FEASIBILITY OF

Small Modular Reactor

DEVELOPMENT AND DEPLOYMENT IN CANADA

Prepared *by* **Ontario Power Generation, Bruce Power, NB Power and SaskPower**

MARCH 2021

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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.

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1 Introduction

Canada has a long and proud history in nuclear energy having been in the global nuclear sector since its inception. Nuclear energy is a strategic asset for Canada. Canada is one of the world's few Tier 1 nuclear nations (Tier 1 is defined as those with a full-spectrum nuclear capabilities). The nuclear sector contributes $17 billion to the economy and provides 76,000 direct and indirect jobs[4]. The current refurbishment at the Darlington and Bruce sites are two of the largest infrastructure projects in the country and enable Canada to maintain a strong, innovative, and growing domestic nuclear industry ensuring the province of Ontario has clean, affordable electricity for decades to come. In June 2020, the first refurbishment was completed on budget by OPG at Darlington Unit 2, a strong start to the plans to refurbish 10 units at Darlington and Bruce. At the same time, units at both the Darlington and Bruce site continue to achieve operational records of excellence, the most recent being Darlington Unit 1 which became the world record holder for continuous operation on September 15, 2020 after operating continuously for 963 days. It then continued to operate until it was shut down for a maintenance outage on February 5, 2021, achieving an incredible 1,106 continuous days of operation. New Brunswick is currently the only other province in Canada with grid connected nuclear power, as home to the CANDU6 unit located in Point Lepreau, New Brunswick, owned and operated by NB Power.

Nuclear energy is also an important part of Canada's non-emitting mix and will be critical to achieving Canada's climate change goals. The country is blessed with great resources and while several provinces can use hydro to provide clean electricity, others will need nuclear energy to provide the non-emitting electricity necessary to reduce carbon emissions. The prime example is Ontario, where the closure of coal fired electricity generation enabled by the restart of six nuclear reactors, led to the largest single reductions in GHGs in North America. As Canada moves to eliminate coal fired electricity by 2030 and meet its 2050 emissions targets, nuclear energy is poised to play a valuable role in that transition. In New Brunswick, 80% of in-province electrical energy consumption was supplied from clean energy sources, with 44% from renewable sources, and 36% from nuclear generation (fiscal year 2019/20).

In Canada and indeed the world, electricity markets are demanding smaller, simpler, and lower cost nuclear energy. SMRs are well positioned to lead this transition and Canada has a tremendous opportunity to play a leading role. SMRs are innovative technologies that are designed to provide more flexibility than their predecessors. Smaller plants mean they are more flexible and can be deployed not only in large established grids but also in smaller grids, remote off grid communities and for resource projects. Their innovative designs and features mean they cannot only provide non-emitting baseload generation but their ability to load follow means they can support intermittent renewable sources like wind and solar. SMRs are capable of not only producing electricity but also steam for industrial purposes. In addition, the development of very small modular reactors (under 10 MW) is going to revolutionize the ability to deploy power quickly and virtually everywhere.

SMRs have the potential to become a new industrial subsector, one that is not only Pan-Canadian in nature but with the opportunity to become an international leader. The

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

development of SMRs will provide a post refurbishment growth opportunity for Ontario's nuclear supply chain while creating a SMR manufacturing/export business in New Brunswick. Looking to new domestic markets, SMRs are likely to be deployed in Saskatchewan, Alberta and northern Canada providing not only the benefit of low cost, reliable, clean electricity to enable economic development but the potential to add new, innovative, high value jobs. Like all new economic opportunities, there is a significant first-mover advantage and Canada must move now to secure that advantage.

In November 2018, the Canadian SMR Roadmap was issued[5]. The SMR Roadmap used a collaborative approach to bring together industry, federal, provincial, and territorial governments, as well as utilities and other interested stakeholders that wanted a pan-Canadian conversation about new options for nuclear energy.

The roadmap clearly set out the opportunity for Canada and concluded that collaborative activities in each of four pillars are required to turn this roadmap into reality:

- Demonstration and deployment – to realize benefits for Canadians and for Canada.
- Capacity-building and indigenous and stakeholder engagement – to increase access to information.
- Policy, legislative and regulatory measures – to make the framework more efficient.
- International partnerships and marketing – to position Canada for leadership in global value chains.

In addition to participating in the development of the SMR Roadmap, The Government of New Brunswick invested $10 million to establish the Advanced Nuclear Research Centre to progress the research and design of two Advanced Generation IV (Stream 2) SMR designs. This initial funding was matched by two technology vendors: ARC Clean Energy Canada and Moltex Energy who subsequently opened offices in Saint John. In early 2021 the Government of New Brunswick committed $20 million towards the next phase of development of an advanced SMR research cluster in New Brunswick, which will be supplemented by $30 of developer funding to progress development activities of their advanced technologies[6]. In March of 2021, the Federal Government announced funding to progress the development of advanced SMR development in New Brunswick[7].

Since the release of the Canadian SMR roadmap, work amongst the provincial governments, power utilities and technology vendors has accelerated. On December 1, 2019, the Provinces of Ontario, New Brunswick and Saskatchewan signed a Collaboration Memorandum of Understanding (MOU)[8] that puts in place a framework for action on deployment of SMRs in their respective jurisdictions including:

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[5] 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

[6] https://www2.gnb.ca/content/gnb/en/departments/premier/news/news_release.2021.02.0094.html. https://www.arcenergy.co/news/31/39/ARC-Canada-Awarded-20-Million-in-Funding-from-the-Province-of-New-Brunswick

[7] https://www.canada.ca/en/innovation-science-economic-development/news/2021/03/government-of-canada-invests-in-research-and-technology-to-create-jobs-and-produce-non-emitting-energy.html

[8] 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

1. Addressing climate change, regional energy demand, economic development (e.g., supply chain, fuel manufacture, skilled employment and export opportunities) and research and innovation opportunities;
2. Addressing key issues for SMR deployment including technological readiness, regulatory frameworks, economics and financing, nuclear waste management and public and Indigenous engagement; and
3. Working cooperatively to engage with the federal government to provide policy support for nuclear as clean energy and funding support for SMR development.

This MOU set out concrete steps to move this initiative forward. To fulfil a key commitment under the MOU, the respective power utilities in the three provinces (i.e., OPG, Bruce Power, NB Power and SaskPower) have prepared this feasibility report for the three provincial ministries, including a business case for the development and deployment of SMRs in their jurisdictions.

The next step under the provincial MOU will be to develop a strategic plan for deployment of SMRs including market opportunities across Canada and globally. This plan will identify the steps required within each stream to achieve project commitments in a timely manner while identifying the key risks and the approach to their mitigation and the policy analysis required to clearly set out the requirements for government support. This next report will be completed in the spring of 2021.

2 SMR Market Evolution

The SMR Roadmap assessed the market for SMRs and a preliminary projection was made of their global potential. The result was an estimate of a market of approximately **CDN$150 billion** per year by 2040. This includes applications for electricity generation, remote mine sites, island nations, and off-grid communities. Given the need for time to develop and bring SMRs to market, the opportunity is primarily for delivery after 2030 when full scale SMR production can be in place.

Since the SMR Roadmap was issued, the case for nuclear in general, and SMRs in particular, has continued to develop as the world recognizes that decarbonization goals cannot be met by following a path based on renewables alone.

The International Energy Agency's (IEA) World Energy Outlook (WEO) 2019[9] opens with a stark reality, stating "*the energy world is marked by a series of deep disparities. The gap between the promise of energy for all and the fact that almost one billion people still do not have access to electricity. The gap between the latest scientific evidence highlighting the need for evermore-rapid cuts in global greenhouse gas emissions and the data showing that energy related emissions hit another historic high in 2018. The gap between expectations of fast, renewables-driven energy transitions and the reality of today's energy systems in which \reliance on fossil fuels remains stubbornly high.*"

In its Stated Policies Scenario (SPS), that represents the future based on government policies that have been announced, primary energy demand continues to grow increasing 25% by 2040. Carbon emissions grow by about 7% while fossil fuels continue to dominate, accounting for about 75% of global energy use.

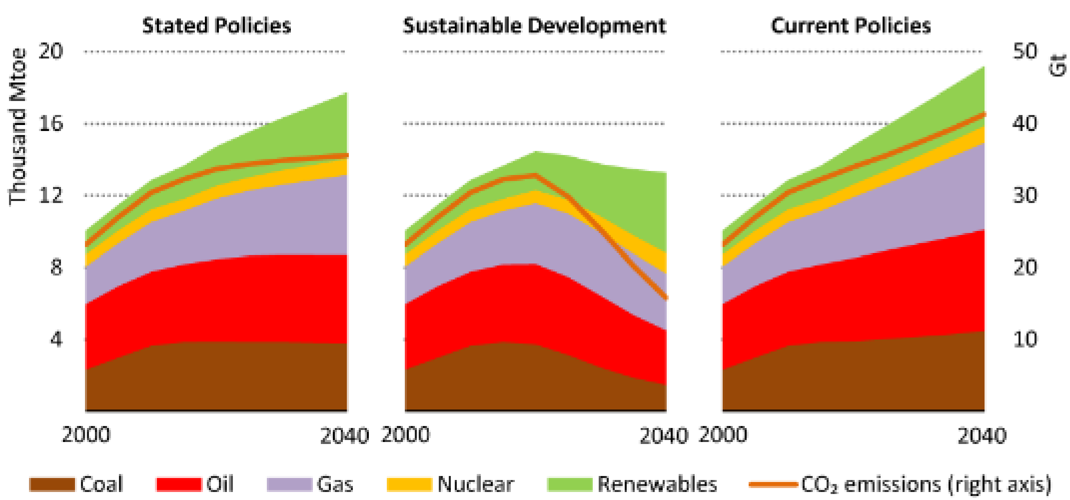

Figure 1 World primary energy demand by fuel and related CO_2 emissions by scenario (WEO Fig 1.1)

The WEO also includes a Sustainable Development Scenario (SDS) to consider how low carbon targets may be achieved. In this scenario electricity use grows at twice the rate of overall energy as it becomes the energy currency of choice in efforts to transition the system into a low carbon one. It is characterized by dramatic increases in energy efficiency resulting

9 https://www.iea.org/reports/world-energy-outlook-2019

in a 7% drop in demand by 2040 (compared to a 25% increase in the SPS) and huge increases in renewable energy, while maintaining the gas share, to meet this goal. With one billion people needing electricity and society's ever-increasing dependence on energy, it is hard to imagine a scenario in which the world uses less energy in 2040 than it does today.

The challenge in meeting the ever-growing energy needs of the world while reducing its carbon footprint is huge. As stated by the IEA, "*More than ever, energy decision makers need to take a hard, evidence-based look at where they stand and the implications of the choices they make*."

Earlier in 2019, in its first report on nuclear power in many years, "Nuclear Power in a Clean Energy System"[10], the IEA acknowledges the important role that nuclear power must play. As stated," *Nuclear power can play an important role in clean energy transitions. Today, it provides 18% of electricity supply in advanced economies, where it is the largest low-carbon source of electricity. Alongside renewable energy and CCUS (Carbon Capture and Sequestration) technologies, nuclear power will* ***be needed*** *for clean energy transitions around the world. Nuclear power also contributes to electricity security as a dispatchable source*."

For nuclear power to meet its full potential in supporting global decarbonization a broad approach is required. This includes:

- Working to ensure the current operating nuclear fleet continues to operate for its full lifetime. Early retirements generally set back decarbonization as these plants are most often replaced with fossil generation. Canada is playing its part in refurbishing its nuclear fleet so that it will operate into the 2060s.
- Continue to build traditional large nuclear plants to meet energy needs. With most Generation III[11] designs having come into service over the past year, they are available for deployment where there are utilities that can accommodate units of these sizes along with their higher capital requirements. Today there are 55 such nuclear units under construction around the world[12].
- Embark upon a program of new SMRs to expand the available market by making nuclear projects more manageable in size, shorter in duration and less in total cost, putting these new projects into the realm of possibility for more utilities, both reducing the capital required for a single project and reducing the overall risk of implementation. This opens up a range of new possibilities and is the basis of the SMR Roadmap market assessment.

In a new report issued in June 2020 (Tracking Clean Energy Progress - Assessing critical energy technologies for global clean energy transitions[13]), the IEA notes that the world is far from on track to meet its Sustainable Development Scenario as set out in its 2019 WEO.

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[10] https://www.iea.org/reports/nuclear-power-in-a-clean-energy-system

[11] Most existing operating nuclear units are considered Generation II plants. Generation III units are evolutions of these operating units building on the decades of lessons learned. Examples are the AP1000, EPR, VVER1200 and APR1400.

[12] https://www.world-nuclear.org/information-library/facts-and-figures/world-nuclear-power-reactors-and-uranium-requireme.aspx (Updated May 2020)

[13] https://www.iea.org/topics/tracking-clean-energy-progress

Renewables are making progress but not fast enough, needing to further accelerate their growth rate. Nuclear power is not on track to meet its goals in this Sustainable Development Scenario. At the current rate of expansion, the nuclear share will fall about one third below 2040 targets.

The key driver for falling short of the goal is nuclear policy uncertainty, partly the result of inconsistencies between stated policy goals – such as climate change mitigation – and policy actions. While the existing nuclear fleet remains the world's second most important low-carbon source of electricity (after hydro), new nuclear construction is not on track with the SDS. Additional lifetime extensions and a doubling of the annual rate of capacity additions are therefore required.

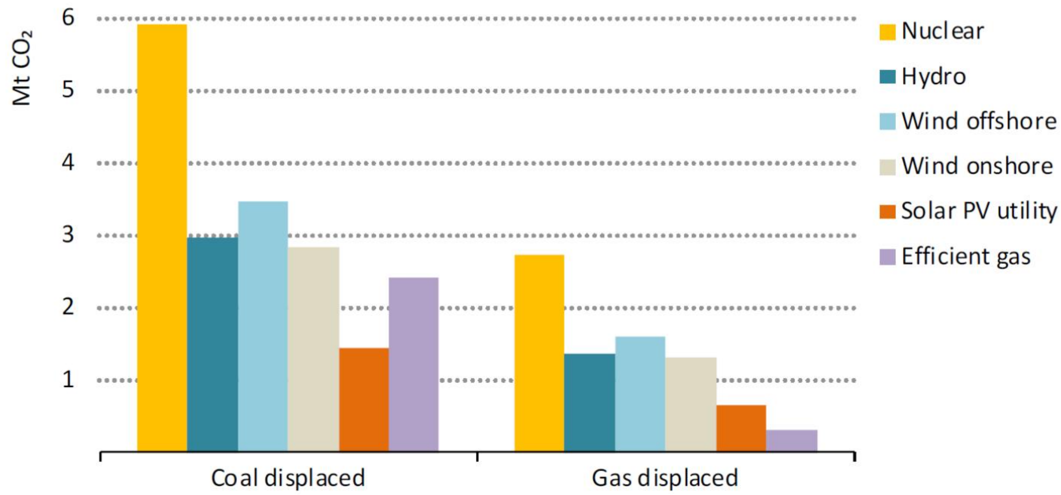
In a just released WEO special report on Sustainable Recovery[14] from the COVID crisis, the IEA notes the critical role played by the energy sector, particularly electricity, in the global response. Uninterrupted energy supplies have been essential to hospitals providing needed health care, delivering food and other essentials, and enabling millions of people to work and study from home while maintaining social contact online. Without access to reliable and affordable electricity, the lockdowns needed to manage the crisis would have resulted in far greater human impact and economic damage.

Now, governments are responding to the economic crisis on a massive scale having announced measures worth about USD 9 trillion, focusing first on emergency financial and economic relief to prevent an even deeper crisis. But with more stimulus coming, attention is now turning to longer-term recovery plans. The IEA is showing that substantial stimulus packages will offer a unique opportunity to put the energy sector on a more sustainable path.

As shown in the figure below, no technology has more impact on carbon reduction than nuclear power.

