Canadian Small Modular Reactor (SMR) Roadmap
Feuille de route pour les petits réacteurs modulaires (PRM) au Canada

Workshop 2: On-Grid Applications
Saint John, April 19-20, 2018

May 14, 2018

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Executive Summary

This report provides a summary of discussion and results from the second workshop associated with the Small Modular Reactor Roadmap. The workshop was held in Saint John on April 19th and 20th, 2018 and focused on On-Grid Applications.

Introduction to the Small Modular Reactor Roadmap

A **Small Modular Reactor (SMR)** is an advanced nuclear reactor that produces electric power up to about 300 MWe, designed to be built in factories, and shipped to a site for installation as required. SMRs provide a range of benefits including reduced greenhouse gas emissions, improved affordability, shorter construction and installation times, a wider range of potential users and applications, site flexibility, and integration with renewables.

In its October 2017 response to the House of Commons Standing Committee report on Nuclear Energy, the Government committed to initiating a dialogue with key stakeholders to develop a **Canadian Roadmap for SMRs** ("SMR Roadmap" or "Roadmap"). The development of the Roadmap was considered critical in light of the following:

- SMRs are a promising potential source of non-emitting power for various applications;
- The technology is at an early stage of development, with many questions that still need answers;
- Future success involves risks and costs, potentially involving both the private and public sectors across Canada; and
- A pan-Canadian approach would help guide important decisions and reduce uncertainty.

Initial research and analysis in support of the Roadmap identified three main applications/markets for SMRs domestically:

1) **On-grid power** generation to replace fossil fuel plants in the existing electric power grid system (~150 to 300 MWe).
2) Providing non-emitting heat and power for **heavy industry** sites such as resource extraction operations (~10 to >170 MWe).
3) Replace existing diesel power generation for electricity, district heating, and desalination in **off-grid northern and remote communities** (<10 MWe, with many < 2.5 MWe).

Approach to the SMR Roadmap

The approach to developing the SMR Roadmap involves a series of workshops with key stakeholders to gain their perspectives on the unique requirements for each of the main applications/markets, and potential technical solutions. Four workshops have been scheduled between March and June 2018. The first of these workshops was a Visioning Session, held in Toronto in March 2018, which focused on establishing a vision for SMRs based on end user demands, and on setting the overall foundation for the Roadmap process. The second workshop was held in Saint John on April 19-20, 2018, and focused on On-Grid Applications.

The SMR Roadmap, and in particular the workshops, are also supported by five Working Groups that have been tasked with conducting analysis and providing insight into key aspects that will impact a future pan-Canadian SMR industry. The areas of study for the five working groups are: Technology; Economic and Finance; Indigenous and Public Engagement; Waste; and Regulatory Readiness.

Results from the On-Grid Applications Workshop

The On-Grid Applications workshop included a series of presentations and roundtable discussions. Presentations were provided by potential on-grid operators, which involved a brief description of their organizations' priorities and future needs, and how SMRs could support addressing those needs. Presentations were also provided by proponents of the nuclear industry's supply chain to offer perspectives on various aspects of a future pan-Canadian SMR supply chain. Additional presentations were also provided by representatives of each of the SMR working groups, with each providing a summary of results from activities undertaken to date. A complete list of presenters is included in Appendix D.

The roundtable discussions were used to collect input from the participants on several topics. However, the two primary topics of discussion included: 1) the key on-grid SMR requirements; and 2) the elements of a future SMR supply chain strategy. A brief summary of results from topics is presented below.

Key On-Grid SMR Requirements

1. A **low carbon**-emitting alternative that results in a reduction in the use of fossil fuels.
2. A **"social license"** by obtaining public and Indigenous acceptance.
3. Costs that are predictable and **competitive** with respect to other options such as natural gas.
4. An ability to **integrate with and support renewable technologies** (e.g. solar, wind).
5. Supports **grid modernization** (e.g. smart grid, load growth) and replaces existing aging infrastructure.
6. An ability to meet **demand growth** through increased market sizes, export opportunities, and/or the introduction of disruptive technologies (e.g. electric car).
7. Provides **regional economic benefits** through a pan-Canadian supply chain.
8. A defined **waste management strategy** that reduces/recycles waste, and that factor in all relevant costs (e.g. decommissioning, transportation, etc.).
9. Established lifecycle **research and development support** (i.e. through the Canadian Nuclear Laboratories to the Canadian nuclear research eco-systems).

Elements of a Future SMR Supply Chain Strategy

1. Timely government decisions and actions in support of a **national strategy** for SMRs is needed to advocate the merits of the program, remove national and international barriers, and set relevant policy (e.g. fuel).
2. **First to market** by either being the first to supply or demonstrate an SMR.
3. Training programs and facilities to establish a **skilled workforce** with appropriate soft and technical skills.
4. A **competitive advantage** that is difficult to achieve and replicate (i.e. cost, unique technology, functionality, etc.).
5. Clearly **defined sharing of risk** related to a FOAK so suppliers fully understand the level of risk they would need to incur.
6. **Timelines** for SMR design and development are defined so suppliers can sufficiently plan, required facilities can be built, and an adequate workforce can be secured.
7. An effective **national research and development program** anchored within the Canadian Nuclear Laboratories (CNL).
8. A **fleet business model** with a centralized supply chain, where all vendors are "on the same page."
9. A reliable and assured source/supply of **fuel**.
10. **Innovative manufacturing** techniques as a means to lower costs.
11. **Regulations and standards** that support off the shelf components.

During the roundtable discussions, participants were also asked to complete an On-Grid Characteristic Framework that was intended to capture the range of potential characteristics required to meet on-grid requirements for an SMR, and to identify the level of need for each characteristic. The results from this exercise are included in Appendix C.

