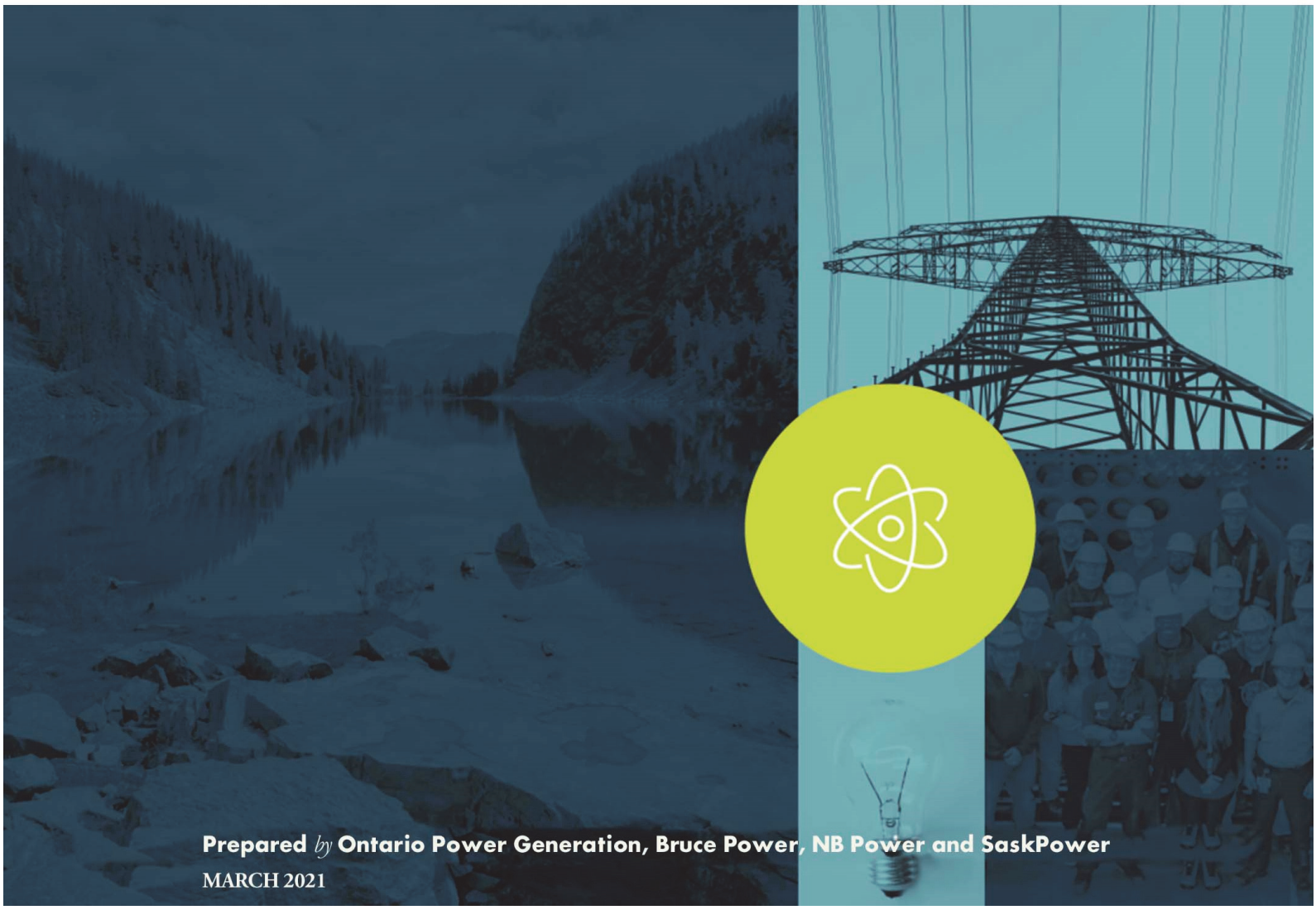
FEASIBILITY OF

Small Modular Reactor

DEVELOPMENT AND DEPLOYMENT IN CANADA

Executive Summary



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Executive Summary

This feasibility report was prepared by Ontario Power Generation (OPG), Bruce Power, NB Power and SaskPower for the governments of Ontario, New Brunswick and Saskatchewan. The report provides a feasibility assessment of Small Modular Reactor (SMR) development and deployment and contains the power companies' business case for SMR implementation in each of the three provinces.

Background

SMRs are the next generation of nuclear energy innovation, with the potential to help address challenges and opportunities related to climate change and economic growth. The 2018 Canadian SMR Roadmap[1] concluded that SMRs provide a source of safe, clean, affordable energy, with the ability to contribute towards a resilient, low-carbon future. SMRs can promote key benefits for Canada and Canadians, such as:

- meeting Canada's climate change commitments;
- unlocking opportunities for job creation and economic growth; and
- sustaining and expanding Canada's leadership in research and innovation.

With these drivers in mind, the provinces of Ontario, New Brunswick and Saskatchewan signed a Memorandum of Understanding (MOU)[2] on December 1, 2019, that establishes a framework for deployment of SMRs in each respective jurisdiction. This feasibility report represents one of the early deliverables from the MOU.