[14] https://www.iea.org/news/iea-offers-world-governments-a-sustainable-recovery-plan-to-boost-economic-growth-create-millions-of-jobs-and-put-emissions-into-structural-decline

Figure 2.8 ▷ **Annual direct CO_2 emissions avoided per 1 GW of installed capacity by technology and displaced fuel**



Nuclear power avoids more CO_2 emissions per GW of capacity than other fuels.

Notes: Mt CO_2 = million tonnes of carbon dioxide. Efficient gas refers to combined-cycle gas turbines. Applied capacity factors are current global fleet averages for nuclear power, hydro and efficient gas, and global averages for new projects completed in 2019 for wind offshore, wind onshore and solar PV.

Figure 2 CO2 Emissions Avoided by technology and displaced fuel

This is why this newest report once again recommends investing in nuclear and for the first time in an IEA report specifically discusses the potential advantages and benefits of developing and deploying SMRs, with the next critical step being the successful deployment of prototypes and first-of-a-kind plants.

Other countries are progressing their SMR programs

Maintaining first mover advantage is critical to ensure Canada receives the full benefits from developing SMRs. And since the SMR Roadmap was issued, others have not been standing still.

Russia has recently made the news announcing its floating nuclear power plant, the Akademik Lomonosov, has reached its destination in Siberia and has now been declared in service.

Figure 3 Akademik Lomonosov floating nuclear power plant

Closer to home, the USA and the UK have continued to increase their investments into SMRs.

USA

The Nuclear Energy Leadership Act (NELA) was passed on 23 July 2019. This act was designed to help the industry develop new products that will allow them to continue to compete and instructs the Secretary of the Department of Energy to take certain actions to re-establish America as a leader including:

- To set up at least one Power Purchase Agreement (PPA), before the end of 2023.
- To complete at least two advanced reactor demonstrations by the end of 2025 and up to five before 2035.
- To develop a 10-year strategic plan that supports advanced nuclear R&D goals and will foster breakthrough innovation to help advanced reactors reach the market.
- To create the capacity for fuel production that will ensure commercial availability of High-Assay Low-Enriched Uranium (HALEU) fuel.
- To create a University Nuclear Leadership Program/Workforce Development Scheme that will provide a world-class, highly skilled workforce

On February 6, 2020 the USDOE published a Request for Information (RFI)/Notice of Intent (NOI) on its Advanced Reactor Demonstration Program in which they indicated that they would spend US$160million (C$210million) for the first year of two advanced reactor demonstrations contributing up to 50% of the costs and a further US$30million (C$40million) for the first year of risk reduction on a range of other advanced reactor developments where they would contribute 80% of the costs. The RFI/NOI is issued to "*solicit information from advanced reactor developers and other interested parties that DOE requires to inform its aggressive strategy to demonstrate two advanced reactor designs within five to seven years of award, and two to five smaller awards to address technical risks in other advanced designs*". On May 8, 2020 the formal request for bids was issued with proposals due in August 2020.

This work, as with all other work paid for by the USDOE (US Department of Energy), must be performed in the United States.

This funding is of a scale that will ensure progress towards demonstration.

In parallel the US Department of Defence has initiated "Project DiLithium" to investigate small (1-10 MWe), transportable (<40 tonnes) SMRs to support tactical deployments. With a clear customer, full funding, and the possibility of fast track licensing this could bring about the first fully developed SMR units and a guaranteed early fleet market.

Further, in April 2020, based on the work of the US Nuclear Fuel Working Group, the Secretary of Energy announced The Strategy to Restore American Nuclear Energy Leadership which recommends:

- Taking ***immediate and bold action to*** strengthen the uranium mining and conversion industries and ***restore the viability of the entire front-end of the nuclear fuel cycle.***
- Utilizing American technological innovation and advanced nuclear RD&D investments to consolidate technical advances and ***strengthen American leadership in the next generation of nuclear energy technologies.***
- Ensuring that there will be a ***healthy and growing nuclear energy sector*** to which uranium miners, fuel cycle providers, and reactor vendors can sell their products and services.
- Taking a whole-of-government approach to ***supporting the U.S. nuclear energy industry in exporting civil nuclear technology in competition with state-owned enterprises***.

In May 2020, the DOE Announced $27 Million for Advanced Nuclear Reactor Systems Operational Technology. And in June, the US International Development Finance Corporation (DFC) has proposed policy changes that would remove a prohibition on it providing support for nuclear power projects. This would enable the DFC to offer financing for projects to deploy technologies such as small modular reactors (SMRs) in developing countries. On October 13, 2020 the USDOE announced[15] that X-energy and TerraPower were selected under the Advanced Reactor Demonstration Program (ARDP) and will each receive $80 Million of funding towards deploying their designs in the US within 5 to 7 years. They plan to invest $3.2 Billion over 7 years in support of this program. On October 16[16], the USDOE approved a multi-year cost share award that could provide up to $1.4 billion to help demonstrate and deploy a 12-module NuScale power plant located at Idaho National Laboratory with the first power module operating at the lab by 2029.

[15] https://www.energy.gov/ne/articles/us-department-energy-announces-160-million-first-awards-under-advanced-reactor

[16] https://www.energy.gov/ne/articles/doe-approves-award-carbon-free-power-project

The United Kingdom

The United Kingdom is also seeking to re-establish itself as an international leader in nuclear technology and sees SMRs as one route to achieving this ambition. It expressed support for domestic SMR development in the 2016 budget. That phase of development concluded in December 2017, with the publication of a series of techno-economic assessments of SMRs.

Figure 4 Rolls Royce SMR

In November 2019, the government confirmed that it is investing £18 million (C$31million) match funding, through the Industrial Strategy Challenge Fund, in the UK SMR consortium led by Rolls-Royce. Just recently in June 2020, the consortium has submitted proposals to Ministers to accelerate the building of a new fleet of up to 16 SMRs in the North of England by 2050. The plan could see construction of high-tech factories to build the small reactors begin as early as next year.

The government is also offering a range of targeted support for advanced nuclear technologies, including small reactors, as part of the nuclear sector deal. Having completed a feasibility study on 8 reactors BEIS is expected to invest up to a total of £44 million (C$75million) in a short list of these designs through the Advanced Modular Reactor (AMR) Feasibility and Development project.

On June 23, 2020, the UK Nuclear Industry Association (NIA) has released "Forty by '50: A Nuclear Roadmap," an assessment produced for the Government/Industry body, the Nuclear Industry Council. This NIC-endorsed report says that, in addition to helping meet long term goals, prompt decisions on a new nuclear power program could unlock mega-projects delivering immediate benefits to help tackle the impact of COVID-19. It recommends an ambitious program—based on existing and new technologies—to provide up to 40% of clean power by 2050 and drive deeper decarbonization through the creation of hydrogen and other clean fuels, along with district heating.

Most recently, on July 10, 2020 the UK government announced the award of £40 million to kick start next-gen nuclear technology going to three advanced reactor developers and for research activities.

3 Commercial Availability of SMR Technologies for Deployment in Canada

As identified in the Pan-Canadian SMR Roadmap, SMRs cover a wide range of power levels, designs, technological readiness levels and end user applications. In Canada, that can range from traditional on-grid generation to co-generation, heavy industry, mining, and remote community applications.

To meet this broad-based Canadian need, the four Utilities (SaskPower, OPG, Bruce Power and NB Power) have been working collectively and investing over the last two years to develop three streams of SMR projects. The three streams of projects will help create flexibility and growth opportunities for communities connected to the grid (Stream 1), will support advancement in nuclear technology and innovative methods to reduce nuclear by-products (Stream 2), and will bring affordable, clean energy to remote communities and mines (Stream 3).

OPG, Bruce Power and SaskPower are planning for design selection for an on-grid Stream 1 reactor in 2021 that will be deployed at the Darlington site in Ontario targeting first power by 2028. Taking advantage of the availability of the licensed facilities at Darlington and Bruce Power site would confirm Canada's first mover advantage and support the next phase of the Stream 1 fleet for Saskatchewan to enable its electricity decarbonisation starting in the early 2030s.

NB Power continues to develop two advanced reactor designs in Stream 2 with the potential deployment timeline at their Point Lepreau Nuclear Generating Station site between 2030 - 2035. These advanced SMR designs bring additional benefits such as enhanced levels of safety which lead to simple low-cost designs and the ability to effectively recycle their own used fuel and reduce current inventories of used CANDU fuel. They have co-generation capabilities for potential application with heavy industry, desalination or hydrogen production, superior load following characteristics to support the intermittent nature of renewable forms of electricity production and have the potential of a substantial export market.

Stream 3 are micro SMRs that can be used for displacing diesel generation currently used in remote areas for mining, and in northern remote communities for heat and electricity generation. These could be demonstrated at the Canadian Nuclear Laboratory site(s) with a first project, a USNC Micro Modular Reactor (MMR) demonstration unit supported by OPG, completed as early as 2026. In addition, Bruce Power and its partners have been exploring opportunities in remote communities for deployment of additional micro-SMR's.

Unlike the development of the CANDU reactor in the past, the majority of the costs to develop and deploy these three streams will come from the private sector, however financial and policy support from the Government of Canada is critical to provide a clear signal to investors.

The following sections provide more details on the streams and high-level plans.

3.1 Stream 1 – Developing SMRs in the short term to provide a clean and innovative energy option

Stream 1 represents an opportunity for early deployment of grid sized SMRs in Canada. Work is underway to move forward with a fleet of grid-scale SMRs with technologies that are ready to deploy thus enabling a clean and innovative energy option for electricity systems which will provide economic, reliable generation for decades, all while further developing the Canadian nuclear supply chain. OPG, Bruce Power and SaskPower are collaborating to complete design selection for an on-grid Stream 1 reactor in 2021 that will first be deployed at the Darlington site in Ontario targeting first power in 2028. Taking advantage of the "shovel ready" status of the licensed nuclear site at Darlington would confirm Canada's first mover advantage and support the next phase of the Stream 1 SMR development in Saskatchewan to support its electricity decarbonization plans with the potential for SMR deployment in the early 2030s. Part of the first mover advantage is the ability to sustain and build Canada's nuclear supply chain which has been strengthened by the CANDU reactor refurbishments in Ontario.

Meeting the need for energy in Saskatchewan while enabling decarbonization requires new low carbon generation from the first SMR to be available as early as 2032. This can be followed by a fleet of similar units about every three years to 2042 to continue the province's move away from fossil generation. Deciding on a first nuclear plant is a big decision for a nonnuclear jurisdiction. Although Saskatchewan is home to the world's highest-grade uranium ore and best-known non-government owned uranium mining company, it currently has no nuclear generation. Almost 75% of its generation is fossil – coal and gas. As part of its plan to introduce nuclear generation and to mitigate its risk of going forward with this new technology, it would like to benefit from the vast expertise already available in other parts of Canada, in Ontario and New Brunswick, by companies who have been operating nuclear plants for decades.

Ontario currently meets about 60% of its electricity needs from nuclear energy and is home to much of the well established Canadian nuclear industry. It is currently in the midst of a large life extension program for its current nuclear fleet. The $26 Billion refurbishment projects at OPG's Darlington site and Bruce Power's Bruce site are the largest clean energy projects underway in Canada. This has reinvigorated and recapitalized the Canadian supply chain which is in an excellent position to take on the development and deployment of a new technology to follow these refurbishments.

OPG has just recently declared the first of its units to be refurbished, Darlington Unit 2, back in service after completing a 44-month refurbishment outage on budget. This demonstrates the strong capability within Ontario to deliver large complex nuclear projects to cost and schedule. In addition to this very recent success, OPG has other important attributes that make it suitable to launch the first of a kind (FOAK) of a new SMR technology. Combined with the nuclear expertise and excellence brought to the table by Bruce Power, the collaboration between these two companies make Ontario the ideal site for the FOAK SMR technology.

Of most importance, the Darlington site is already licensed to prepare for a new build. The environmental assessment has been performed and the regulator has provided a Power Reactor Site Preparation License (PRSL). This means that OPG can move quickly to help Canada maintain the important first mover advantage to demonstrate a new SMR technology at the site. The next step in the CNSC licensing process after site preparation is the application of a license to construct based on the SMR technology to be selected by OPG. The willingness to consider a FOAK unit and the ability to get started now has attracted interest from a number of SMR developers. In exchange, it is anticipated that Canada will receive economic benefits from the selected developer by providing it an opportunity for FOAK build followed by a Canadian fleet in terms of locating supply in Canada to make use of its already strong and ready supply chain. This will maximize the benefits to Canada of SMR deployment and provide the necessary demonstration to launch the SMR industry.

A study undertaken for Ontario and Saskatchewan by the Conference Board of Canada (CBOC)[17] assesses the economic impact of SMRs in both provinces.

A single demonstration unit built in Ontario and operated for 60 years would result in the following economic impact to Ontario and Canada as whole:

For Ontario:

- Create direct, indirect, and induced employment on an average annual basis as follows:
  - 684 jobs during project development
  - 1,604 jobs during manufacturing and construction
  - 210 jobs during operations and
  - 163 jobs during decommissioning
- Have a positive impact on GDP (direct, indirect and induced) of over $2.5 billion
- Result in an increase of provincial revenues of over $870 million

For all of Canada (including ON):

- Create direct, indirect, and induced employment on an average annual basis as follows:
  - 742 jobs during project development
  - 1,939 jobs during manufacturing and construction
  - 296 jobs during operations and
  - 183 jobs during decommissioning
- Have a positive impact on GDP (direct, indirect, and induced) close to $3.4 billion
- Result in an increase of government revenue of over $1.1 billion

Following this demonstration unit in Ontario, a fleet of four units in Saskatchewan each operated for 60 years would result in the following economic impact:

For Saskatchewan

- Create direct, indirect, and induced employment on an average annual basis as follows:
  - 718 jobs during project development
  - 7,042 jobs during manufacturing and construction
  - 728 jobs during operations and

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[17] "A New Power: Economic Impacts of Small Modular Nuclear Reactors in Electricity Grids", Conference Board of Canada, March 2021

    - 833 jobs during decommissioning
- Have a positive impact on GDP (direct, indirect, and induced) of over $8.8 billion
- Result in an increase of provincial revenues of over $3 billion

For all of Canada (including ON):

- Create direct, indirect, and induced employment on an average annual basis as follows:
    - 786 jobs during project development
    - 10,516 jobs during manufacturing and construction
    - 1,173 jobs during operations and
    - 1,015 jobs during decommissioning
- Have a positive impact on GDP (direct, indirect, and induced) of $13.5 billion
- Result in an increase of government revenue of over $4.3 billion

In a post COVID world, this is the most shovel ready SMR project anywhere and will be the first of a pan Canadian fleet. In summary the Stream 1 pathway:

- Provides a clean energy option for meeting future electricity demand and reducing emissions on provincial electricity systems
- Ensures the advantages of the Darlington site are exploited to secure the best economic development for Canada from a potential SMR developer
- Leverages the expertise and existing infrastructure of the two Ontario based operators, OPG and Bruce Power
- Supports the development of the Saskatchewan market together with SaskPower to be ready to meet the Saskatchewan requirements for low carbon capacity
- Moves quickly to demonstrate SMR deployment with a product that is near ready today being in a position to select a technology by the end of 2021 followed by a decision for the first project in 2023 (subject to licensing approval)
- Supports a SMR fleet to 2050 creating opportunity for other new jurisdictions to follow
- Ensures Canada remains a first mover and leader in SMR development

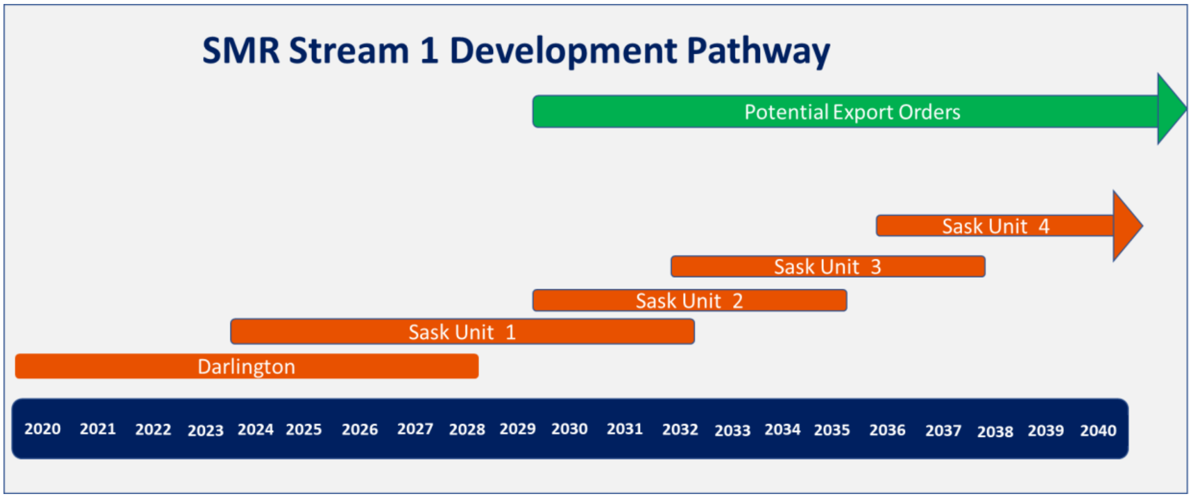

Figure 5 Stream 1 Development Pathway

The current state of development for Stream 1 is to select a technology that can meet this shovel ready project timeline and be a first mover amongst SMR developers. To date, OPG, Bruce Power and SaskPower have been leading a process to identify technologies that can meet their requirements for deployment with a manageable risk profile.