Next Steps in the SMR Roadmap Process

Two remaining workshops are planned in the SMR Roadmap. The next workshop will be held in Iqaluit, Nunavut on May 10-11, 2018. The focus of this workshop will be on the off-grid and remote communities applications/markets.

The final workshop will be held in Calgary, Alberta on June 19-20. The focus of this workshop will be on the heavy industries applications/markets.

1. Introduction

This report provides a summary of discussion and results from the second workshop associated with the Small Modular Reactor (SMR) Roadmap. The workshop was held in Saint John on April 19th and 20th, 2018 and focused on On-Grid Applications. A list of participants at the workshop is included in Appendix A.

1.1 What is an SMR?

The International Atomic Energy Agency (IAEA) defines SMRs as "advanced reactors that produce electric power up to 300 MWe, designed to be built in factories and shipped to utilities for installation as demand arises." SMRs represent a nuclear option to meet the need of flexible power generation for a wide range of potential users and applications.

> The word "small" in SMR refers to the power output relative to traditional reactors, where output from current on-grid reactors is typically measured in giga-watts. As described in IAEA's definition above, SMRs refer to reactors that produce less than 300 MWe, with a subset described as "very small" (vSMRs) that produce less than 15 MWe. The physical sizes of SMRs vary, but are generally much smaller than current on-grid nuclear reactors.
>
> The word "modular" in SMR refers to the technology being manufactured in dedicated facilities and transported to sites for installation as needed. This is expected to lead to reduced on-site installation times, advanced quality assurance controls over standardized models at manufacturing facilities, and improved cost efficiencies through economies of series.
>
> The word "reactor" in SMR refers to nuclear technology that will supply power within the SMR. There are currently a large variation of reactor types under development within the industry, and large variations of designs within reactor types.

The benefits of SMRs include reduced greenhouse gas emissions, better affordability, shorter construction and installation times, a wider range of potential users and applications, site flexibility, and integration with renewables.

1.2 What is the SMR Roadmap?

In its October 2017 response to the House of Commons Standing Committee report on Nuclear Energy, the Government committed to use its convening power to initiate a dialogue to develop a Canadian Roadmap for SMRs ("SMR Roadmap" or "Roadmap"). The Roadmap would be a plan for the development and deployment of SMRs that addresses the collective needs and challenges of all stakeholders.

Natural Resources Canada (NRCan) convened the Inter-utility Consultative Committee on Nuclear (ICCN) to provide a forum for discussion that supports a collaborative and coordinated approach when it comes to nuclear. Membership of the ICCN was open to all provincial and territorial governments and utility representatives regardless of nuclear policy direction in their jurisdiction. The network acknowledged the need for a Canadian SMR Roadmap particularly in light of the following:

- SMRs are a promising potential source of non-emitting power for various applications;
- The technology is at an early stage of development, with many questions that still need solutions;
- Future success involves risks and costs, involving both the private and public sectors across Canada; and
- A pan-Canadian approach would help guide important decisions and reduce uncertainty.

As a result, the ICCN agreed to establish a sub-committee for developing a Canadian Roadmap for SMRs, the SMR Roadmap Steering Committee ("Steering Committee"). A listing of the Steering Committee organizations is included as Appendix B. The Steering Committee officially launched the SMR Roadmap process in December 2017.

Initial research and analysis in support of the Roadmap identified three main applications/markets for SMRs domestically, which are listed below.

Three Main Domestic Applications/Markets for SMRs

1) **On-grid power** generation to replace fossil fuel plants in the existing electric power grid system (~150 to 300 MWe).
2) Providing non-emitting heat and power for **heavy industry** sites such as resource extraction operations (~10 to >170 MWe).
3) Replace existing diesel power generation for electricity, district heating, and desalination in **off-grid northern and remote communities** (<10 MWe, with many < 2.5 MWe).

Developing the SMR Roadmap involves a series of workshops with key stakeholders to gain their perspectives on the unique requirements for each of the main applications/markets, and potential technical solutions. Four workshops have been scheduled between March and June 2018. The first of these workshops was a Visioning Session, held in Toronto in March 2018, which focused on establishing a vision for SMRs based on end user demands, and on setting the overall foundation for the Roadmap process. The second workshop was held in Saint John on April 19-20, 2018, and focused on On-Grid Applications. Two subsequent workshops are to follow: one focused on Heavy Industry Applications and another on Off-Grid Northern and Remote Communities.

The SMR Roadmap, and in particular the workshops, are also supported by five Working Groups that have been tasked with conducting analysis and providing insight into key aspects that will impact a future pan-Canadian SMR industry. The areas of study for the five working groups are: Technology; Regulatory Readiness; Economic and Finance; Indigenous and Public Engagement; and Waste.

1.3 Intended Outcomes of the SMR Roadmap

The Steering Committee has identified the following as the intended outcomes for the SMR Roadmap:

- Clarity on needs and priorities of stakeholders and Canadians;

- Understanding of the value proposition of different SMR technology categories;
- Identification of key issues related to regulatory readiness, waste management, and transportation policy;
- Appreciation of risks and challenges; and
- Identification of policy levers that may impact SMR feasibility in Canada.

