications," *International Journal of Energy, Environment, Economics* 23, no. INL/JOU-15-34963 (2015): 34.

Finally, simply due to luck, the Canadian Nuclear Laboratories at Chalk River is but a few kilometers from another Canadian Forces Base. Such proximity would allow collaboration between the military as the lead customer and Chalk River which is attempting to become a global hub for the development of SMRs.[63] Studies indicate that the development and building of a nuclear power plant to supply electricity and heat to a military base and its community is financially viable[64] and a legitimate alternative to being a standard grid customer. Finally, military bases often have huge swaths of deserted property which are designed to test and operate military equipment and weapons while providing a safe separation from the local population. Canada's military bases are legitimate locations for the construction of the next generation SMR.

The idea of having a nuclear revival led by the military has its detractors, some would rather the revival be led by private industry or a nuclear agency. The main arguments against using the military to develop SMRs surrounds the balance of operational requirements which may come into conflict with those of a SMR designed for utility use. This argument is correct, designing a very small modular reactor or MMR, one which is small enough to rapidly deploy to forward operating bases is a system significantly different than a SMR for utility use. However, developing a MMR which is deployable to a foreign county in a conflict zone is putting the horse before the cart and would not be the target of the project recommended here, which is to clear the path for the first generation of new SMRs for utility use. The project team would need to be

[63] "Small Modular Reactor Technology," accessed May 2, 2020, https://www.cnl.ca/en/home/facilities-and-expertise/smr/default.aspx.
[64] Marcus King, R LaVar Huntzinger, and Thoi Nguyen, *Feasibility of Nuclear Power on US Military Installations* (CNA, 2011), 53.

practical in their goals and requirements and balance the need to commercialise with the militaries need for a deployable SMR. The military does not yet need a SMR which can be rapidly deployed overseas, it needs a proven source of energy which is safe and sustainable and can be slowly transported to our own communities which need energy.

Detractors also point out the contracting methodologies the military is likely to use in developing SMRs. The two most likely would be either a tightly controlled development process such as the Joint Strike Fighter or a "bid for service" where the military requests commercial entities to bid and develop a SMR almost as a service to provide power to a military base[65]. The first methodology is the most likely but should be avoided as it would require a significant amount of military resources and would in all likelihood create a militarised version of the SMR which would be harder to deliver and commercialise.

DND has been directed by the GoC to investigate new sources of power to reduce its carbon emissions, has the capacity to run large projects, is a-political and routinely engages with multiple stakeholders. The military is unique in requiring transportable power at a utility level and has the community and land where new SMRs could be conceivably built. DND is an excellent strategic fit for the development of the next generation of SMRs.

Bold Ideas Generate Friction

Nuclear power is confronted with four main design issues: proliferation, costs, waste and safety. Those main design drivers need to be balanced and proponents of SMRs need to be careful, some

[65] Michael J Ford, Ahmed Abdulla, and M Granger Morgan, "Nuclear Power Needs Leadership, but Not from the Military," *Issues in Science and Technology* 34, no. 4 (2018): 5.

have presented their designs as capable of solving all four issues which is a technical fantasy[66] given the current un proven designs. However, proliferation and security risks can be minimised or even eliminated by new designs which either do not use weapon grade fuel, or are hardened to a point where the fuel is inaccessible, never handled, the system is fuelled once per lifetime. An act of terrorism against a nuclear system has never occurred and some argue we may have become complacent[67]. However, by placing the plant on a military base, it does allow more flexibility in the design choices as the first prototypes could be constructed on a military base, and sustained and protected by a military force which would make it inherently difficult for a criminal or terrorist organization to target and seize nuclear fuel.

According to experts the main driver which prevents proliferation is diplomatic and institutional pressure from various alliance, countries and organizations[68]. As a leader in nuclear energy and having no nuclear weapons of its own, Canada is positioned to lead and mediate the necessary discussions as an expert in the field, but without the burden of having its own arsenal of nuclear weapons. By having healthy discussions on the topic, at the right levels of government, the risk of proliferation can be minimised and other design drivers such as costs can be considered.