In October 2020, OPG announced it is advancing engineering and design work with three grid-scale Small Modular Reactor (SMR) developers: GE Hitachi, Terrestrial Energy and X-Energy. The utilities will go through a rigorous review to determine who can best meet the Stream 1 requirements with regards to technology readiness, economics, and potential for Canadian content, with a final technology selection planned to be made at the end of 2021.

3.2 Stream 2 - Advanced On-grid SMRs being developed in New Brunswick

As part of the overall energy supply planning and to address the requirements for green-house gas emission reductions, starting in 2017, NB Power reviewed various nuclear supply options. The potential benefits of the emerging SMR market was noteworthy and warranted further assessment. As a result, NB Power examined the potential benefits of various grid sized SMR technologies for New Brunswick.

NB Power reviewed a large selection of small modular reactors technologies for on-grid application. Based on a number of criteria such as increased level of nuclear safety, proliferation resistance, reliability, environmental sustainability, reduction in waste volumes, fuel supply, cost competitiveness, technological readiness, public acceptance and potential for economic benefits, NB Power focused on advanced fast neutron spectrum reactors.

Advanced fast spectrum SMRs are generally known as Generation IV reactors. They use a coolant other than water, such as molten salt or sodium and have inherent safety characteristics, simpler design, lower cost, ability to recycle their own used fuel, and will have superior ability to follow the intermittent output from renewable power sources. Conventional nuclear reactors do not produce much high-level radioactive waste (HLRW) because they are a high-density power source. Advanced fast reactors can reuse their own used fuel many times over to produce up to about 100 times less (HLRW) than their Generation III predecessors and with a relatively shorter life cycle for disposal. Furthermore, these SMRs have the ability to reuse CANDU used fuel reducing the volume and associated long term storage requirements.

Reactor designs that have the above-mentioned attributes, when combined with today's advanced manufacturing and modularization techniques are expected to be cost competitive with fossil fuel generation and would present a tremendous opportunity for New Brunswick and Canada.

Aware of this opportunity, and the advantages that Canada has to progress the development and deployment of SMRs as identified in the Pan-Canadian SMR Roadmap, in the summer 2018, the Government of New Brunswick committed $10 million toward the establishment of an advanced SMR Research Cluster in New Brunswick[18]. Based on the earlier technology review, Moltex Energy and Advanced Reactor Concepts (ARC) through its subsidiary ARC Clean Energy Canada, Inc. (ARC Clean Energy), were selected and elected to join the cluster, each investing matching funds of $5 million to progress research and development of their advanced technologies[19]. In early 2021 the Government of New Brunswick committed $20 million towards the next phase of development of an advanced SMR research cluster in New Brunswick, which will be supplemented by $30 of developer funding to progress development activities of their advanced technologies[20]. In March of 2021, the Federal Government announced over $50.5 million in funding for Moltex Energy and over $6 million to NB Power and the Centre for Nuclear Energy Research to progress the development of advanced SMR development in New Brunswick[21]. Later in March 2021, OPG's Centre for Canadian Nuclear Sustainability announced it would provide $1 million in funding to support the development of the Moltex fuel conversion technology[22].

In addition to the broad benefits of SMRs such as low carbon emissions and factory build supporting rapid deployment, these advanced reactors share the following specific characteristics;

- The reactivity feedback is such that if they get too hot the power automatically decreases without any intervention, so the fuel can't overheat avoiding fission product release from the fuel
- They are non-pressurized pool type reactor designs so there is no large pressure difference to provide a motive force for fission product transport should the fuel fail for any reason
- The coolants have excellent fission product retention characteristics should fuel fail for any reason
- More inherent safety characteristics and use of low-pressure reactor vessels means the reactor requires many less engineered systems and components leading to lower

[18] https://www2.gnb.ca/content/gnb/en/departments/erd/news/news_release.2018.06.0832.html
[19] https://www2.gnb.ca/content/gnb/en/news/news_release.2018.07.0906.html. https://www2.gnb.ca/content/gnb/en/departments/erd/news/news_release.2018.07.0930.html
[20] https://www2.gnb.ca/content/gnb/en/departments/premier/news/news_release.2021.02.0094.html. https://www.arcenergy.co/news/31/39/ARC-Canada-Awarded-20-Million-in-Funding-from-the-Province-of-New-Brunswick
[21] https://www.canada.ca/en/innovation-science-economic-development/news/2021/03/government-of-canada-invests-in-research-and-technology-to-create-jobs-and-produce-non-emitting-energy.html
[22] https://www.opg.com/media_releases/opg-collaborating-with-moltex-to-study-clean-energy-solutions/

construction costs and less operating and maintenance staff leading to lower Operating and Maintenance costs
- The physical nature of the designs provides excellent load following capability leading them to support a grid with a larger component of renewable energy
- They produce high temperature steam which allows them to have co-generation capability for use with either industrial applications as well as hydrogen production.
- They can recycle their used fuel repeatedly to consume much of the radionuclides with the highest levels of radiotoxicity and longest half-lives (the transuranics / actinides), significantly reducing their amount.

In terms of their unique attributes:

The ARC-100 is a 100 MW(e) liquid sodium cooled fast reactor. It uses HALEU metallic fuel and has a 20-year refuelling cycle. It is a proven technology as demonstrated by the Experimental Breeder Reactor II (EBR-II) at Argonne National Laboratories. This prototype ran safely and effectively for more than 30 years. EBR-II also demonstrated the ability to recycle its used fuel and the use of other types of fuel.

The Moltex SSR-W is a 300MW(e) stable salt fast reactor. Its liquid fuel is derived from used Uranium Dioxide fuel, such as used CANDU fuel using the WAste to Stable Salt (WATSS) process. The fuel salt is in individual fuel tubes and as such, is separate from the liquid coolant salt. This improves corrosion control, simplifies safeguard accounting and verification, simplifies reactor physics modelling and avoids fission products circulating though out the coolant system. It uses on-power refuelling and will recycle its used fuel, allowing existing inventories of used CANDU fuel to be used to generate power and be recycled again and again converting it largely to shorter lived fission products. The plant design incorporates a Grid Reserve System for storing heat, which allows the plant to provide peaking power for shorter periods of time up to three times the nominal power. This supports the use of intermediate renewable energy sources as well as smoothing out daily power peaks. The use of salt tanks for storing heat is a much lower cost way of storing energy relative to battery storage commonly associated with the use of renewable energy.

Since 2018, both vendors have established offices in Saint John New Brunswick and hired staff, progressed their designs, progressing through the CNSC Vendor Design Review process, advanced their project planning, and worked with UNB to establish chair positions, curriculum, and plans for R&D to be performed at CNER/UNB. Both vendors have performed supply chain studies and have held discussions related to establishing a supply chain in New Brunswick. They have also been active in discussions and engagement within the province to increase understanding of advanced Small Modular Reactor technologies.

NB Power has been actively progressing engagement activities with First Nations representatives and the general public to both inform and to listen to potential concerns. They are also providing technical support to the vendors, and progressing project planning activities.

Both Vendors have also been actively progressing activities to ensure that fuel will be available in a timeline to supply the demonstration units.

- Moltex is working on the conceptual design for WATSS and validation activities at UNB and CNL are underway to demonstrate the economics of the process and to develop the design of the industrial scale facility. The plan is to co-locate the

WATSS facility alongside the SSR-W on the Point Lepreau site to avoid the unnecessary transportation of used CANDU fuel.

- ARC Clean Energy is working with fuel suppliers to ensure a secure supply of HALEU and with Canadian fuel manufacturers for the manufacture of the metallic fuel bundle assemblies for the first unit. It should be noted that several different reactor designs use HALEU fuel and it is a priority of the US Department of Energy to assist fuel suppliers establish this capability. Further, conceptual work is occurring regarding a reconstitution facility to allow the reuse of the ARC-100 fuel as well as the ability to deal with used CANDU fuel. Given the 20-year fuel cycle, this facility is not required for the first unit.

No technical impediment is foreseen in providing the supply of fuel for either design. Discussions with NRCan are on-going to ensure there are no inhibitors for the import of HALEU from countries capable of supplying HALEU. Discussions with NRCan are also on-going to ensure there are no inhibitors for the type of fuel reprocessing associated with these two technologies, which by the nature of the processes used, are more proliferation resistant than the processes used more widely around the world.

The ARC Clean Energy ARC-100[23] and the Moltex SSR-W[24] technologies have different market applications and are well suited for Canadian and international markets. The SSR-W provides a solution to those countries with existing inventories of used fuel, and its larger size is well suited for countries such as Canada, UK, US and Europe. The ARC-100, with its smaller size, cogeneration capability and 20 year fuel cycle and capability to recycle its used fuel and use other fuels, is ideal for application in western Canada. Its relatively low expected cost should be affordable for smaller utilities. It is ideal for applications such as desalination and hydrogen production, for which there is demand all around the globe. Like the SSR-W, it can be an excellent clean energy replacement for stranded fossil fuel assets. Both vendors are engaged in discussions in Canada and abroad to obtain finances that are required to progress subsequent phases of their project. NB Power staff are supporting this endeavor by engaging with the vendors, Government and NB academia to provide assistance to increase the likelihood of success and to progress overall planning. NB Energy and Resource Development staff resources continue to support the initiative through regular engagement with the vendors, NB Power, Government, and NB academia.

New Brunswick is an attractive location because it has a population that is generally supportive of nuclear power and has an experienced nuclear operator with a solid reputation with the regulator and for innovation. The Point Lepreau Nuclear Generating Station site is attractive and is a valuable strategic asset to the province. It is well characterized and can accommodate at least two demonstration reactors in addition to the existing well run nuclear plant. There have also been a number of environmental and ecological risk assessments performed over the years providing an excellent base to draw upon.

The motivation or value proposition for the province of New Brunswick for the development and deployment of advanced Generation IV SMRs is the establishment of a new industrial supply sector and fleet support services to supply modules, equipment, and services for these

[23] https://www.arcenergy.co/technology
[24] https://www.moltexenergy.com/stablesaltreactors/

advanced designs aimed at both the Canadian and international markets. This supply sector would be largely based in New Brunswick and would build upon and leverage the existing strong Canadian Nuclear Supply chain that is largely centered in Ontario.

This is possible due to the market opportunities arising from the additional advantages the Stream 2 advanced generation IV SMRs designs bring.

Recognizing both the need for ever increasing energy demand around the world, and the need to reduce the carbon footprint, these designs address many of the current reservations the general public has towards nuclear and are projected to be cost competitive with other forms of energy and affordable in terms of capital cost. This results in a potential market not only within New Brunswick with potential export to neighbouring jurisdictions, but elsewhere in Canada and more significantly internationally.

Supply chain assessment studies by both vendors have shown that between 50 to 60% of the components could be manufactured in New Brunswick, and this figure could be increased with some capability development. Much of the remaining components can be supplied within the rest of Canada. This high percentage is made possible due to the simplicity of design resulting from the inherent safety characteristics of these advanced designs; however, the capacity of the New Brunswick facilities will need to be expanded considerably to meet the anticipated demand.

Information from market studies, supply chain assessments, construction, site operation and fleet services operation were used to produce an economic impact assessment of the potential of the Stream 2 technologies. Based on the results of the NB SMR Economic Impact Analysis[25], the activities required to develop the technologies, finalize the designs, construct/commission, and complete the owner/operator pre-operational activities for the two NB advanced on-grid SMR demonstration units at Point Lepreau will have the following one-time economic impact during the 2020-2035 timeframe:

Table 1 NB SMR Technology development and two demonstration units (2020-2035)

Technology development and demonstration units	**Person-years of employment**	**GDP**	**Government Revenue**
New Brunswick	11,280	$1.06B	$120M
Canada	21,870	$2.15B	$198M

The successful development of the technologies and operation of the demonstration units will lead to fleet deployment in New Brunswick, Canada and Internationally. The graphs in Figure 6 and Figure 7 include the potential economic impact of the deployment of the two fleets. They include impacts from engineering, supply chain, construction, commissioning,

[25] small reactors, big opportunities – Investing in Small Modular Reactor (SMR) technology is a made in New Brunswick contribution to the low carbon economy. https://www.nbpower.com/en/about-us/in-the-community/point-lepreau-nuclear-generating-station

operation, and on-going fleet technical support and assume a fleet size of 1 GW(e), 4 GW(e), and 50 GW(e) in New Brunswick, rest of Canada and Internationally respectively.

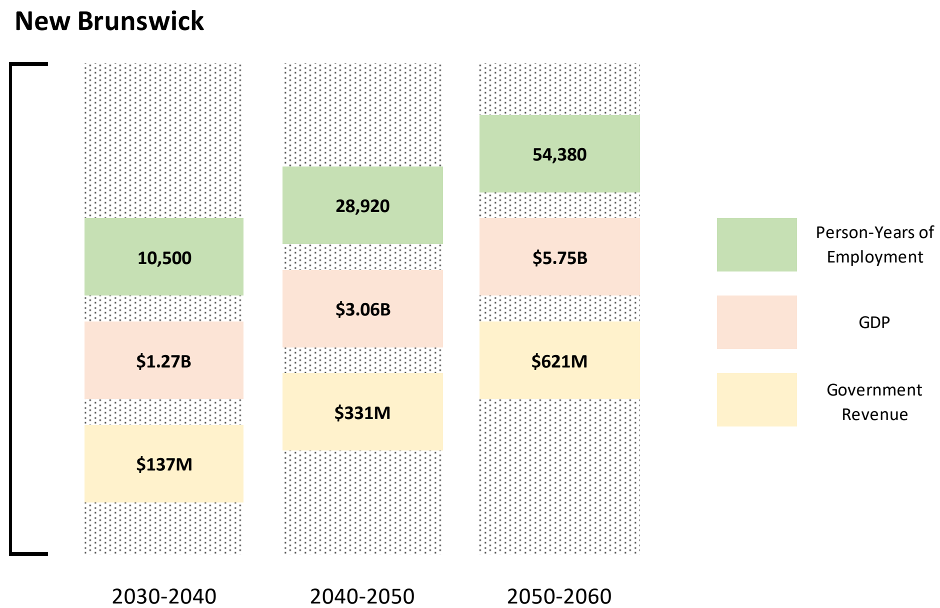

Figure 6 New Brunswick economic impact of fleet deployment

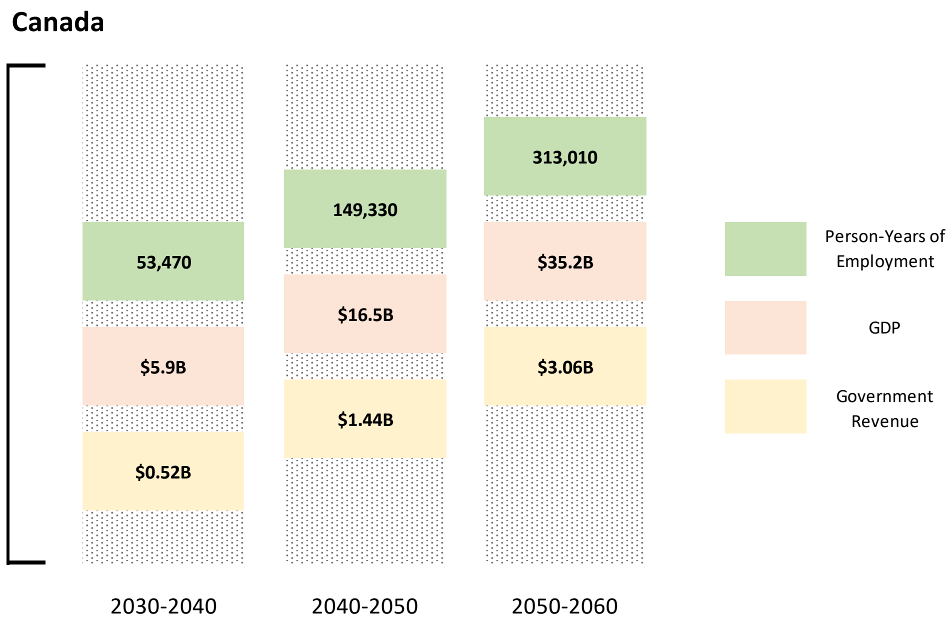

Figure 7 Canadian economic impact of fleet deployment

The all of Canada results indicate the value proposition for Canada is analogous to that for New Brunswick; that being economic development, clean energy to meet demand and fight climate change, and fuel the growth of science and innovation.