In addition, the Roadmap process will ***seek to encourage and develop broad agreement*** *among the essential enabling partners on the* ***way forward*** *to position Canada for success domestically and for best advantage in the emerging global SMR market.*

1.4 Objectives of the On-Grid Applications Workshop

The objectives of the On-Grid Applications Workshop were to discuss collaboratively the following questions:

- What are the regional and national opportunities for on-grid power generation by SMRs?
- What characteristics are required for SMRs on-grid?
- What are the opportunities and risks for the Canadian supply chain?
- What policy levers and industry contributions will be necessary to support SMRs

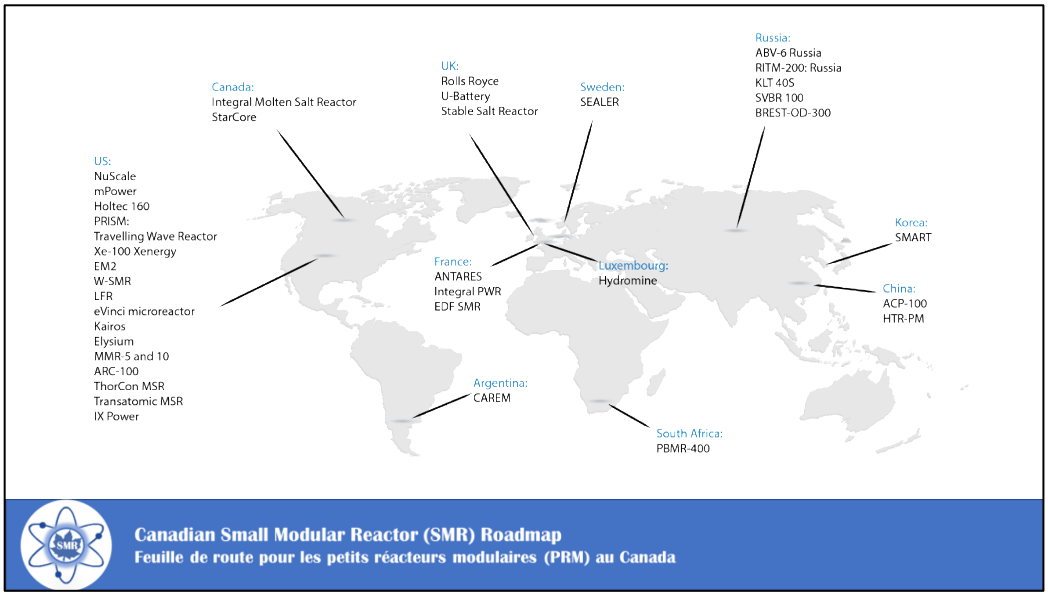
2. Presentations From the SMR Technical Working Groups

The On-Grid Applications workshop included presentations from each of the working groups. Generally, each provided an overview of the activities undertaken by the working group, as well as a summary of results from those activities. The following sub-sections provide a brief summary and excerpts from these presentations.

2.1 Technology Working Group

Bronwyn Hyland, Program Manager of Small Modular and Advanced Reactor Technologies at the Canadian Nuclear Laboratories, and Co-Chair of the Technology Working Group provided an overview of SMR definitions and benefits (included in Section 1.1 above), and an overview of the state of current SMR designs worldwide. The following provides a brief summary of the presentation.

There are currently over 100 different SMR designs being proposed worldwide. Some of these designs look similar to existing nuclear plants, but some are dramatically different. The following map provides an indication of the number of designs and countries involved in SMR development.



In recent years, the industry has looked towards Canada to play a leading role in SMR development and deployment. There are many reasons for this attention on Canada including:

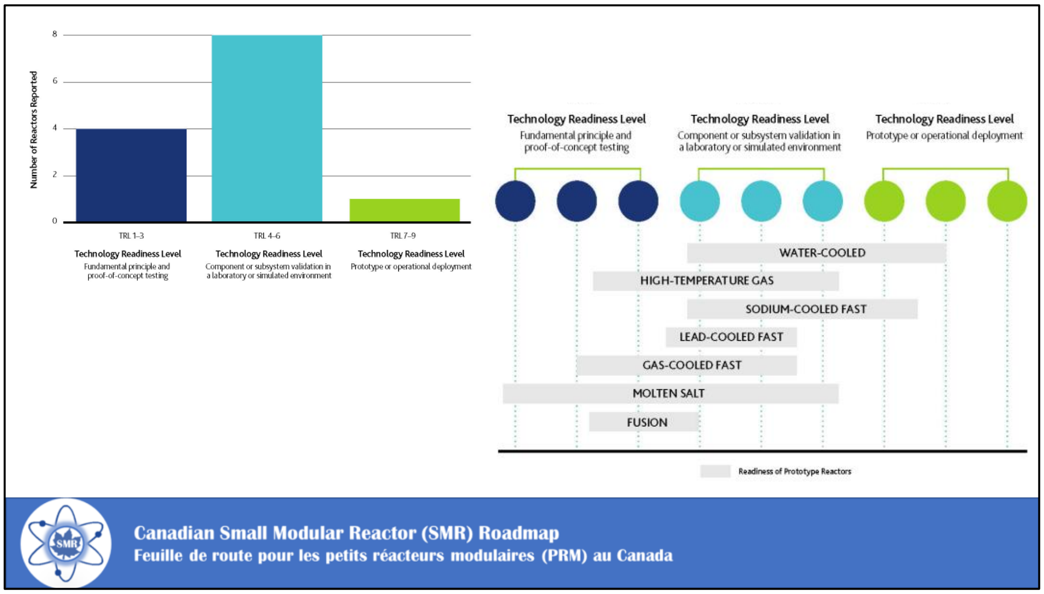
- A world class and respected nuclear regulatory framework;
- An efficient gateway to the North American market;
- A pressing domestic need for the technology;
- An existing, capable, and established supply chain; and
- A stable political system with a government that is committed to action on climate change.

In terms of on-grid applications, where power output would require over 50 MWe, there are five feasible design types.[1] These are:

- Water-cooled;
- Gas-cooled;
- Sodium-cooled;
- Lead-cooled; and
- Molten salt-cooled.