The three provinces share a collective interest in SMRs as a clean energy option to address climate change and meet regional energy demands, while responding to the need for economic growth and innovation. The provinces have also agreed to engage with the federal government on key issues related to SMR deployment, including technological readiness, regulatory frameworks, economics and financing, nuclear waste management and public and Indigenous engagement.

Canada and its provinces are already home to a world-class nuclear industry with extensive experience in the design, construction and servicing of reactors in Ontario, New Brunswick and around the globe. The nuclear sector plays a key role in Canada's economy, contributing $17 billion annually, while supporting 76,000 Canadian jobs[3] (i.e. direct, indirect and induced). In addition, Canada is home to the planet's richest uranium resource – the Athabasca basin in Saskatchewan – and is the second-largest producer of uranium in the world.

The SMR Advantage

SMRs are nuclear reactors that produce 300 megawatts (MW) of electricity or less. Much smaller than traditional nuclear power plants, SMRs are cheaper to mass produce and easier to deploy. Their modular design allows for deployment in large established grids, small grids, remote off-grid communities and as an energy source for resource projects. SMRs provide

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[1] Canadian Small Modular Reactor Roadmap Steering Committee (2018). *A Call to Action: A Canadian Roadmap for Small Modular Reactors*. Ottawa, Ontario, Canada. www.smrroadmap.ca

[2] https://news.ontario.ca/opo/en/2019/12/premier-ford-premier-higgs-and-premier-moe-sign-agreement-on-the-development-of-small-modular-reacto.html

[3] https://cna.ca/news/new-study-finds-nuclear-industry-accounts-for-76000-jobs-across-canada/

non-greenhouse gas (GHG) emitting energy that can meet new electricity demands and support renewable sources, such as wind and solar. Other countries have recognized nuclear power as a clean energy source, and with growing interest in SMRs there is an exciting opportunity for Canada to export technology and expertise to address global issues such as climate change and energy security.

Feasibility of SMRs

Economics: The power companies assess that SMRs have the potential to be an economically competitive source of energy. However, that will depend on other low-carbon alternatives available to each jurisdiction. Natural gas prices and carbon pricing also play a significant role in potential feasibility. Solar and wind generate energy intermittently, meaning they produce only some of the time and not always when needed. As provinces reduce reliance on fossil fuels in electricity generation, an optimum capacity mix will need to be achieved – with nuclear playing a potentially larger role in the future.

Energy generated by SMRs in Ontario and Saskatchewan is expected to be economical compared to other low-carbon alternatives and could be used to support reduction in carbon emissions and meet new energy demands. The choice of SMR technology and speed of commercialization will play a significant role in the cost of deployment.

For off-grid applications, such as remote mines or communities, SMRs need to be economically competitive with diesel generation (i.e. including the cost of fuel and transport). SMRs could potentially reduce energy costs for remote sites and communities with electricity demands between 10 and 20 MW. For smaller communities (e.g. those with demands of 3 MW), the costs are near break-even. As with on-grid applications, the choice of technology and speed of commercialization will play a key role in the cost of SMR deployment and its ability to compete with diesel.

Technology: SMRs cover a wide range of power levels, designs, technological readiness levels and end-user applications. To meet Canada's broad needs, the four power companies have been working collectively over the last two years to develop three streams of SMR project proposals. As such, the SMR projects being proposed to the governments of Ontario, New Brunswick and Saskatchewan are based on the following assessments and assumptions:

- **Stream 1** proposes a first grid-scale SMR project of about 300 MW constructed at the Darlington site by 2028, followed by up to four subsequent units in Saskatchewan, with the first unit in Saskatchewan being in service in 2032. This "fleet" approach would identify a common SMR technology to be more quickly and efficiently deployed in multiple jurisdictions.
    - OPG, Bruce Power and SaskPower are collaborating to select the technology and developer by the end of 2021.
    - SMRs can be economically competitive in both jurisdictions as additional sources of clean energy.
    - The shovel-ready status of the Darlington site makes it a vital strategic asset, providing opportunity for an SMR developer to launch a fleet of units.
    - Stream 1 can create economic benefits for Canada from a single unit in Ontario and four units in Saskatchewan over their lifetime of:

        - direct, indirect, and induced employment on an average annual basis as follows:
            - 1,528 jobs during project development
            - 12,455 jobs during manufacturing and construction
            - 1,469 jobs during operations and
            - 1,193 jobs during decommissioning
        - a positive impact on GDP of $17 billion; and
        - an increase of government revenue of $5.4 billion.