The lead purchaser of a FOAK is always subject to bearing the initial costs, and bearing such a cost without other partners is deemed to be too much risk for the US[69]. Studies in the US recommend against the Department of Energy (DoE) or Department of Defense (DoD) becoming the first adopter of SMR technology. The exception to this study being if the DoE and DoD

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[66] M.V. Ramana and Zia Mian, "One Size Doesn't Fit All: Social Priorities and Technical Conflicts for Small Modular Reactors," *Energy Research & Social Science* 2 (June 2014): 115–24, doi:10.1016/j.erss.2014.04.015.
[67] Matthew Bunn and Martin B. Malin, "Enabling a Nuclear Revival—And Managing Its Risks," *Innovations: Technology, Governance, Globalization* 4, no. 4 (October 2009): 180, doi:10.1162/itgg.2009.4.4.173.
[68] Ibid., 184.
[69] King, Huntzinger, and Nguyen, *Feasibility of Nuclear Power on US Military Installations*.

partner together, a recipe for significant bureaucracy and stakeholder competition. Detractors in the US argue the military should support the development and the DoE should lead the next nuclear revolution[70]. Although this is a realistic argument in the US due to the DoE's portfolio of nuclear responsibilities, significant budget and large amount of personnel, in Canada, no such comparable organization exists and our own nuclear organisation do not have the budget and capacity to buy enough nuclear plants to create a market.

In the US, the DoD has shown some interest in developing SMRs, but their priority and resources have been committed elsewhere and the developments of SMRs would likely be sacrificed if budget cuts were required[71]. In Canada however, as the country is under pressure to increase its defence budget to meet NATO agreements, Canada has an interest at the highest levels to support a military project which develops dual use technology and has the potential to create a new civilian industry and global marketplace. Canadian think thanks agree SMRs are the future of energy and assess the economic potential to be 5 billion in Canada, and "globally over $150 billion between 2025 and 2040"[72]. They also recommend the step to commercialisation is a partnership between government, utilities and the private investor. The government's stake in such a project could be led by DND which has a legitimate need for such a capability and has the capacity to both absorb cost overruns and the team of personnel capable of handling the inevitable bureaucratic processes from a cost increase.

[70] Ford, Abdulla, and Morgan, "Nuclear Power Needs Leadership, but Not from the Military."
[71] Ibid.
[72] "Small Modular Reactors Are the Future of Nuclear Energy: Duane Bratt," *Macdonald-Laurier Institute*, August 21, 2019, https://www.macdonaldlaurier.ca/small-modular-reactors-future-nuclear-energy-duane-bratt-inside-policy/.

With the government as the lead purchaser and underwriting the financial risks, this situation would allow suppliers more lee-way in designing a prototype or production unit. And as costs reduce and a market develops, the next versions of the design could be tailored to another purpose such as burning nuclear waste or further reduction in size and increased transportability. Small Modular Reactors are going to become reality, the world needs power and the promise of this technology is attractive to countries, especially those without access to gas and oil.

A country, an alliance or consortium of companies will become the lead in this technology which will drive the design and economics of the technology. By mandating DND to steward the development of the first wave of technology in Canada, to Canadian requirements, Canada will see a return on investment and significant value-for-money. There are issues but they can only be addressed if we fund industry to address them. Unlike the majority of financial investor and venture capitalist, Canada has interests in this technology beyond financial ones. By leading this technology, Canada can direct it to fill its own needs and solve some uniquely Canadian problems in the arctic and remote communities.

Conclusion

The world finds itself balancing the need to reduce emissions and the ever-increasing need for electricity. Multiple parties are competing for this technology and after years of attempts, private industry has been unable to muster the financial capacity to tackle such an endeavor. The purpose of this paper was to discuss the strategic context around using DND to support a fledgling industry, using DND to be the first customer of a new generation of nuclear power plants. Governments do not solely rely on financial indicators to make investments and they have often used the military to lead innovation and develop new technology. DND is uniquely

positioned in Canada to steward the next generation of nuclear energy because of its organisational capacity, ability to collaborate with partners and potential nuclear generation sites within its portfolio of properties.

This new technology will create a new Canadian industry which will provide the energy necessary to combat climate change and power developing countries, this new industry will provide jobs and income to Canadians and their communities. Detractors abound, but their opposition is dwindling as we come to terms with the concrete and necessary steps to solve climate change. As a leader in nuclear energy, Canada has the opportunity to lead the design of this next generation and ensure they meet the expectations of Canadians, those of a safe, environmentally friendly and secure source of power.

Canada should leverage its military and nuclear industrial capabilities to develop and build a new generation of small and safe nuclear reactors. This idea requires bold action from decision makers so we can change the world for our children, “change will not come if we wait for some other person or some other time. We are the ones we've been waiting for. We are the change that we seek.”[73]

[73] Barack Obama, “We Are the Ones We’ve Been Waiting For” (Chicago, February 5, 2008), https://www.youtube.com/watch?v=3EWLeKGI0ro.

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