However, within these design types, the Technology Working Group identified over 80 unique designs. Further, the Technology Readiness Levels (TRLs) widely vary within these design types, with some in the proof of concept stages and others closer to commercial readiness. The graphs below provide an indication of the TRLs of the design types based on research conducted by the Technology Working Group.[2]

[1] Note that reactor designs are typically categorized by its coolant.
[2] Note that TRLs were self-assessed by the vendors, and were provided guidance on how to accurately self-assess their design



Generally, larger sized designs are closer to being commercially ready, and designs with less traditional or more unusual coolants (e.g. molten salt, gas) are further from being commercially ready. Each design will require development steps before a prototype or demonstration project can be launched. These steps will involve some work in Canada, and also work underway or planned in other countries.

From a pan-Canadian perspective, it is impractical to study and pursue development of hundreds of designs. The list of potential options needs to be narrowed down based on end-user needs. While developing a "short list" of potential designs does not rule out others, it does conserve and target our limited available resources. As such, the Technology Working Group is looking to workshop participants to provide insight into the requirements and characteristics for SMRs to meet near- and longer-term user needs (through the roundtable discussions). This will assist in refining the scope of potential designs that the Technology Working Group will focus its efforts on moving forward.

2.2 Regulatory Readiness Working Group

Robin Manley, Vice-President of Nuclear Regulatory Affairs and Stakeholder Relations from Ontario Power Generation, and the Co-Chair of the Regulatory Readiness Working Group provided an overview of the mandate and key activities of the working group, a summary of findings from preliminary work, and some identified risks and potential mitigation strategies. The following provides a brief summary of the presentation.

The mandate of the Regulatory Readiness Working Group is to "identify barriers and challenges to the deployment of SMRs under the current regulatory regime." Key activities for the working group include:

- Analysis of the current regulatory regime for SMR deployment in Canada;
- Identification of potential gaps, and a proposed way forward; and
- Identification of areas of potential excessive regulatory cost or burden for SMR deployment.

The work thus far undertaken by the working group has focused on the regulatory framework in Canada today. With the potential to access international markets, concerns were raised by the working group that its scope may be too narrow. As such, future work may involve broadening its focus to international regulations.

There have been several studies already undertaken by other organizations related to the Canadian regulatory framework in preparation for SMRs. Generally, the results from all of these studies indicated that SMRs can be regulated in Canada, though some concerns or uncertainties remain. The following paragraphs provide a brief summary of these studies.

> The Canadian Nuclear Safety Commission (CNSC) published a discussion paper and a "what we heard" report based on engagements and workshops with stakeholders. The conclusion from this study was that existing regulations do not pose an "insurmountable challenge," and that CNSC is in a position to consider an application to license an SMR, and has the necessary licensing processes in place. However, vendors requested more details on CNSC's "graded approach," which prompted CNSC to hold a workshop with stakeholders on the topic. The results from the workshop were that vendors (and operators) would still need to guarantee the safety of the reactor in terms of Control, Cool, and Contain. However, concerns were raised related to the amount of safety analysis currently required to prove that a reactor is safe. If a similar level of effort is required for each new SMR site, then deployment becomes unfeasible as this would neutralize any efficiencies gained through modularity.
>
> The CANDU Owner's Group (COG) Small and Medium Reactor Technology Forum (SMRTF) undertook a series of discussions with SMR vendors regarding their readiness to commence with the licensing process for SMRs. The vendors did not identify any critical "show-stopping" issues. However, these vendors are looking for additional clarity regarding some of the following:
>
> - Accident Frequency estimation ("PSA") methodology applied to new designs;
> - Security regulations and cyber security;
> - Human Factors and Human Performance as it applies to operations;
> - Fire protection;
> - Division of responsibilities between vendor and licensee;
> - Failure frequencies for passive safety features and inherent characteristics;
> - Use of computer codes (modelling) for safety analysis;
> - Safety System Classification; and
> - Defence-in-depth.
>
> As part of CNSC's stakeholder engagement initiatives (discussed above), industry members were asked to submit input for the above noted discussion paper. The consensus across these industry-provided inputs was that again "SMRs do not inherently pose any insurmountable challenge to existing regulatory requirements in Canada." However, several challenges and opportunities were identified. In terms of challenges, concerns were raised regarding the staffing level complements that would be required from a regulatory perspective, as operationally they would need to be much lower than a traditional reactor in order for SMRs to be economically viable. Another identified challenge involved the level of insurance that would be required under the *Nuclear Liability and Compensation Act*, and whether it would be dependent on the application (e.g. on-grid, remote). In terms of opportunities, the industry inputs identified some of the following:

- Clarifications to the existing regulatory framework, or resolution of certain questions, could considerably simplify the licensing process for SMRs.
- How can the regulatory process be aligned to permit alternative solutions to regulatory requirements for such aspects?
- Application of "risk-informed" and "graded approach" concepts to SMR designs that will make extensive use of passive engineered design features and/or strongly inherent safety features.
- Key issue arises in the area of licensing of nth-of-a-kind reactors, that is, economy-of-scale in licensing cost. Streamline licensing process for factory manufactured, identical units.

As discussed above, preliminary studies of Canada's regulatory readiness has been undertaken by multiple organizations, and the general consensus is that SMRs can be licensed in Canada. These studies also identified a number of potential challenges (or risks) and opportunities, as summarized in the slide below.

There is a general acknowledgement from stakeholders that some revisions to regulatory requirements will be required, particularly considering that most of the Canadian Standards Association (CSA) standards supports licensing of traditional hard-water reactors. These standards may not be applicable to newer SMR designs, and new standards development can take several years. As such, once designs are selected, it will be a high priority to begin revisions to these standards, as changing requirements during development could introduce risk.