- **Stream 2** involves two 4th generation, advanced small modular reactor designs that will be developed in New Brunswick through the construction of demonstration units at the Point Lepreau nuclear site in NB. By fostering a strong collaboration among the various research, manufacturing, federal and provincial agencies, New Brunswick will see the completion of an initial ARC Clean Energy demonstration unit by 2030, and Moltex Energy's waste recycling facility and reactor, operational by the early 2030s. With these timelines, New Brunswick will be supporting the additional clean energy needs within Atlantic Canada and with partnering jurisdictions starting in 2030. New Brunswick is positioned to become the leader in the development and deployment of these 4th generation technologies through its efforts, its partnerships and its support. These designs represent a significant opportunity for advancing domestically produced energy within Canada and around the world that is both clean and safe. Through ongoing support and collaborations, these advanced technologies can start being deployed as early as 2030 in support of the industrial needs in areas like Saskatchewan and Alberta, and indeed, around the globe. The made in New Brunswick designs represent significant economic diversification opportunities for the province and will place New Brunswick as a world leader in the deployment of 4th generation advanced SMR technologies.
    - With funding of $30 million from the provincial government, two developers (Moltex Energy and ARC Clean Energy Canada Inc.) have opened offices in New Brunswick. Companies are developing delivery capability in New Brunswick with the promise of local economic development.
    - These two designs are expected to result in new lower-cost units that recycle nuclear waste, have more inherent safety attributes and are attractive for global deployment.
    - Stream 2 can create economic benefits for Canada for demonstration units in New Brunswick (2020 – 2035) of:
        - 21,870 person-years of direct and indirect employment;
        - a positive impact on GDP (direct and indirect) of $2.15 billion; and
        - an increase of government revenue of $198 million.

      with the opportunity to expand this through a fleet of both Canadian and export units to 2060 of:

        - 537,000 person-years of direct and indirect employment;
        - a positive impact on GDP (direct and indirect) of $59 billion; and
        - an increase of government revenue of $5.2 billion.

- **Stream 3** proposes a new class of micro SMRs designed primarily to replace diesel use in remote communities and mines. To advance this technology, a 5 MW gas-cooled reactor project by Ultra Safe Nuclear Corporation (USNC) is underway at the Chalk River site in Ontario and is expected to be in service by 2026.
    - OPG has partnered with USNC for this demonstration project on the basis of shared investment from OPG, USNC and expected funding from the federal government.
    - This project is not intended to be commercially economical, but analysis shows that future two-unit 10 MW plants will be economically competitive with diesel and will provide the opportunity for returns to cover demonstration project costs.
    - Looking to advance nuclear in remote communities, Bruce Power and its partners at the Nuclear Innovation Institute have been exploring opportunities with the Westinghouse Canada eVinci Micro-Reactor.
    - Stream 3 can create economic benefits for Canada from a four-unit commercial deployment (20 MW) of USNC reactors at a mining site over its operating life of:
        - direct, indirect, and induced employment on an average annual basis as follows:
            - 240 jobs during project development
            - 638 jobs during manufacturing and construction
            - 282 jobs during operations and
            - 180 jobs during decommissioning
        - a positive impact on GDP (direct, indirect, and induced) of $877 million; and
        - an increase of government revenue of $311 million.

These projects are advancing rapidly and are all demonstrating commercial and technical feasibility.

There are three other factors the power companies have identified in assessing SMR feasibility:

Federal support: An important part of project feasibility is cost and risk-sharing with the federal government. These projects would support Canada's goals of phasing out coal by 2030, becoming carbon net zero by 2050 and providing affordable clean energy to remote communities. Additionally, these projects would create a new sub-category of nuclear industrial activity that would see Canada well placed to be a major player in the global

deployment of SMR technologies. Securing support from the federal government in a timely manner is essential to continued progress.

In addition to cost and risk-sharing, the federal government can provide policy support for nuclear energy as a clean technology, ensure regulatory processes are in place to recognize the unique characteristics of SMRs, support research and development through Canada's national laboratories, and ensure a robust framework for the management of nuclear waste from all reactors.

Provincial support: Provincial governments will need to establish policy and regulatory frameworks to enable SMRs as a clean energy option and support training programs to enhance the skilled workforce needed for an SMR industry. In addition, provincial governments can work with power companies to ensure project development is carried out with appropriate oversight, and that public and Indigenous engagement is conducted in a responsible and respectful manner.

Nuclear industry support: A critical success factor for the deployment of SMRs in Canada is a strong domestic supply chain. This includes Canadian small and medium-sized nuclear suppliers, uranium mining, and world-leading nuclear research. The flexibility and experience of these suppliers will be valuable to SMR deployment and complement the capabilities of Canada's manufacturing and engineering companies. Once selection of a fleet model is determined, the power companies would engage suppliers and leverage skilled workforces to ensure readiness for SMR deployment.

Next Step

The next step under the provincial MOU is to develop a strategic plan for deployment of SMRs. This plan will identify steps required within each stream to achieve project commitments in a timely manner, while identifying key risks, mitigation measures, as well as the policy and regulatory analysis required to enable and govern expanded deployment of nuclear technology in Canada.

The strategic plan is to be completed in the spring of 2021.

The provinces of Ontario, New Brunswick and Saskatchewan are proud to lead the way on SMR development in Canada. They will continue to work together and across the nuclear industry, to help ensure Canada remains at the forefront of nuclear innovation, while creating new opportunities for jobs, economic growth and innovation and a lower carbon future.