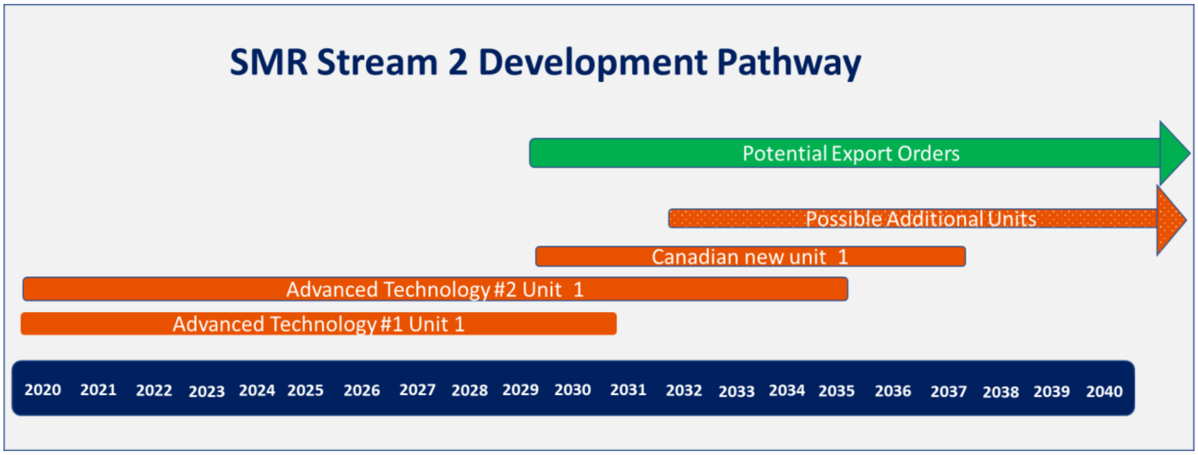

Figure 8 Stream 2 Development Pathway

Central to the ability to attract the export market is the need for a commercial demonstration of these two technologies. This is envisioned to take place at the Point Lepreau Nuclear Generation Station site which already houses Atlantic Canada's only CANDU 6 reactor. This additional nuclear capacity is one of the options being considered to meet the energy needs for the province which considers projected demand, GHG reduction, SMART grid evolution and retirement of generation assets such as the Belledune coal fired station. It is envisioned the owner consortium would sell electricity to NB Power under a Power Purchase Agreement. Several different business models are being investigated however all of them rely on spreading the development costs over a number of units. Federal support in providing financial backstops for risk mitigation for the FOAK projects, such as loan guarantees, cost overrun protection and risk sharing some of the life cycle costs of management and disposal of radioactive waste is also viewed as essential.

3.3 Stream 3 – small micro reactors for off grid use

The small micro-reactors of stream 3 range in size from approximately 2 - 15 MW thermal energy although they can be joined in parallel to increase the net output. These reactors offer the possibility of significant portability that has not been possible in civilian nuclear power until now. The portability can be achieved not only by transporting the smaller modules to a remote site by road or rail but also by constructing both the reactor and the deployment platform in a central site and then transporting both to site as a single unit ready to operate. A number of different platforms are possible but one of the most promising is a marine platform constructed at a shipyard with the small reactor installed before it is towed to site.

The reactors are very safe and simple to operate. This combined with their small size offers the possibility of installation in industrial facilities or in larger marine vessels.

The primary market in Canada for these very small reactors is for off-grid use, to support mining or other industrial applications, and to power remote, mostly indigenous communities. Currently these markets are dependent upon diesel fuel to meet their energy needs resulting in relatively high carbon emissions and increasing risks of ensuring adequate fuel supply at their sites due their remote locations.

Both reactor designs, currently being reviewed in Canada use high temperature gas as the reactor coolant with a variety of secondary side outputs. The eVinci, being explored by Bruce

Power and its partners, uses heatpipe technology to operate a small Brayton cycle turbine to produce electricity in a very small unit compared to today's reactors. The USNC reactor likewise uses high temperature gas as the reactor coolant to provide process heat to an adjacent plant, via a molten salt heat exchange system. OPG is partnering with USNC as Global First Power (GFP) to construct a reactor prototype on the CNL site and is currently pursuing an environmental assessment to support CNSC Licensing. Many vendors make claims about their designs allowing for electricity generation that is cost-competitive with diesel generation: one of the primary goals of the GFP project is to test that claim and determine a commercial model for off-grid deployment of vSMRs.

Building a four-unit 20 MW USNC plant at a single mining site would create the following economic impact[26]:

For Ontario:

- Create direct, indirect, and induced employment on an average annual basis as follows:
  - 221 jobs during project development
  - 525 jobs during manufacturing and construction
  - 199 jobs during operations and
  - 154 jobs during decommissioning
- Have a positive impact on GDP (direct, indirect, and induced) of over $659 million
- Result in an increase of provincial revenues of over $235 million

For all of Canada (including ON):

- Create 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
- Result in an increase of government revenue of over $311 million

The first micro SMRs likely to be deployed as commercial demonstrators as early as 2026 have the capability to truly transform the nuclear industry by providing energy to those that have never considered the nuclear option before.

[26] "Emerging Frontiers: Economic Impacts of Very Small Nuclear Reactors in Remote Off-Grid Mining" Conference Board of Canada, October 28, 2020

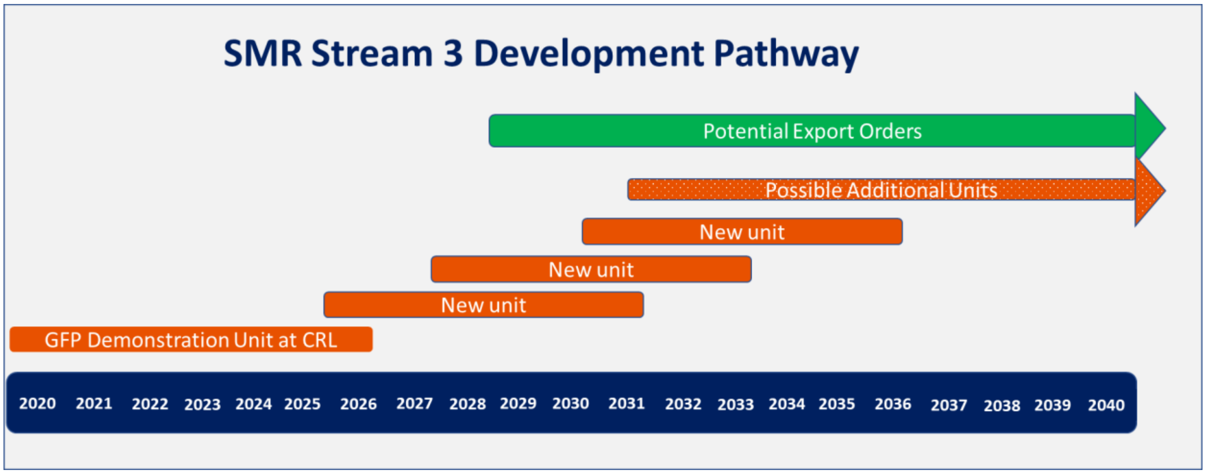

Figure 9 Stream 3 Development Pathway

4 Economic Competitiveness of SMR Technologies

The global nuclear industry is working to disrupt the market with the development of SMRs. The objective is to simplify designs, reduce overall capital requirements and enable shorter project construction times, to the benefit of the market. Traditional economies of scale are to be overcome through the economies of numbers, where large fleets of standard plants should give rise to lower costs in both capital and operation.

The lower outputs mean they can access markets not previously open to conventional nuclear power while proximity to the customer and higher operating temperatures open the possibility of providing both heat and power. SMRs will target not only traditional on-grid electricity generation to replace fossil fuels as the fuel of choice; but also, the needs of heavy industry and mining, as well as support remote communities who do not have ready access to energy. The economic assessments are different for each market segment.

The Economic and Financing Working Group (EWFG) performed a rigorous economic analysis as part of the Canadian SMR Roadmap. It included an exhaustive literature search resulting in numerous inputs based on developer data, academic studies and other literature. Since the roadmap was issued, there has been little new published data to drive any great change to the SMR roadmap analysis and, as such, it remains valid today, especially given the uncertainty in SMR cost inputs.

As shown in the roadmap, the range of capital cost estimates is large. The estimates for more advanced designs that are earlier in their development cycle tend to be lower than those for more traditional light water designs who have done more work to substantiate their cost estimates. This may be due to more optimism by their developers at this stage of development. Or, as proposed by advanced design proponents, it may be that the additional inherent safety and other features will reduce costs, making these designs more economic than scaled down light water reactors. In all cases, there is insufficient work completed to date to provide reliable cost estimates.

The economics of potential on grid SMRs is shown in Figure 10. SMRs have the potential to be economically competitive, especially compared to other low carbon alternatives. Not shown in the figure is the variation specific to a given province. The economics for on-grid application of SMRs will depend upon the alternative low carbon emitting options available to each jurisdiction. For example, gas prices vary considerably throughout the country with very low prices in the west and higher prices in Ontario and the Maritimes. In some scenarios, SMRs compete with gas even without carbon pricing. Adding a price for carbon or carbon capture technology to gas fired generation will enhance the competitiveness of SMRs.

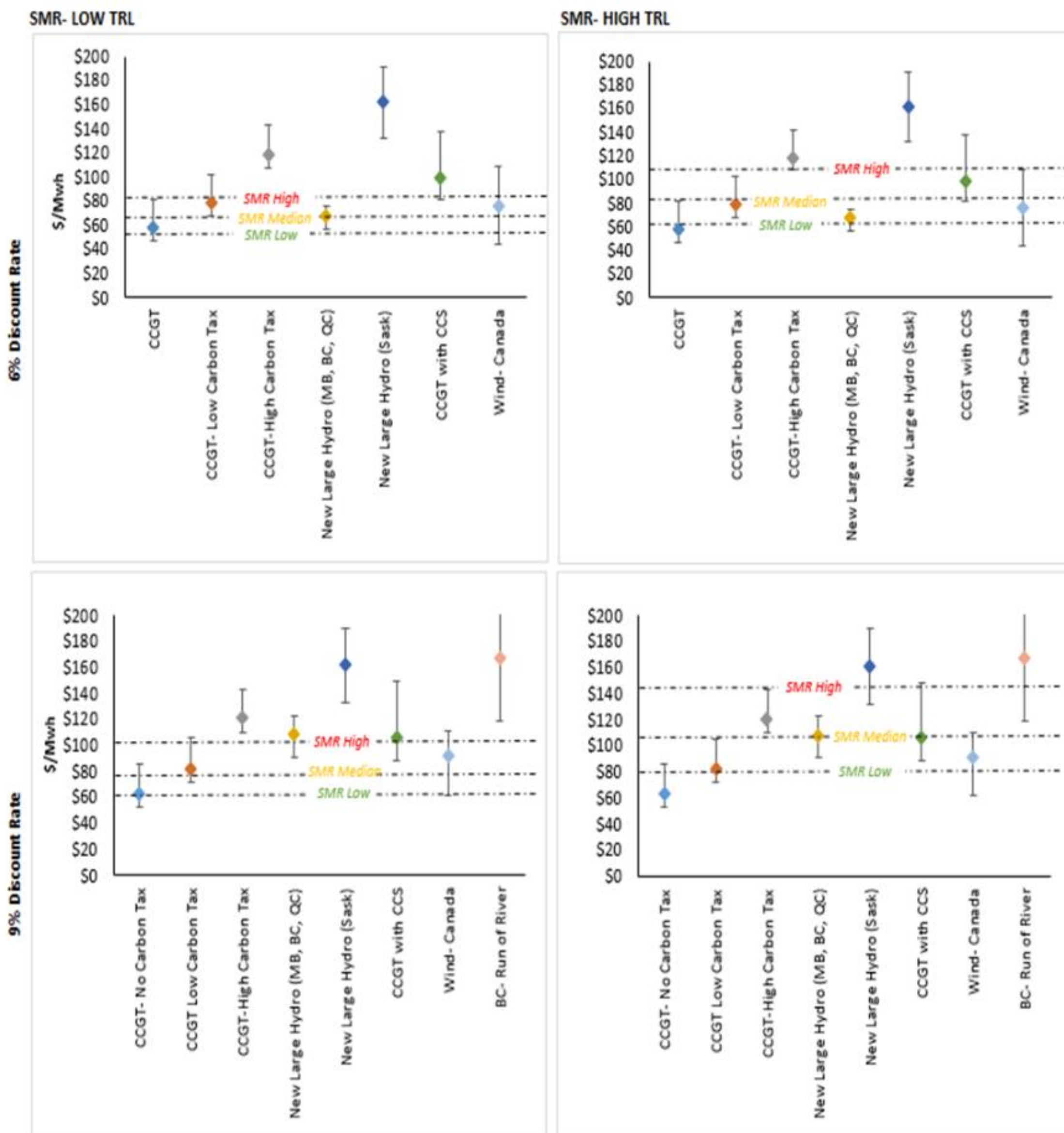

Figure 10 On-grid LCOE at 6% and 9% discount rates

One issue is that Levelized Cost of Electricity (LCOE) is no longer the best approach to determining competitiveness. It is intended to compare similar alternatives to be implemented in a single spot on the system with similar system characteristics. With variable, intermittent, renewables on the system, LCOE alone no longer provides a basis for direct comparison. System costs to maintain the reliability of renewable generation as delivered by dispatchable resources like nuclear, hydro and fossil generation are substantial and increase the larger the penetration of renewables.

A 2018 study undertaken by MIT "The Future of Nuclear Energy in a Carbon Constrained World" considers the impact of nuclear power on the cost of electricity systems when deep decarbonization is desired. It looks at various jurisdictions around the world and the conclusion is always the same; the cost of electricity is lower with a larger nuclear share than trying to decarbonize with renewables alone.

This MIT study looks at a range of scenarios, first varying the cost of nuclear power to illustrate its impact on its future share, and then looking at deeper and deeper decarbonization from a reference system that emits 500 g/kWh all the way down to a fully decarbonized system emitting only 1 g/kWh. The figures below show that as each system is decarbonized the scenarios with nuclear tend to reduce the average cost of generation with the largest impact being once systems reach deep decarbonization of 10 g/kWh, or less, as using predominantly intermittent energy sources with storage becomes more and more difficult.