There are also concerns arising from stakeholders regarding whether SMRs will fall under the federal government's new Impact Assessment Legislation, which is replacing the need for an environment assessment. It is currently unclear whether each SMR site would be sufficiently small so that it falls outside the scope of this legislation. If not, this would introduce additional costs.

2.3 Economic and Finance Working Group

Nicolle Butcher, Vice President of Strategy and Acquisitions from Ontario Power Generation, and the Chair of the Economics and Finance Working Group provided a presentation on spreading the First-of-a-Kind (FOAK) risk for on-grid applications. The following provides a brief summary of the presentation.

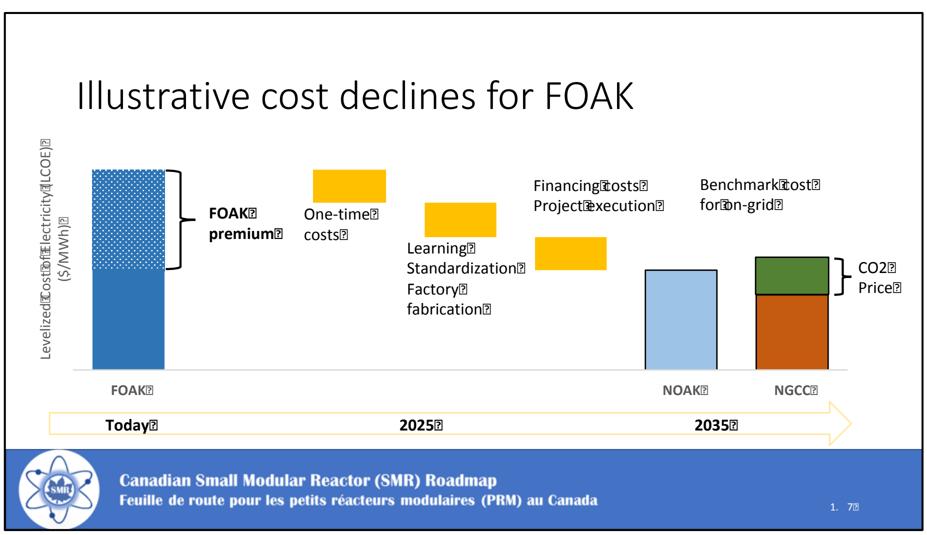
SMRs are early in their product development cycle and are expected to reach first deployment in the 2025 to 2035 timeframe. The SMR community believes Canada has a strong, but narrow, opportunity to be an early adopter and global leader in this area. However, to do so will require taking on FOAK risk, which will be costly. Spreading the FOAK risk involves bridging the cost gap (or FOAK premium) between deploying a FOAK SMR and achieving an Nth-of-a-Kind (NOAK) SMR that is cost competitive to alternative on-grid benchmarks. FOAK risk needs to be shared with all levels of government and the private sector.

The working group reviewed a number of studies related to cost declines from FOAK to NOAK within the nuclear industry. This research identified that generally costs declined in the range of 15% to 55% after successive deployment of an NOAK. Further, SMRs are expected to achieve cost declines in the higher echelon of that range (i.e. closer to 55%) because of a higher degree of standardization, a reduction in regulation, and reduced construction times relative to larger reactors.

There are a number of key economic drivers that will reduce the FOAK premium over time towards successful deployment of an NOAK. These include:

- One-time costs related to research and development (engineering design finalization, safety analysis, regulatory learning);
- Reduction in contingency through improved cost estimates;
- Learning through mass production and fabrication standardization of parts (e.g. aircraft industry);
- Reduction in financing costs and project execution risk; and
- Supply chain development and supporting infrastructure.

The following graphic demonstrates the cost declines (and drivers of those declines) from FOAK to NOAK. Please note that the comparable benchmark is natural gas and carbon costs.



The following table was also provided during the presentation. It breaks down the FOAK risk into three broad categories: technology; project execution and operations; and political. It is intended to illustrate specific risks related to each category, and to promote discussion related to potential mitigation measures that will support the economics of SMRs.

Technology	
Risk	**Mitigation**
• Vendor designs at different levels of commercial maturity/technology readiness • Cost elements may not be comparable to large reactors • On-site and long term disposal of waste • Safety and public perception • Limited sharing of supply chain elements between designs • Grid performance requirements (capacity factor, scalable size, renewable integration, economic life, etc.)	• Support for national laboratory R&D • Learning from pilot and demonstration plants • Passive safety and reduced complexity • Government back-stop for long-term waste disposal • Support for economic development of supply chain and infrastructure • Market incentives for grid performance (black-start, capacity market, flexibility payments etc.)
Project Execution and Operations	
Risk	**Mitigation**
• Large upfront capital cost for construction and development • Construction delays and long-lead times • High financing cost • Uneconomic when compared to incumbent competing technologies (high LCOE) • Security of fuel supply	• Funding or cost-sharing for one time development costs • Reduction in contingency and improved cost estimates through experience, bulk purchases • Regulatory certainty and streamlined licensing to support successive unit deployment • Policy tools (tax credits, loan guarantee, accelerated depreciation, PPA, GHG credit etc.) • Reduction in owner's costs and operational staff
Political	
Risk	**Mitigation**
• SMR deployment and product development outside political timeframes • Public perception and outreach • Lack of industry coordination between supply chain, technology design and market applications	• Macro-economic benefits to Canada through jobs, GDP etc. • Alignment with Climate Change targets • Long term commitment and support from the public sector (federal, provincial, municipal) • Public-private partnerships, cost sharing, government funding • Advancement in nuclear innovation, science and technology

2.4 Indigenous and Public Engagement

George Christidis, Director of Government Affairs from the Canadian Nuclear Association, and the Chair of the Indigenous and Public Engagement Working Group provided an overview of the mandate and planned activities of the working group, as well as results from initial engagements and other activities undertaken to date. The following provides a brief summary of the presentation.

The mandate of the working group is "to develop a Public and Indigenous Engagement work plan that would feed into the SMR Technology Roadmap." For all energy and natural resource projects, social engagement and acceptance is fundamental to its success. The working group is focused on building on past experiences, and identifying strengths and best practices to establish an effective engagement strategy. The approach being employed by the working group includes:

- A literature review to identify best practices and approaches;
- The development of a stakeholder mapping to map out the broader public context along with current ongoing Indigenous policy discussions; and
- Regional outreach activities with Indigenous representatives to identify opportunities and challenges.

Ideally, the objective of the working group is to commence a policy dialogue, raise the appropriate questions, and identify the organizations to work with well in advance of any specific project(s) being launched. This dialogue is intended to link with broader public goals and Indigenous community needs to explore how SMRs could be an option for them. As such, the working group will look to explore how SMRs support broader public goals related to, but not necessarily exclusive of the following:

- Climate change;
- Reducing particulates emissions;
- Enabling clean resource extraction;
- Addressing energy poverty;
- Indigenous nation capacity building; and
- Health and social benefits.

In terms of work undertaken to date, the literature review has begun, which has included a focus on obtaining an understanding of past engagement experiences in Alberta, Ontario, New Brunswick, and elsewhere. The working group is leveraging existing contacts and relationships held by provincial utility organizations (i.e. NB Power, OPG, etc.) to undertake some of this work. Further, the review is also looking at, and attempting to learn from, past experiences that were not effective (e.g. Quebec uranium mine).

The first engagement with Indigenous representatives was held on April 18, 2018 in Saint John, prior to the On-Grid Applications workshop. The following slide presents some key takeaways from the discussion.

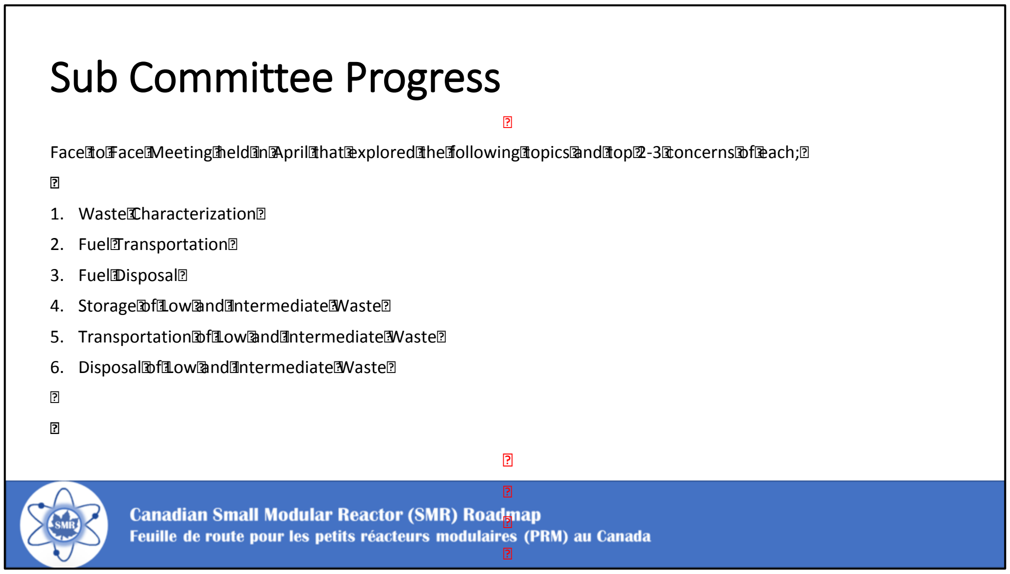
Based on the discussion with the Indigenous representatives who attended, it was apparent that any engagement efforts with Indigenous groups need to consider historical relationships with government and industry. Further, traditional knowledge will also need to be considered in any engagement strategy.

The Indigenous representatives at the meeting seemed more interested on discussing how SMRs could lead to longer-term partnerships, more so than just immediate economic benefits (i.e. jobs). There seemed to be some interest in the potential of an SMR on reserve acting as a distributed energy source. However, a key theme from the discussion was land, and risk to the land, with a view to how SMRs could impact the land several generations from now.

2.5 Waste Working Group

Derek Wilson, Chief Engineer and Vice-President of Contract Management at the Nuclear Waste Management Organization, and member of the Waste Working Group provided an overview of the results produced by the working group to date. The following provides a brief summary of the presentation.

In Canada, nuclear waste producers and owners are responsible, in accordance with the principle of "polluter pays," for the funding, organization, management, and operation of disposal and other facilities required for their waste. This recognizes that arrangements may be different for nuclear fuel waste, low-level radioactive waste, and uranium mine and mill tailings. With this in mind, the Waste Working Group met in early April 2018 to discuss and explore key topics related to establishing a waste management strategy for SMRs. The following slide presents the topics that were explored.



For each of these topics, the working group identified gaps where there is either a lack of a defined solution for SMRs, or a lack of understanding of future SMR characteristics that would have an impact on waste management. The following table presents the gaps identified by the Waste Working Group for each of these topics.