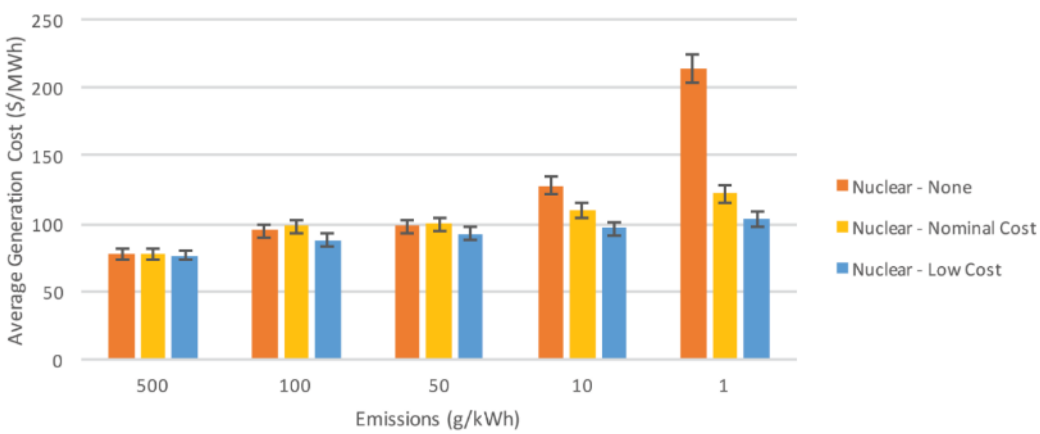

Figure 11 New England cost of electricity generation (MIT Fig 1.5a)

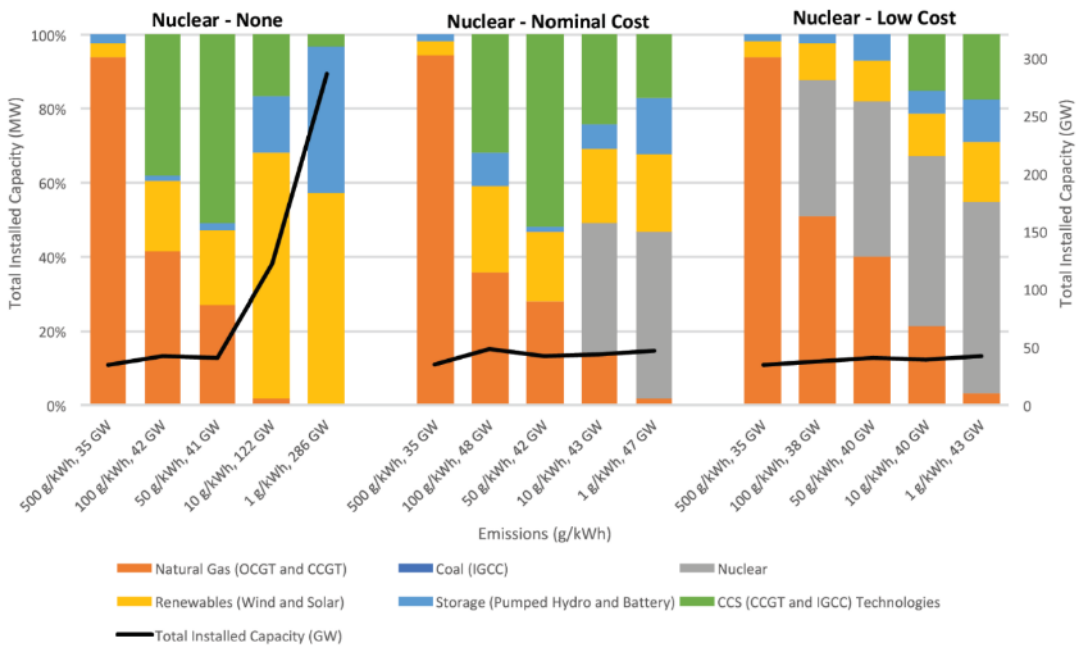

Figure 12 Optimal capacity mixes for New England (MIT Fig 1.6)

The reason for this impact is more clearly shown in the figure looking at the optimal capacity mixes. As the amount of dispatchable fossil generation is reduced, in the case of New England, which is currently predominantly gas, the share of renewables increases. Since renewables are intermittent and have relatively low capacity factors, the amount of renewables required, as they become an increasing share of the total systems, rises dramatically.

Solar and wind only generate when the sun shines and the wind blows, meaning they produce only some of the time and not always when needed. Figure 13 below from the WEO shows the average capacity factors of these technologies in various countries with the world average capacity factor of 17% for solar and 29% for wind. Contrast this with the 24/7 availability of nuclear power, which can operate at capacity factors of more than 90%.

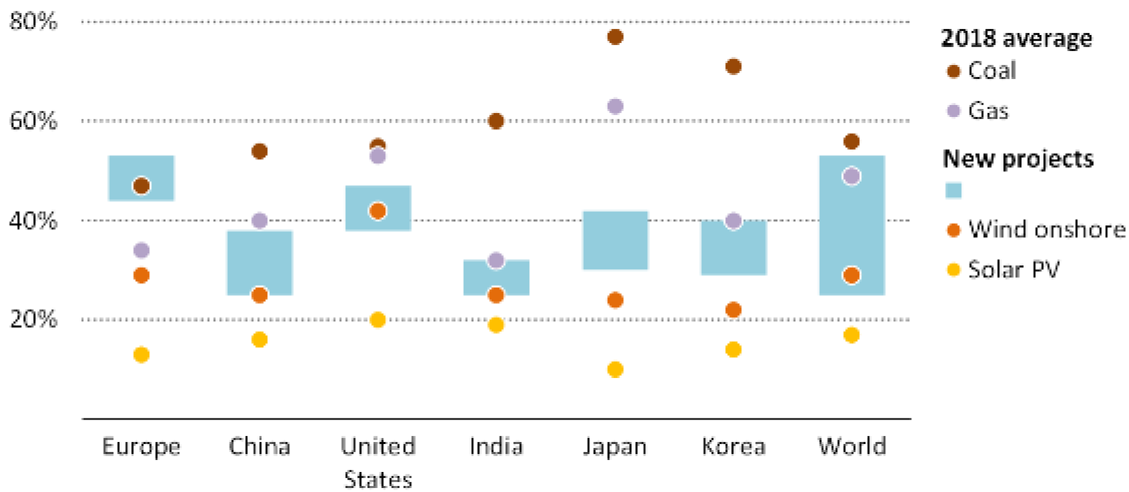

Figure 13 Average annual capacity factors for various power generation technologies by country (WEO Fig 1.16)

The impact on electricity systems is clear. In New England, in the base case the total system capacity is 35 GW but grows to 286 GW for a fully decarbonized system without nuclear while only growing to 43 to 47 GW depending upon the nuclear costs (lower nuclear costs increase the nuclear share and reduce the size of the system). This confirms that nuclear should play a larger role in the future electricity mix.

This was further substantiated by Staffan Qvist (co-author of "A Bright Future") in a study presented at the WNA Annual Symposium in September 2019 for Sweden, which from a resource perspective, is in a better position than most to achieve 100% renewables. The results of his modelling (using a similar model to the MIT study), looking at about 20 different scenarios for full decarbonization, always come out the same; in every scenario the most cost-effective system has continued long-term operation of existing nuclear.

With the potential established, the real question becomes what must be done to ensure this outcome? The LCOE for SMRs is most sensitive to two parameters, cost of capital and capital cost. Each is considered in more detail below.

Figure 14 Sensitivity of LCOE for on grid SMRs to key parameters (source: SMR Roadmap)

The following figure shows that the LCOE from a FOAK unit can be almost double the expected outcome for an Nth of A kind (NOAK), fully developed, commercial unit which would be achieved following a number of units being deployed (the number varies for different designs). Significant improvements in delivery are needed to achieve these reductions.

Figure 15 Estimated cost reductions from first SMR to commercial deployment (Source: SMR Roadmap)

In Saskatchewan, Ontario, New Brunswick and Nova Scotia, the utilities are regulated, although they do allow some private generation with the specific approach depending upon the jurisdiction. Only Alberta has a fully de-regulated market. It is managed by the AESO. With regulated cost of capitals applied to an SMR project there can be a big improvement in cost (LG + Reg Return bar in chart). Then comes the reduction in capital cost attributed to learning. This is where the use of factory build, repeating the same tasks in a controlled environment for a large fleet, is essential to product success.

Canada already benefits from the relatively low cost of nuclear energy. Table 2 shows that nuclear is the second lowest cost source of electricity on Ontario next to hydro.

Table 2 Ontario Cost of Energy by type

Generation	Total unit cost ¢/kWh
Nuclear	8.9¢
Hydro	6.0¢
Gas	14.3¢
Wind	14.8¢
Solar	49.7¢
Bioenergy	25.1¢

Source: Regulated Price Plan, Price Report, November 1, 2020 to October 31, 2021, Ontario Energy Board, October 13, 2020

For off-grid SMRs to be implemented in remote communities, the main source of competition is diesel generation creating a different competitive target than for on-grid units.

The figure below shows the results in the SMR roadmap analysis when comparing the costs of SMRs versus diesel in these remote communities. The results show a strong potential for SMRs to save communities a considerable amount from their energy bills. The only exception is for very small communities where the costs are near breakeven.

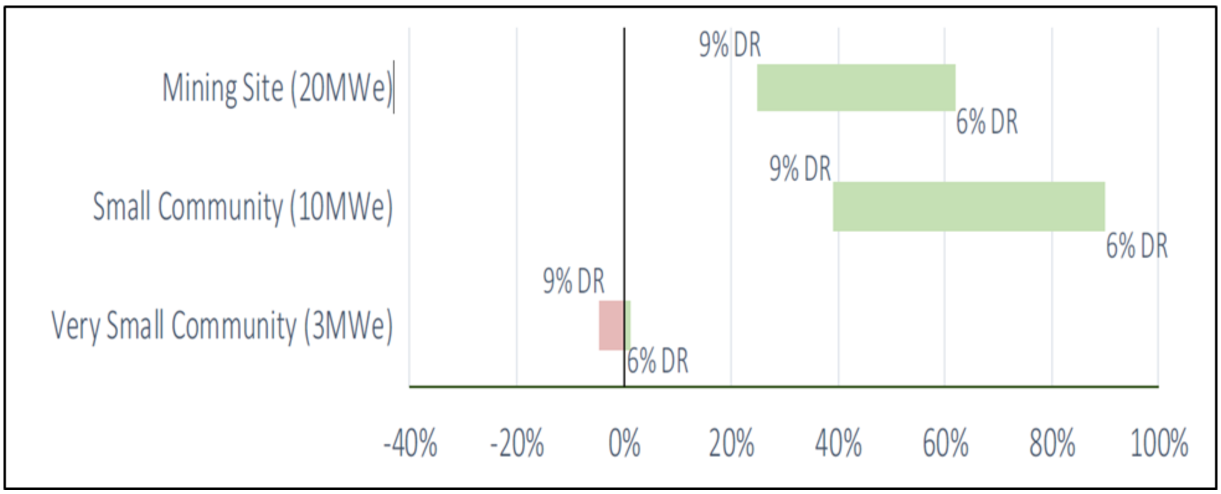

Figure 16 Potential Savings when implementing SMRs in remote communities (LCOE)

For off-grid communities there is a more recent study conducted by the US Nuclear Energy Institute (NEI)[27]. This study confirms the analysis previously performed for the SMR roadmap and estimates the cost to generate electricity, from these very small reactors, will fall by about a third as factories build capacity and experience, once again supporting the need to build these units repetitively in significant numbers. The range of costs is due to variations in transport accessibility, site conditions, the technology, the ability to reduce future costs through lessons learned and the type of owner, i.e., private or public. The diesel generation costs are primarily driven by the cost of fuel and the cost to transport the fuel to remote locations.

[27] https://www.nei.org/resources/reports-briefs/cost-competitiveness-micro-reactors-remote-markets

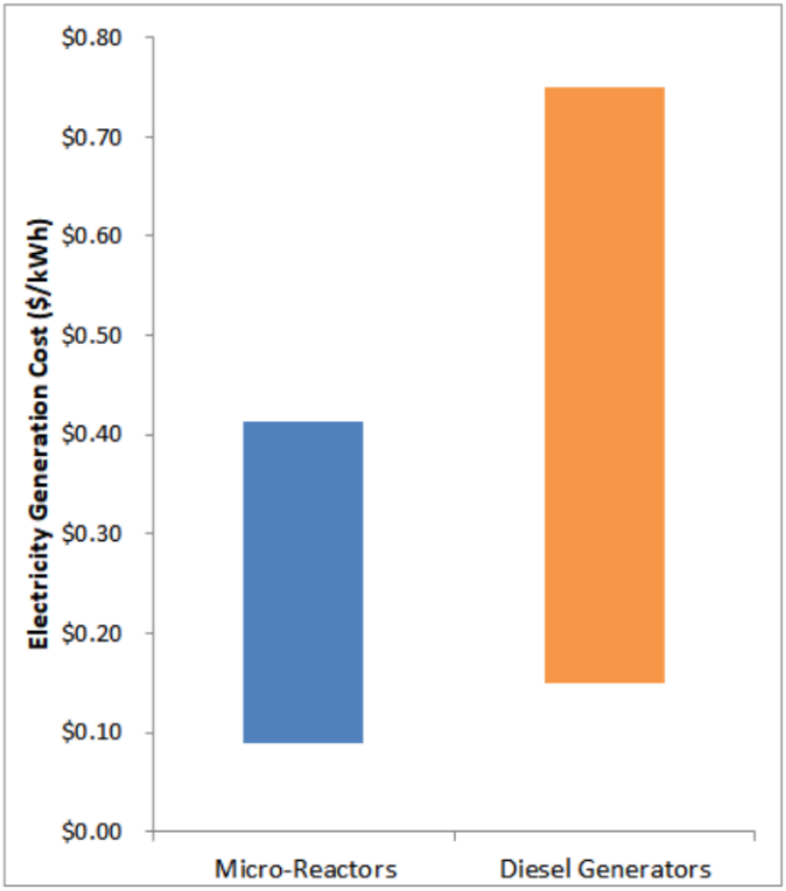

Figure 17 Estimated LCOE of Micro-Reactors and Diesel Generators
Source: NEI Study 2019

5 Key Requirements for SMR Feasibility in Canada

It is widely acknowledged that climate change is one of the greatest challenges facing the world. For Canada and the world to meet the Paris Accord climate targets, Canadians must change their production and use of energy.

Canada is fortunate to have an abundance of energy sources and a highly skilled, innovative energy sector. Canada can lead the way by using that knowledge and by harnessing all of its energy sources to not only meet its targets but help the world meet its targets as well.

For that to happen, greater electrification in areas like transportation, industrial processes and resource development will be required as electricity becomes the clean energy currency of the future. While several provinces can use hydro to provide clean electricity, others will need nuclear energy to provide the non-emitting electricity necessary for greater electrification.

SMRs are as their name implies smaller plants but they are more flexible and can be deployed not only in large established grids but also in smaller grids, remote off grid communities and resource projects. SMRs can play a critical role in reducing the emissions intensity of resource projects such as oil sands and natural gas thus enabling continued development of those critical sectors.

As stated in the SMR Roadmap, SMRs are a clear route to addressing Canada's climate change targets and represent an essential tool in decarbonizing the electricity sector. Once this new technology is adopted to achieve climate goals, it becomes so much more. The additional potential benefits for Canada include:

- Creation of a new industrial sub-sector
- Anchoring cutting-edge research in Canada
- Canada at the centre of a global export market
- Leadership in the mining sector
- Global leadership in SMR policy expertise
- Canada as an international standard-setter
- Meeting Canada's climate change commitments
- Unlocking regional growth opportunities
- Constructive partnerships and a positive energy dialogue

It is this broad range of benefits that have supported a pan Canadian vision for SMR technology. As a result, the SMR Roadmap recommended that there is an essential role for the Canadian government in supporting SMR success. It recommended that:

- The federal government and provincial governments interested in SMRs should provide funding to cost share with industry in one or more SMR demonstration projects for advanced reactor designs.
- Federal and provincial governments should implement measures to share risk with private investors to incentivize first commercial deployment of SMRs in Canada, with the potential of exporting SMR technologies and related innovations developed in Canada to international markets.
- The federal government should work to align the modernization of Canada's federal impact assessment process with other initiatives to develop and deploy SMRs.

- The federal government should review liability regulations under the *Nuclear Liability and Compensation Act*, in order to ensure that nuclear liability limits for SMRs are aligned with the risks they pose, using a graded scale based on risk informed criteria.
- Building on the constructive dialogues that were launched under the Roadmap, federal, provincial and territorial governments and utilities interested in SMRs should continue with meaningful, two-way engagement with Indigenous peoples and communities on the subject of SMRs, well in advance of specific project proposals.
- The federal government, with support from industry, labs, and academia, should continue strong and effective international engagement on SMRs. In particular, to influence the development of international enabling frameworks for these technologies.

This support from the government of Canada can be summarized as falling into two broad categories: a) policy support, and b) financial support.

5.1 Policy support

Canada is continuing to lead when it comes to supportive nuclear policy. Its SMR Roadmap issued in 2018 is seen across the world as an example of how to proceed with new SMR development. Since that time government has committed to preparing an SMR Action Plan to be issued later this year.

Of most importance, the government, through the Minister of Natural Resources Canada, has stated unequivocally that nuclear is clean energy, and that the government's ambitions to achieve carbon net zero by 2050 can only be achieved with nuclear energy as part of the solution. This is in stark contrast to that stated by the IEA in its clean energy progress report issued this June, that nuclear is falling behind its potential due to the lack of policy action by government.

Further policy action is needed at a more detailed level, to ensure that regulatory processes in place to support SMR development are not a barrier for SMR development and licensing. Again, this is an area where Canada can be a world leader. One of the advantages Canada is generally seen to have in the effort to become a world leader in SMR development is a regulatory process that is more safety goal oriented than rule based. While Canada's existing regulatory framework is capable of handling SMRs there are still some regulatory and procedural changes necessary to recognize the lower inherent risk and safety of SMRs.

As SMR projects will be smaller and less complex than existing nuclear projects, regulatory certainty remains a critical consideration for investors and operators. Because SMRs have a smaller output and therefore smaller revenue stream, it is essential that the regulatory process acknowledge and credit their inherent safety and reduced risk. For SMRs to be successful, investors and operators must have certainty in the regulatory process with respect to transparency, costs, and timelines. And given the smaller cost and shorter schedules to deploy this technology, regulatory costs and schedules need to be shortened when compared to traditional larger units. For example, to deploy an SMR as the power source for a mine in a remote community, the cost and time to secure approval for the SMR cannot be longer and more complex than securing approval for the mine itself. This would create an impediment to considering this option rather than choosing the well-known and understood, but carbon intense, diesel for generating this energy.

Similarly, once a reactor is licensed and operational, the licensing of subsequent units should be significantly more efficient provided there are no design changes. This will provide investors and operators the certainty necessary to move forward with a fleet approach which is necessary to make the business case for SMRs.

Among the advantages of SMRs is a reduced inherent risk, improved safety margins and design improvements that lead to reduced maintenance and staffing requirements, including security and emergency staff but these changes need to be reflected in CNSC policies and regulations. The CNSC's framework applies a risk informed and graded approach to SMRs. The result of this approach for specific SMR projects is subject to regulatory decision-making but would allow for a licensing strategy that is proportional to the safety risk of each SMR technology.

5.2 Financial support

The real measure of government support for SMR development is making funding available for needed activities. The decision in Ontario to proceed with life extending the nuclear fleet through refurbishment at Darlington and Bruce at a cost of $26 Billion, and the earlier life extension of Point Lepreau in New Brunswick, is testament to the commitment to a nuclear future.

Developing a new generation of technology that meets pan Canadian needs for clean energy while bringing economic benefits to those communities that implement these projects and the broader Canadian supply chain requires investment.

Financial support required includes:

Stream 1

- Support for the CNSC licensing of the FOAK technology to be deployed as part of Stream 1 in Ontario (four-year funding commitment, starting in 2021)
- Support for site selection, SMR vendor selection, development of site and construction license applications, impact assessment and engagement required to support SMR deployment in Saskatchewan (five-year funding commitment starting in 2020 and matched by SaskPower).

Stream 2

- Support for each of the two advanced SMR technologies being developed in New Brunswick for On-grid application:
    - Complete preliminary design, R&D, CNSC VDR Phase 2, progress waste discussions with NWMO and input into the environmental studies and begin work on detailed design.
    - Support for demonstration of ONWARD project to demonstrate conversion of used CANDU fuel to molten salt fuel (WATSS) technology
    - Provide backstops for the commercial demonstration unit (loan guarantees, cost overruns, long term waste liability)
    - Includes existing SIF and/or SDTC applications. Recommended the applications be approved as soon as possible

- Support for NB Power to conduct environmental studies, site placement studies, pre-licensing activities, Engineering support and work to secure private financing for two commercial FOAK demonstrations at the Point Lepreau Nuclear Generating site
    - Government of New Brunswick's initial investment, which was matched by the vendors is fully allocated, and NB Power's operating budget is subject to Energy and Utilities Board approvals. This support is critical to being able to continue to leverage NB power's nuclear expertise while respecting the existing regulatory rate setting process.

Stream 3

- Support for the OPG GFP demonstration project at Chalk River by sharing costs with OPG and the private sector
- Support for a federally sponsored Westinghouse Canada eVinci Micro Reactor demonstration project within Canada by 2026.
- Recognition that Stream 3 technologies could reduce GHG emissions by replacing fossil-fueled energy for remote communities and for industrial and resource extraction operations (e.g., mining, oil sands, and hydrogen production). Federal cost-sharing of Stream 3 projects could lead to Canadian job creation & supply chain maturity, as well as position Canada with an early mover advantage in the SMR export market.

6 Key Requirements for SMR Feasibility in Ontario

6.1 On-grid SMR development at the Darlington nuclear site

6.1.1 Project Objectives

The Objectives of an SMR project at the Darlington site include:

- To maintain a diverse generation supply mix to minimize carbon emissions from electricity generation in the province
- To demonstrate a FOAK SMR to be ready for deployment across Canada by 2030
- To ensure economic development by securing Canadian content both for domestic and export projects from the developer in exchange for providing the opportunity to deploy their FOAK unit and be a first mover towards an SMR fleet

6.1.2 Project Description

The project is to build a 300 MW class SMR at the Darlington site

Project Schedule**:** To be in service by 2028. A preliminary project schedule is shown in the figure below.

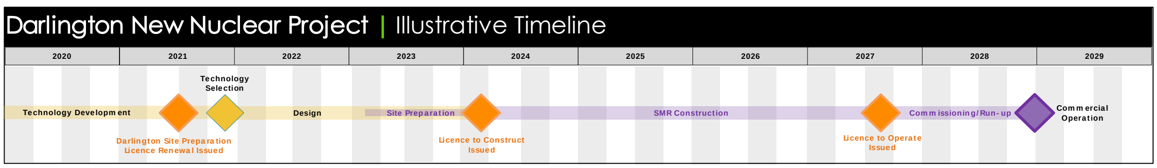

Figure 18 DNNP Potential Milestones and Timeline

Technology**:** To be selected through a collaboration between OPG, Bruce Power and SaskPower planned for 2021. A FOAK design is acceptable. A review process is underway, and based on progress to date, it is anticipated that a suitable technology will be available.

Project Cost**:** The capital cost of the project is expected to be less than $3 Billion (overnight capital cost) resulting in an LCOE of less than $100/MWh.

Additional Support: OPG and its partners Bruce Power and SaskPower are requesting support from the federal government over 4 years to support FOAK costs and risks in licensing and to acknowledge the costs incurred that will benefit future customers across Canada such as SaskPower.

6.1.3 Assessment of Feasibility

a. *The market* - Ontario's system operator's (IESO) reference case planning assumes modest but positive load growth: approximately 1% annually through 2040 in both energy and summer peak load. With the scheduled Pickering closure in 2024/2025, 3000 MW of baseload low carbon generation will be lost. OPG's assessment is that undertaking this opportunity to deploy an SMR, essential to SMR success across Canada, will meet anticipated energy and capacity needs in Ontario. Adding baseload generation capability post 2030 will allow the system to meet demand growth largely driven by modest growth in the residential, commercial and agricultural sectors, as well as the increased electrification of transportation, with non-carbon emitting generation. In addition, OPG's assessment is that SMRs can provide stable backup support for wind and solar generation on the system to contribute to system reliability. The alternative is to continue to use gas as a flexible generation option that will increase carbon emissions as demand and capacity needs arise. The IESO high growth scenario further supports implementing an SMR. This will also ensure that the Ontario based operators will be in a good position to deploy further units should decisions be taken to increase electrification of transport and home heating in the years ahead to meet carbon net zero targets by 2050.

b. *Economic benefits* - Ontario is home to a mature, multi-billion dollar nuclear industry that is a source of innovation in nuclear and non-nuclear applications. Ontario's nuclear supply chain consists of more than 200 companies that manufacture major components and specialized equipment as well provide engineering services for nuclear power stations in Canada and around the world. Development and deployment of SMRs represent new opportunities for Ontario's world-class nuclear industry to grow further and export their products and services around the world.

A study undertaken for Ontario and Saskatchewan by the Conference Board of Canada[28] assesses the economic impact of a SMR unit at Darlington operated for 60 years as:

For Ontario:

- Create direct, indirect, and induced employment on an average annual basis as follows:
  - 684 jobs during project development
  - 1,604 jobs during manufacturing and construction
  - 210 jobs during operations and
  - 163 jobs during decommissioning
- Have a positive impact on GDP (direct, indirect, and induced) of over $2.5 billion
- Result in an increase of provincial revenues of over $870 million

For all of Canada (including ON):

- Create direct, indirect, and induced employment on an average annual basis as follows:
  - 742 jobs during project development
  - 1,939 jobs during manufacturing and construction
  - 296 jobs during operations and
  - 183 jobs during decommissioning
- Have a positive impact on GDP (direct, indirect, and induced) close to $3.4 billion

[28] "A New Power: Economic Impacts of Small Modular Nuclear Reactors in Electricity Grids", Conference Board of Canada, March 2021

- Result in an increase of government revenue of over $1.1 billion

c. *Technology readiness* – During 2020, OPG, Bruce Power and SaskPower have been reviewing developers and their proposed SMR technologies. In October 2020, OPG announced it is advancing engineering and design work with three grid-scale SMR developers: GE Hitachi, Terrestrial Energy and X-Energy. The reviews undertaken so far demonstrate the schedule can be achievable for more than one technology. Risk remains related to the time required to license a new technology in Canada (see below) and the ability to move forward the design and ready the supply chain. The utilities continue to work with the developers to fully assess the work required to meet the schedule. This work will be critical over the next year to make the final technology selection by the end of 2021.

d. *Cost and competitiveness* - A preliminary assessment based on the data provided by the developers under consideration results in potential LCOE values less than $100 /MWh supporting economic feasibility (with estimates currently at a Class 5 level). This compares well to the prices for wind ($91/MWh) and solar ($162/MWh) based on the latest LRP2 clearing prices escalated to 2019 $'s. Lower costs for wind and solar are being projected in other jurisdictions. The impact on future costs in Ontario is unknown. More work is required to confirm project costs and economics as the selection is made and the project develops.

e. *Regulatory readiness* – All designs under consideration have their vendor design reviews (VDR) with the CNSC underway. The CNSC has never licensed a commercial reactor design that is not CANDU. As the global standard for nuclear, light water designs are considered low risk and the CNSC VDR process is a valid approach to determining regulatory risk prior to final technology selection.

f. *Schedule risk* – OPG's assessment is that the timing of the project both meets the need for capacity in Ontario and importantly, completes the FOAK project in time to provide the necessary risk mitigation to Saskatchewan. As a nonnuclear jurisdiction, Saskatchewan is looking to Ontario as an expert in nuclear operations to support it taking the step to implement SMRs and a commitment by OPG and Bruce Power to be first goes a long way to alleviating concerns.

g. Fuel availability – Consideration of different designs needs to account for whether they use traditional light water reactor fuel or a more advanced fuel. Most SMR designs require enrichment which also has a healthy international market. Light water reactor fuel is unlikely to be localized in Canada but is readily available on the open market. Other SMRs that might be considered require fuel that has more development ahead of it (e.g., advanced reactor designs using metallic, ceramic or intermetallic fuels). However, if the technology is selected, the fuel may be more likely to be produced in Canada although the enrichment services would be imported. One of them uses a fuel which requires High Assay Low Enriched Uranium (HALEU), for which the supply chain requires some development.

6.1.4 Summary

A 300 MW SMR would be a clean source of energy and deliver needed capacity to the Ontario electricity system. The energy generated by the SMR would maintain generation diversity to support ongoing reductions in carbon emissions.

An SMR is likely to be economic compared to low carbon alternatives and it is anticipated the project can meet the desired schedule.

An SMR project at Darlington is expected to generate thousands of jobs and billions of dollars in economic activity in Ontario and across Canada, as well as create new growth and export opportunities for Ontario's nuclear companies.

Public and Indigenous engagement efforts around the Darlington site have been ongoing, in addition to Indigenous consultations required under the Federal duty to consult as part of Canada's regulatory processes. Building and maintaining relationships with the public and Indigenous communities remains an important and ongoing aspect of the project.

Federal support for up front design selection and licensing is required to mitigate these risks as the benefits of success apply beyond Ontario to other provinces.

6.2 Off-Grid Development Project at the Chalk River site

6.2.1 Project Objectives

The Objectives of building the FOAK MMR at the Chalk river site include:

- To demonstrate the technology in Canada
- To serve as the model for potential future deployment under commercial contracts to energy end users in the heavy industry/mining and remote community markets
- To secure economic benefits for Canada from being a first mover

6.2.2 Project Description

OPG has entered into a relationship with USNC to be known as Global First Power (GFP) for the deployment of a FOAK micro SMR at the Canadian Nuclear Laboratories' Chalk River site.

Technology - The project will be to build the MMR reactor designed by USNC. A single 5 MWe unit (15 MWth) will be built to demonstrate the technology. Future units will be two-unit 10 MW plants to replace diesels at mines and for remote communities.

Project schedule – To be in service in 2026.

Project cost – Estimated to be less than $200 M (overnight capital cost). The demonstration unit is expected to be jointly funded by OPG, USNC and the Federal Government. A PPA to cover the ongoing operating costs is required to mitigate operating risk. Investment costs would be recovered from future commercial units.

6.2.3 Assessment of Feasibility

a. *The market* – MMRs are intended to replace diesel, which is the current energy source in the north. The benefits relate to combating climate change and improving the quality of life in remote communities. There are currently 200-300 MW of remote mines that are candidates for vSMRs, but some of these mines will likely be at or nearing end of life by the time the SMR market develops. The potential exists for SMRs at future mines, but this has been conservatively excluded from the current assessment. A market exists for remote community uses in a small number of larger communities. Below is the projected demand for the 10 MW USNC MMR units in the remote mining and remote community markets, based on the different market studies. Each market study assumed the levelized cost of an MMR would be equal to diesel, therefore displacing it.