Topic Area	Identified Gaps
1. Waste Characterization	Availability of waste characterization information required to support safety cases for waste management licence applications for transportation, storage, or disposal of new waste forms.
	Novel waste characterization methods for new waste forms created by SMR technologies, including reprocessing technologies, with different characteristics from current used fuel and radioactive wastes. New technologies could concentrate certain radionuclides that are difficult to detect. • Different radionuclides are important to transportation, repository design, and long-term safety of radioactive waste management • Potential new mixed wastes
2. Fuel Transportation	**Fuel Characteristics** Projected post-irradiation fuel characteristics are required in order to support a comprehensive evaluation of SMR fuel transportation challenges. • Key characteristics required include fuel configuration, fission product inventory, decay heat generation, chemical form, and fissionable material content. • These characteristics will drive the transportation assessment, including whether the fuel can be shipped while adhering to current regulatory requirements, if any existing fuel packages are feasible, how much decay time will be required at the SMR site prior to transport, and any pre-transport processing requirements.
	Infrastructure Demands Fuel transportation packages have significant mass in order to provide the shielding and containment to meet transportation regulations. Therefore, they typically require modern transportation infrastructure such as highways, rail network, or deep-water ports. This infrastructure may not exist for remote SMR deployment sites, and alternate approaches may be required.
	Emergency Response Response to emergency situations (or even just mechanical failures of transportation equipment) may be significantly impeded in remote jurisdictions. This gap is common to waste transportation, but more acute for used fuel transportation due to the additional safeguards and security requirements for fissionable material.
3. Fuel Disposal	**Site Characterization** (Greenfield vs. a Class 1 existing facility) • Greenfield ○ No security in place

Topic Area	Identified Gaps
	○ Emergency preparedness zoning ○ Ability to get a licence • Existing Facility ○ All of the above in place
	Technology type • Wide spectrum of materials (PWR close to existing fuel type, molten salts, sodium, gas cooled, and the list goes on) • Issues can be dealt with technically but the cost is unknown • Need some direction or cross talk from the Technology Working Group
	When core is done • The need for processing or not? • How do we ship? • Does it need to stay on site for an extended period before it is shipped? • What does shielding look like and would it make it not passable on roads? • Soluability of solid sodium or salt - what happens if in an accident? • How would NWMO accept it and in what form?
4. Storage of Low and Intermediate Waste	SMR owners will continue to work with Government to determine their own solutions for interim storage until a final disposal option exists. In other words, the duration of interim storage becomes indefinite until a final disposal solution is in effect.
	The knowledge base and safety culture associated with on-site or centralized interim storage may not be as effective in a small operator/owner scenarios compared to today's large traditional operators. Cultural divides between industry, Indigenous communities, and surrounding public within remote regions in Canada may add to the challenges facing the required safety culture for handling and storing of waste materials.
5. Transportation of Low and Intermediate Waste	Transportation Emergency Response infrastructure may not be available or effective in all areas of Canada and in particular, remote Northern locations and the response time to reach the scene of an event may be long.
	While the technology, package design, and operating experience exists internationally for radioactive material transportation by air, rail, and water, there is not much if any operational experience in Canada to draw from. This may lead to concerns and issues in the areas of Emergency Management, available licensed companies and social license considerations.
6. Disposal of Low and Intermediate Waste	No one in Canada has long-term disposal available, for current industry or future SMRs. There are two options going forward for SMRs for low and intermediate waste at present: • When there is a national plan completed, then SMR owners would have disposal capacity available to them for a fair fee. • At present, SMR owners will be responsible to put in place their own disposal, either individually or collectively.

The Waste Working Group also acknowledged that collaboration with other working groups would be required to fully study the impacts of these gaps. In particular, the Technology Working Group to ensure that waste and its costs are considered as part of the overall technology solution, the Regulatory Working Group to understand the waste streams with different technologies prior to issuing a license to construct, and the Finance Working Group to ensure waste costs are factored into costing over the project life. Depending upon defined requirements and if SMR owners/operators will be responsible for waste, costs associated with waste management could present a significant barrier to market entry.

3. Summary of Roundtable Discussions

The On-Grid Applications workshop also included three roundtable discussions used to collect input from the participants on multiple topics. These topics involved the nature of on-grid requirements, supply chain risk and opportunities, and SMR characteristics needed to meet on-grid requirements. The following sub-sections provide a summary of the results from these roundtable discussions.

3.1 On-Grid Requirements

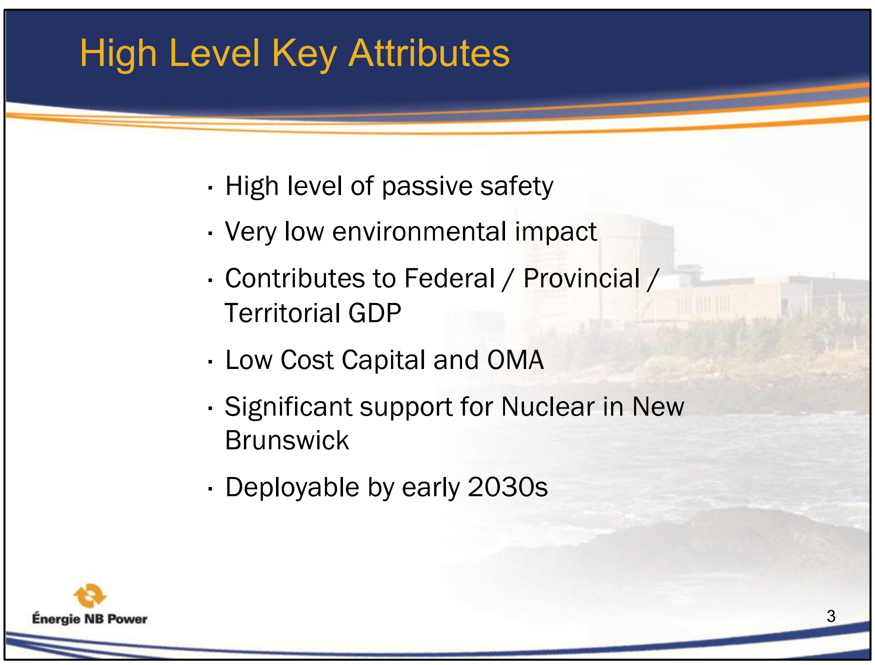
Prior to the roundtable discussion related to on-grid requirements, presentations were made by the following:

- Brett Plummer, Vice-President and Chief Nuclear Officer, NB Power
- Iain Harry, Senior Business Advisor, Generation Asset Management and Planning, SaskPower

These presentations were intended to provide a brief description of their organizations' priorities and future needs, and how SMRs could support addressing those needs. The following provides a brief summary and excerpts from each presentation.