Below is an aggregate summary of the two markets:

Table 3 Project Demand for 10 MW USNC MMR Units

	2031-2040	**2041-2050**	**Total**
Remote Mining	1-3 units	2-4 units	3-7 units
Remote Communities	1-2 units	3-4 units	4-6 units
Total	**2-5 units**	**5-8 units**	**7-13 units**

The above is a conservative estimate of the market. As this is a new market for nuclear power, product success is expected to support further market expansion.

b. *Economic Benefits* – Providing the opportunity for USNC to construct its first MMR at Chalk River and lay the groundwork for a Canadian fleet is expected to result in most of the supply coming from Canadian companies

A study undertaken for Ontario by the Conference Board of Canada[29] assesses the economic impact of a four-unit USNC 20 MW plant at a mining site operated for 20 years as:

For Ontario:

- Create direct, indirect, and induced employment on an average annual basis as follows:
  - 221 jobs during project development
  - 525 jobs during manufacturing and construction
  - 199 jobs during operations and
  - 154 jobs during decommissioning
- Have a positive impact on GDP (direct, indirect, and induced) of over $659 million
- Result in an increase of provincial revenues of over $235 million

[29] "Emerging Frontiers: Economic Impacts of Very Small Nuclear Reactors in Remote Off-Grid Mining" Conference Board of Canada, October 28, 2020

For all of Canada (including ON):

- Create 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
- Have a positive impact on GDP (direct, indirect, and induced) of $877 million
- Result in an increase of government revenue of over $311 million.

c. *Technology readiness* – The technology to be used is a gas cooled graphite moderated reactor using TRISO fuel. This technology has a good technical basis and the technology itself is relatively proven. Some key components require further development and testing. This may add risk to the project schedule.

d. *Cost and competitiveness* – The cost estimate is based on a well-developed cost model. The first unit at Chalk River is a demonstration unit. A power purchase agreement (PPA) with Canadian Nuclear Laboratories and/or Atomic Energy of Canada Limited is required to recover ongoing operating costs. OPG is staging its investment over time with off ramps should the project not meet agreed milestones.

   Further units have been assessed and at a projected cost of $200 million (overnight capital cost) for a 10 MW two-unit configuration, analysis shows the units will be competitive with diesel. There will also be some additional profit potential to support repaying some of the investment for the demonstration unit.

e. *Regulatory readiness* – USNC has completed Phase 1 of the CNSC vendor design review (VDR) process and is working towards Phase 2 completion is 2021. This should reduce the timeframe for the formal licensing process. This is necessary for general SMR success but remains a risk. Fuel qualification will be on the regulatory critical path.

f. *Schedule risk* – As a FOAK design, there is schedule risk. It is mostly associated with design progression, licensing, and fuel development. Plans are in place to mitigate these risks.

g. *Fuel availability* – Fuel is USNC proprietary FCM TRISO fuel. This is the strength of the design and what provides the high level of inherent safety. Fuel development is on the critical path and requires prompt review and approval by the regulator. It is possible to develop a manufacturing facility for the fuel in Canada. However, given this reactor does not require refuelling for 20 years, the new projects in the pipeline would need to support such a facility. Enrichment is at 13%. Acquiring this level of enrichment remains an issue to be resolved.

6.2.4 Summary

OPG has established a partnership with USNC to implement a demonstration MMR single unit at the Chalk River site by 2026.

The demonstration unit will be jointly funded by OPG, USNC and the Federal Government. A PPA to cover the ongoing operating costs is required to mitigate operating risk.

Economic analysis shows that subsequent two-unit 10 MW plants would be competitive with diesel for remote communities and mines and support some repayment of investment into the demonstration unit.

Commercial deployment of micro SMRs also represents an important opportunity for Ontario's nuclear companies, with the potential to generate thousands of jobs and billions of dollars for Ontario's and Canada's economy.

7 Key Requirements for SMR Feasibility in New Brunswick

7.1 Project Objectives

The objectives of developing and constructing advanced SMR reactor designs in New Brunswick at the Point Lepreau site include:

- Developing generation options to support New Brunswick decarbonizing its electricity grid by replacing and avoiding new fossil generation
- Developing new advanced nuclear technologies that offer the potential for increased safety, reduced cost and use of existing used nuclear fuel as a fuel both extracting value from this resource and reducing nuclear waste streams
- Economic development to the province and the rest of Canada to support this new industry of advanced reactor deployment

7.2 Project Description

NB Power has agreements with both Moltex Energy and Advanced Reactor Concepts (ARC Clean Energy) for the development and potential deployment of commercial demonstrations of their respective designs at the Point Lepreau site.

Technology - The project is for the development and deployment of both the Moltex SSR-W, a 300MW(e) stable salt fast reactor, including the WATSS fuel conversion facility, and the ARC-100, a 100 MW(e) sodium cooled fast reactor. In addition to developing the New Brunswick supply chain, facilities to support operations are also anticipated.

Project schedule – to be in service between 2030 and 2035, with a currently envisioned initial submission for an application to prepare site as early as the summer of 2022, assuming timely Federal support.

Project cost – It is premature to state costs of the potential demonstration projects as these technologies remain in the product development phase. Federal investment spread over the next three years, with the initial instalment starting this year, is required to unlock the necessary private investment to continue development and keep the New Brunswick option viable. This amount is considerably less than the total project costs, which in turn is significantly less than the overall development costs. For the demonstration projects, it is envisioned the owner consortium would sell electricity to NB Power under a Power Purchase Agreement. Several different business models are being investigated.

7.3 Assessment of Feasibility

The model for previous reactor development in Canada has been through government investment with support from various utilities. The model for the advanced Generation IV SMRs designs is based on a private investment model with limited support from government. While limited, this government support in clean energy technology is essential to advance the designs and instill confidence on the part of the investor community.

As identified in section 3.2, the New Brunswick provincial government has made a $30M investment into two leading advanced SMR technologies that was matched with private investment. This New Brunswick investment provided the ability for two vendors to move forward with their conceptual design and the CNSC phase 1 VDR Process. At this time, ARC

Clean Energy has completed Phase 1 and is ready to proceed into preliminary design and phase 2, and Moltex is completing its final input to the CNSC and preparing for preliminary design. NB Power continues to provide assistance to both vendors through expert advice. Federal investment is now required to protect the investment made by New Brunswick into both technologies, and to get these designs through the preliminary design and CNSC Phase 2 of the VDR processes. Such a Federal investment should unlock the private investment needed for the commercial demonstrations.

While there are many activities that need to happen to take a conceptual design through to demonstration and establishment of a viable export industry, the following fundamental outcomes will be needed.

Firstly, is the strong indication of **support from the Federal Government**. This includes financial support for the preliminary designs and financial backstops such as loan guarantees, cost overrun protection and risk sharing some of the life cycle costs of management and disposal of radioactive waste. In addition, a clear policy statement that nuclear is a clean form of energy is required. Support from the Federal Government for first of a kind demonstration is related to *recommendations 01 and 02 from the Pan Canadian SMR Roadmap report*.

Secondly, **both vendors need to successfully complete VDR2**. This provides confidence to investors that there are no fundamental barriers to licensing these designs in Canada. The fact that these are non-water based designs does not pose a regulatory barrier since the CNSC regulatory processes are more safety goal oriented than rule based as pointed out by the SMR Roadmap. The VDR process also provides an excellent opportunity for CNSC to become familiar with the underlying technologies which will be beneficial during the downstream formal licensing process.

Thirdly, as a result of completing the preliminary design and VDR2, **the designs are sufficiently simple so that the Nth of a kind designs are confirmed to be cost competitive with gas**, opening up the potential international market and providing sufficient margin to recover development costs.

The fourth is **a clear path forward for the supply of fuel is established**. Both designs use advanced fuels. The ARC-100 uses High Assay Low Enriched Uranium metallic fuel for the initial core load. It has the capability to recycle its used fuel. Moltex SSR-W uses a molten salt produced from converted spent CANDU or oxide fuel, as well as will recycle its used fuel. Although there are activities that still need to be done, as indicated in Section 3.2, no technical impediments to the supply of fuel is envisioned. However due to the nature of these advanced fuels and how they are produced, policy support from the Federal Government will be required. It should be noted that paving the way for the use of advanced fuels *was recommendation 08 from the Pan Canadian roadmap report*.

The fifth is related to **a clear path forward for the long-term storage of radioactive wastes from these designs**. Although both reactors can recycle their used fuel and thus produce a much reduced volume of long term radioactive wastes and with a relatively shorter life cycle, there is still a need for storage of radioactive waste from the fuel conversion and recycling processes, as well as the final core load. These are in different forms than the current oxide used fuel upon which the DGR has been designed around. Discussions with the NWMO and the Federal Government are necessary to determine the appropriate strategies and costs associated with managing the radioactive waste. This will be important for those that will need to establish the financial guarantees. This is associated with r*ecommendations 03,30 and 45 from the Pan Canadian roadmap report*.

All of the above are necessary to **attract additional private investors and or partnerships to finalize the designs and form the owner consortium for the commercial demonstration**s. Partnerships may involve EPC companies interested in the FOAK and subsequent units in the fleet. *This is related to recommendations 38, 41 and 46 from the Pan Canadian roadmap report.*

Supply chains principally located in New Brunswick and elsewhere in Canada will need to be established.   This sets the foundation for the supply chain for the fleet.

The **FOAK designs are finalized, licensed, constructed, and commercial operation demonstrated at the Point Lepreau site in a timeline of 2030 to 2035**. This is related *to recommendation 40 from the Pan Canadian roadmap report*. While a lot of activities are required to achieve this goal, this is necessary to demonstrate the technologies on this timeline so that they can be deployed to other areas in Canada and around the world.

Subsequent orders are received, and fleet technical services established. *This is related to recommendation 47 from the Pan Canadian roadmap report.*

7.4 Summary

New Brunswick is investing in the development of two complementary advanced reactor designs to meet the needs of diversity, supporting intermediate renewables and decarbonizing the provincial electricity system while creating a new supporting industry in the province.

With appropriate financial and policy support one or both designs may be able to have first units in service by 2030 and create opportunity for New Brunswick and other Canadian supply for follow on units both in Canada and for export.

The Stream 2 advanced SMR development and deployment in New Brunswick is feasible but relies on certain fundamental outcomes as identified above. Work continues to maximize the likelihood of these outcomes being positive. Building on existing investment from the province, utility, vendors and private industry, limited support is required from the Federal Government in a timely fashion to ensure the potentially significant economic impact materializes.

8 Key Requirements for SMR Feasibility in Saskatchewan

8.1 Project Objectives

The primary objectives of SaskPower's SMR evaluation are to assess:

- The economic and technical feasibility of deploying nuclear power from SMRs in Saskatchewan;
- the role of SMRs in support of an economically sustainable transition from coal and gas fired electricity generation to achieve a zero-emissions electricity grid;
- the impact of SMR deployment in Saskatchewan in terms of new job creation, increased economic development; and
- the potential for SMR deployment in Saskatchewan to support an expansion of the global market for Saskatchewan uranium.

8.2 Project Description

SaskPower is evaluating the economic and technical feasibility of deploying 300 MW of nuclear power from SMRs by 2032 following the successful deployment of the same SMR design by Ontario Power Generation (OPG) at its Darlington Nuclear Power Station in 2028.

For planning purposes, SaskPower is also evaluating the potential deployment of an additional 900 MW of generating capacity from SMRs between 2035 and 2042.

Technology - SaskPower is collaborating with OPG and Bruce Power to evaluate leading North American SMR technologies with the objective of selecting an SMR design by the end of 2021 for fleet-based deployment in Ontario by 2028 and then in Saskatchewan between 2032 and 2042.

Project Schedule – SaskPower expects to complete its SMR evaluation and make a recommendation on whether to proceed with the planning phase of Saskatchewan's first SMR deployment in 2021. Planning phase activities in Saskatchewan are expected to take eight to nine years and would include:

- SMR site selection;
- SMR technology selection including evaluation nuclear fuel availability;
- Evaluation of the business case for including SMRs in SaskPower's long-term electricity supply plan;
- Preparation, submission and approval of a *License to Prepare a Site* from the CNSC;
- Preparation, submission and approval of a *Licence to Construct* an SMR from the CNSC;
- Preparation of a *License to Operate* an SMR from the CNSC;
- Environmental, social, economic and Indigenous impact assessment as required by federal and provincial regulators; and
- Extensive and ongoing Indigenous, stakeholder, customer and public engagement.

Construction phase work is expected to take approximately three years and would result in the completion of the first Saskatchewan SMR in 2032.

However, a final decision to construct the first 300 MW of SMR generation in Saskatchewan would not be made until 2029 following the successful completion of OPG's first SMR deployment at Darlington.

8.3 The Opportunity for SMRs in Saskatchewan's Long-Term Electricity Supply Plan

SaskPower is committed to develop and execute a long-term energy supply strategy that delivers electricity to its customers at the lowest cost while meeting all federal and provincial regulatory requirements and achieving the standards for system reliability and security set by the North American Electric Reliability Corporation (NERC).

In 2020, conventional coal and natural gas accounted for 73% of SaskPower's total generating capacity with renewables (hydro, wind and solar) and coal with carbon capture contributing the remaining 27% of generating capacity.

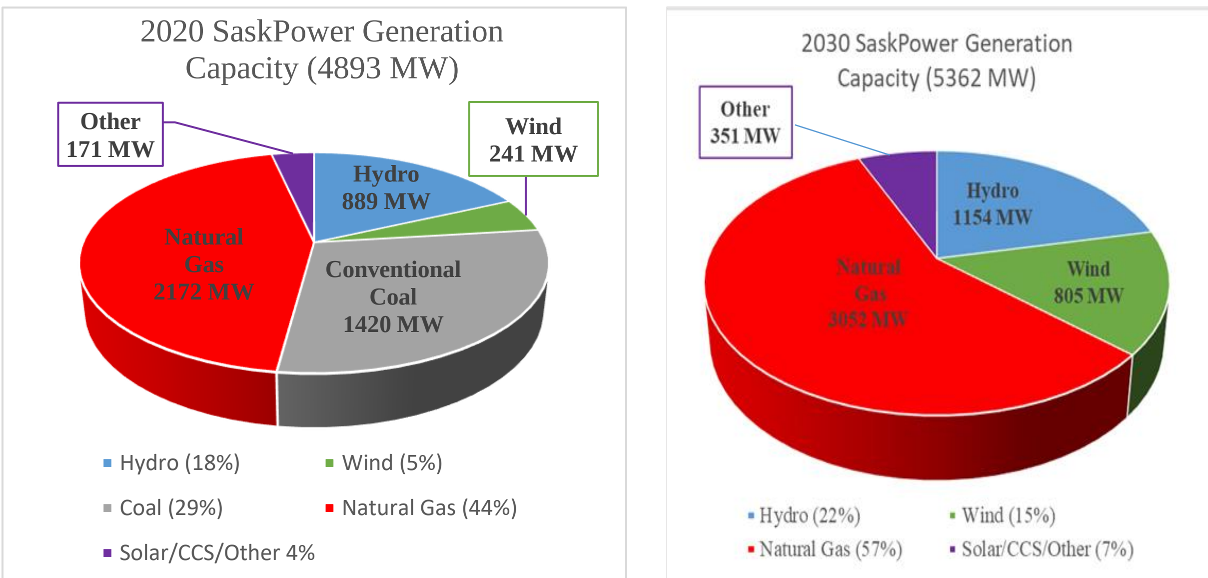

Figure 19 SaskPower Generation Capacity in 2020 and 2030

Federal regulations require SaskPower to retire 1,420 Megawatts (MW) of conventional coal fired power generation by 2030[30]. SaskPower has also committed to increase its renewable power generation to 40% of total generating capacity by 2030. To achieve these two objectives and meet Saskatchewan's growing demand for electricity, SaskPower plans to add 1,118 MW of natural gas generation, 685 MW of wind generation, 190 MW of hydro imports from Manitoba and 183 MW of solar/other between 2021 and 2029.

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[30] Conventional coal fired power generation refers to the generation of electricity by burning coal in a boiler without technology that captures the carbon dioxide (CO2) that is a biproduct of coal combustion. SaskPower operates one of the world's first and largest carbon capture and storage (CCS) facilities in the world at Boundary Dam Power Station in southeast Saskatchewan. The Boundary Dam CCS facility has the capacity to capture up to 90% of the CO2 emitted by a 150 MW conventional coal generation unit. SaskPower is evaluating the feasibility of retrofitting additional conventional coal generation units in Saskatchewan with carbon capture and storage technology as part of the company's long terms supply plans.

This adjustment to SaskPower's electricity generation mix will eliminate 100% of conventional coal generation in Saskatchewan while achieving our renewable generation capacity target and reducing greenhouse gas (GHG) emissions by at least 40% from 2005 levels by 2030. However, it will also result in natural gas generation making up almost 60% of SaskPower's electrical generation capacity by 2030 which will make further reductions in GHG emissions from power generation difficult until the 2040s.

At the same time, SaskPower anticipates 1) an increase in demand for zero emissions electricity to support the electrification of transportation and other key sectors; and 2) increasingly stringent regulations that will require further reductions in CO2 emissions from power generation after 2030. In response, SaskPower is re-evaluating its long-term electricity supply strategy with a view to limiting the deployment of new natural gas generation in the 2025 - 2030 timeframe.

SaskPower is evaluating several potential alternative low emissions pathways that could include a combination of some or all of the following: expanded electricity imports, expanded generation from solar and wind, expanded application of carbon capture and storage technology and the deployment of nuclear power from SMRs.

8.4 Assessment of Feasibility

8.4.1 Competitive Price for Power

One of the key drivers of SMR feasibility in Saskatchewan is a competitive price for power—the electricity from SMRs must be competitive with alternative large scale zero-emissions, base load generation options available to Saskatchewan including hydro and, in the future, wind and solar supported by energy storage. While feasibility work to date in collaboration with OPG and Bruce Power has been promising with regard to the potential for SMRs to generate competitively priced power, more detailed cost estimates will be developed as SMR developers progress with their designs and OPG progresses with construction of its FOAK SMR project at Darlington.

8.4.2 Commercial Deployment of First-of-a-Kind (FOAK) SMR in Ontario

With no experience in licensing, building or operating nuclear power plants, it is not feasible for SaskPower or the Government of Saskatchewan to shoulder the significant financial, licensing and deployment risks associated with deploying the first utility scale SMR in Canada. Saskatchewan needs partners with nuclear operating experience in Canada and at least one completed SMR project in Canada at a commercial scale to adequately assess the economic feasibility of deploying SMRs in Saskatchewan.

To address this challenge, SaskPower has engaged with all three of Canada's existing nuclear power plant operators -- Ontario Power Generation, New Brunswick Power and Bruce Power – to assess the potential for SMR deployment in all three jurisdictions.

In 2017, SaskPower signed an MOU with OPG to collaborate on the evaluation of SMR deployment in both Ontario and Saskatchewan. In 2019, the Premiers of Saskatchewan, Ontario and New Brunswick signed an MOU to collaborate on the development and deployment of SMRs in all three provinces and in Northern Canada.

As noted in Section 6 of this Feasibility Report, OPG is advancing a plan to build Canada's first utility scale 300 MWe SMR at the existing Darlington Nuclear Generating Station approximately 75 kilometers east of Toronto, Ontario. The goal is to have its first SMR in commercial operation by the end of 2028. OPG and SaskPower are collaborating closely in the assessment of the SMR technology that will be selected for the FOAK project. OPG's experience in licensing, construction and commissioning a first SMR project at Darlington has the potential to reduce the cost and schedule for deployment of a second SMR project in Saskatchewan and to provide detailed information on the capital and operating costs.

8.4.3 Fleet-based deployment of SMRs in Canada

Fleet-based deployment, where the same SMR design is deployed in multiple Canadian jurisdictions, is another key requirement of SMR feasibility in Saskatchewan.

The completion of a FOAK SMR project in Ontario is the first step to fleet-based deployment where the same SMR design is deployed in Ontario and then in Saskatchewan.

Fleet-based deployment will drive the cost of electricity from SMRs lower by reducing the timeframe and cost of licensing as well as reducing capital and operating costs. It will also support the potential for deployment of additional SMR generation in Saskatchewan and in other provinces.

Fleet-based deployment also creates the potential to maximize the supply chain opportunities for Canadian businesses and to support the eventual export of SMR technology developed and demonstrated in Canada to international markets where it's deployment could lead to meaningful global reductions in GHG emissions while creating good, high-paying jobs for Canadians.

In 2020, SaskPower signed a Collaboration Agreement with OPG and Bruce Power to evaluate the business case and potential business models for fleet-based deployment in Canada.

8.4.4 Strong Risk-Sharing Partnership with the Government of Canada

Another key condition of SMR feasibility in Saskatchewan is a strong risk sharing partnership with the Government of Canada.

The Pan-Canadian benefits of fleet-based deployment of SMRs in Ontario and Saskatchewan -- including deep reductions in GHG emissions, support for decarbonization of the western electricity grid and expansion of Canada's nuclear industry – make a strong case for federal risk-sharing in the planning phase of SMR deployment.

SaskPower has worked with OPG, Bruce Power and NB Power to develop an SMR funding proposal that includes a proposed 50-50 cost-share of SMR planning phase costs in Saskatchewan. Without a clear federal commitment to cost-sharing the planning phase of SMR development, SMR deployment in Saskatchewan is unlikely to proceed.

8.4.5 Expanded Regional Electrical Transmission Capacity

Expanding regional transmission capacity by the mid to late 2020s is also key to the feasibility of deploying nuclear power from SMRs in Saskatchewan in the early 2030s. Without access to expanded electricity imports by the mid to late 2020s, SaskPower will likely be forced to replace retiring coal generation with new natural gas generation and would therefore eliminate the need for baseload nuclear power from SMRs until the mid-2040s.

The net impact of a pivot from Saskatchewan's current dependence of coal and natural gas for electricity to a future combination of cleaner electricity imports and nuclear power from SMRs in Saskatchewan is that SaskPower could achieve emission reductions from electricity generation of as much as 70% below 2005 levels by 2040 and zero emissions by 2050 or sooner.

In addition, the combination of expanded electricity imports and the addition of reliable, zero emissions power from SMRs could facilitate an expansion of intermittent renewable generation from wind and solar in Saskatchewan after 2030.

8.5 Potential Benefits of SMR Deployment in Saskatchewan

The fleet-based deployment of SMRs in partnership with Canada's existing nuclear operators (OPG, New Brunswick Power and Bruce Power) and the Government of Canada could also deliver significant economic and environmental benefits for Saskatchewan including:

8.5.1 Deep GHG Emission Reduction

The deployment of SMRs in Saskatchewan as part of a diversified generation mix that also includes electricity imports along with expanded wind and solar generation, could avoid the emission of as much as 73 Megatonnes of CO2 in Saskatchewan between 2025 and 2050 while supporting the economically sustainable decarbonization of Saskatchewan's electrical grid.

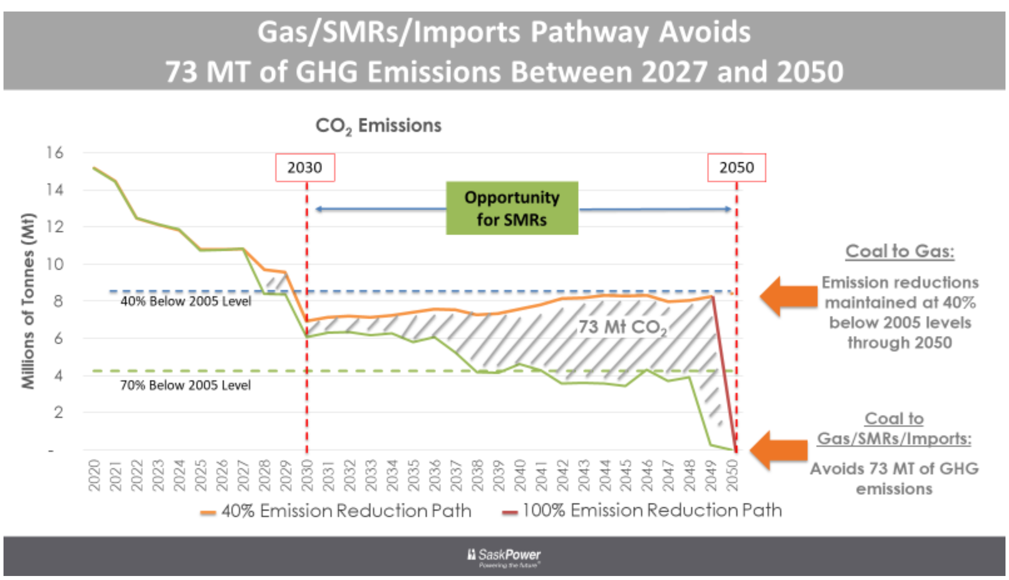

Figure 20 SaskPower Emissions Profile to 2050

8.5.2 Economic Support for the Phase-out of Conventional Coal

The deployment of SMRs in Saskatchewan starting in the early 2030s could substantially offset the negative economic impact in Saskatchewan of the Government of Canada's mandated phase-out of conventional coal fired power generation. A study undertaken for Ontario and Saskatchewan by the Conference Board of Canada (CBOC)[31] assesses the economic impact of deploying four SMR units each with 300 MW of generating capacity (total of 1,200 MW) in Saskatchewan between 2032 and 2042 and then operating each SMR unit for 60 years as follows:

Table 4 Economic Impact in Saskatchewan

	GDP ($million)	Wages ($million)	Taxes ($million)
2021-2032	1,649	944	526
2033-2042	2,765	1,637	910
2043-2104	4,441	3,032	1,521
Total	8,855	5,613	2,958

Deployment of 1,200 MW of nuclear power from SMRs between 2032 and 2042 in Saskatchewan would also create thousands of new jobs in the province:

Table 5 Job Creation in Saskatchewan 2021-2104

2021-2036	2029-2040	2032-2099	2092-2104
Project Development	Manufacturing & Construction	Plant Operation	Plant Decommissioning
179 jobs per plant, per year	1,760 jobs per plant, per year	182 jobs per plant, per year*	208 jobs per plant, per year
*728 jobs per year when all four SMR units are operational			

8.5.3 Economic Benefits to the Rest of Canada

The CBOC analysis shows that SMR deployment in Saskatchewan would deliver significant positive economic benefits to the rest of Canada as summarized in the table below.

Table 6 Economic Impact - Rest of Canada

Economic Impact - Rest of Canada			
	GDP ($million)	Wages ($million)	Taxes ($million)
2021-2104	4,675	2,447	1,375

[31] "A New Power: Economic Impacts of Small Modular Nuclear Reactors in Electricity Grids", Conference Board of Canada, March 2021

The CBOC Report also shows that SMR deployment in Saskatchewan would support job creation in the rest of Canada as follows:

Table 7 Job Creation - Rest of Canada

Job Creation – Rest of Canada			
2021-2036	2029-2040	2032-2099	2092-2104
Project Development	Manufacturing & Construction	Plant Operation	Plant Decommissioning
17 jobs per plant, per year	868 jobs per plant, per year	111 jobs per plant, per year*	46 jobs per plant, per year
*445 jobs per year when all four units are operational			

Further comparative analysis is required to evaluate 1) the net economic impact on Saskatchewan as a result of the phase-out of the coal mining and coal fired power generation business in the 2020s followed by the deployment of SMRs in the 2030s. The same comparative economic impact analysis will also be applied to other potential low emissions pathways including 1) the replacement of conventional coal generation in Saskatchewan with increased electricity imports from Manitoba, Alberta and/or the United States; 2) renewables (wind and solar) with energy storage; and 3) refitting emitting generation with carbon capture and storage technology.

8.5.4 Reduced Dependence on Natural Gas Price

An electricity supply strategy that deploys SMRs in the early to mid-2030s would reduce SaskPower's dependence on natural gas, support the phase-out of natural gas for base load generation between 2030 and 2050 and reduce the risk of stranding capital investments in natural gas generation resulting from more stringent future GHG emissions regulations.

8.5.5 Indigenous Participation in Clean Energy Development

The development of nuclear power from SMRs creates an opportunity for participation by Saskatchewan's Indigenous communities in sustainable, emissions-free energy development which could provide stable, long term financial returns and create high quality jobs for Indigenous people for generations to come.

8.5.6 Creation of New Markets for Saskatchewan Uranium

The 2018 Canadian Roadmap for Small Modular Reactors report estimated the global market for SMRs at approximately $150 billion per year between 2030 and 2040. If even a fraction of this market is achieved, it would significantly increase demand for Saskatchewan's rich uranium resources.

8.5.7 Adding Value to Saskatchewan's Uranium Resources

Saskatchewan has the richest deposits of uranium in the world. With the deployment of a fleet of SMRs in Canada comes the opportunity to source Saskatchewan uranium and use it to fabricate the nuclear fuel that will be required to operate the fleet. While nuclear fuel fabrication is not a condition of SMR feasibility, fleet-based deployment in Canada, where multiple SMRs are deployed in Saskatchewan, creates an opportunity for fuel fabrication capacity to be developed in Saskatchewan, not only to supply the Canadian-based SMR fleet but also to supply nuclear fuel using Saskatchewan uranium to SMRs deployed globally while creating hundreds of high paying jobs in Saskatchewan.

Further evaluation of the business case for development of nuclear fuel fabrication capacity in Saskatchewan is required including engagement and consultation with provincial and national stakeholders, Indigenous communities and Rights Holders, Canada's existing nuclear utilities, CAMECO and the Government of Canada.

8.5.8 Expanding Saskatchewan's Nuclear Research Capacity:

SMR deployment in Saskatchewan will also create research, development and training opportunities for a wide range of organizations including the University of Saskatchewan, University of Regina, Saskatchewan Polytech, Saskatchewan Indian Institute of Technologies, the Fedoruk Canadian Centre for Nuclear Innovation, the Saskatchewan Centre for Cyclotron Sciences, the Canadian Light Source, the Saskatchewan Research Council and the Johnson Shoyama Graduate School of Public Policy.

8.6 Summary

Based on feasibility work to date by SaskPower in collaboration with other interested Canadian utilities and provinces, nuclear power from Small Modular Reactors (SMRs) could provide competitively priced, emissions free, baseload electricity in Saskatchewan by the early 2030s and could also deliver significant economic and environmental benefits to Saskatchewan and Canada.

However, further planning and evaluation work by SaskPower and the Province of Saskatchewan accompanied by ongoing public engagement regarding the province's future electricity generation options is required to inform a decision to deploy SMRs for power generation in Saskatchewan.

9 Recommendations

SMRs represent an opportunity for Canada to be part of the next phase of global nuclear development. These new smaller nuclear plants disrupt the market by offering new approaches to support global decarbonization with designs that can be deployed by new customers who are not in a position to implement more traditional large nuclear units, either due to their large size, the associated large capital outlays and relatively long project schedules, or both.

Canada is in an ideal position to take the lead in SMR development and deployment. The 2018 SMR Roadmap makes the case and establishes the requirements for success. Since the roadmap was issued, Canadian Nuclear Utilities and vendors have continued to progress the development of SMRs for use in Canada and for export. The MOU signed by New Brunswick, Ontario and Saskatchewan December 1, 2019 is testament to the both the commitment to SMRs and the need to collaborate to develop pan Canadian solutions.

Considerable progress has been made in the development of SMRs following a three-stream approach to SMR development.

- **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 will 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 (direct, indirect, and induced) 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) 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 of $877 million; and
    - an increase of government revenue of $311 million.

These project proposals are advancing rapidly and demonstrate the potential to be both commercially and technically feasible. An important part of these projects' feasibility is cost and risk sharing with the Federal government as these projects support its goals of phasing out coal by 2030, becoming carbon net zero by 2050 and providing affordable clean energy to indigenous communities. Additionally, these proposed projects would create a new subcategory of nuclear industrial activity that would see Canada well placed to be a major player in the global deployment of these technologies. Securing Federal government support in a timely manner is essential to continued good progress along all pathways.

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.

It is recommended that provincial governments support a collaborative approach with the Federal government to reducing emissions and growing the economy in a manner that meets the specific needs and economic priorities of each province. Working together on the opportunities provided by SMR deployment, industry and governments will continue to find innovative energy solutions while creating an ideal business environment to attract jobs and growth in regions across the country and for the export market.