NB Power has Defined High Level Attributes Required for SMR Deployment

NB Power has significant experience with reactor technologies, and has been looking at the possibility of SMRs for about a year and a half, to transition its energy mix away from coal. In doing so, it has established a set of high level attributes that a potential SMR solution must meet. The following slide presents those attributes.



Generally, NB Power would be looking for a solution, deployable in the early 2030s, which is inherently safe and involves a "walk away reactor." This would include less reliance on multiple complex systems, no need for auxiliary power for passive core cooling, and no active emergency core cooling systems. Further, the emergency planning zone (EPZ) should be very small, ideally at the plant boundary.

The SMR solution should also result in significantly lower operating emissions, with little to no production of high level waste, and ideally reduces or eliminates legacy high level waste. It also needs to provide national and regional economic benefits.

It terms of costs, an SMR solution must be able to compete with natural gas, and be in the range of about five to six cents per kilowatt hour. Ideally, costs would be kept low through simplicity of design, central manufacturing, modularity, and simple on-site construction.

Finally, SMRs will require public and Indigenous support, which will require significant engagement efforts. This will be needed to obtain a “social license” and environmental assessment (EA) approval.

The key challenge to an early 2030s deployment is the timeline itself, and the uncertainties regarding: research and development; fuel conversation and reprocessing; shipment of reprocessed fuel; and regulatory requirements related to operations, maintenance, and administration (OMA). Finally, under the correct circumstances NB Power would be prepared to consider a first of a kind SMR project.

SaskPower is Looking at SMRs to Meet its Clean Energy Goals and Increasing Demand

SaskPower has set aggressive clean energy goals for its operations. Specifically, by 2030, it is looking to double renewable generation capacity to 50% and cut carbon emissions by 40%. Further, there is also a significant increase in energy demand anticipated in the near future in Saskatchewan. Based on existing SaskPower owned resources and projected demands, the supply/demand gap will be approximately 3,500 MW by 2036 (SaskPower’s current peak demand is 3,800 MW, with capacity of 4,400 MW). As such, SaskPower is evaluating several potential supply options to meet these goals and increased demands including SMRs.

SaskPower’s current assessment of SMRs is that it could provide a viable option under the right conditions. It is unfeasible to have a large-scale reactor on a small grid like in Saskatchewan. As such, SMRs could be a viable nuclear alternative because of its small size and magnitude of energy output.

SMRs could also assist in moving closer to zero carbon emissions in the West, and would also offset any economic loss of a sun-setting coal industry. It is anticipated that there will be a cost in the future for carbon, and SMRs could help alleviate these costs and uncertainties. There is also a big opportunity for wind-generated energy in Saskatchewan, and SMRs are viewed as a potential source to supplement it.

The following slide presents some of the key barriers that would need to be addressed for deployment in Saskatchewan.

Barriers to SMR Development/Deployment in Canada

- Developing technology – not commercially available today
- First-of-a-Kind (FOAK) regulatory/schedule/ financial risks
- Price of natural gas
- Comparatively long project schedule (10-12 years) vs natural gas/wind/solar
- Public acceptance

For SMRs to be deployed in Saskatchewan, it would need to be cost competitive to alternatives. Specifically, natural gas prices are currently quite low and are expected to remain low in the near future. This would require low capital costs and modular construction processes. There are also concerns around safety. SMRs should be “walk away” safe, and transportation of fuel and waste needs to be considered.

These presentations were intended for information purposes and to promote discussion in the subsequent roundtable. Participants were then asked to discuss the following questions (at their respective table) and report back to the larger group.

- **What is the nature of the on-grid requirement? (What is the on-grid “problem” we are trying to solve?)**
- **Is there a regional/geographic difference in the nature of this requirement?**
- **Is there a timeframe consideration (i.e. in the short-term, medium-term, longer-term)?**
- **How would you organize and rank these requirements?**

The following provides a summary of the results from these discussions.

Summary of On-Grid Requirements

The following were the highest priority on-grid requirements reported back to the larger group after the roundtable discussion:

1. A **low carbon**-emitting alternative that results in a reduction in the use of fossil fuels.
2. A **“social license”** by obtaining public and Indigenous acceptance.
3. Costs that are predictable and **competitive** with respect to other options such as natural gas.
4. An ability to **integrate with and support renewable technologies** (e.g. solar, wind).
5. Supports **grid modernization** (e.g. smart grid, load growth) and replaces existing aging infrastructure.
6. An ability to meet **demand growth** through increased market sizes, export opportunities, and/or the introduction of disruptive technologies (e.g. electric car).
7. Provides **regional economic benefits** through a pan-Canadian supply chain.
8. A defined **waste management strategy** that reduces/recycles waste, and that factor in all relevant costs (e.g. decommissioning, transportation, etc.).
9. Established lifecycle **research and development support** (i.e. through the Canadian Nuclear Laboratories to the Canadian nuclear research eco-systems).

Summary of Regional Differences

The following are the key regional differences reported back to the larger group after the roundtable discussion:

1. Regional **demand** for electricity that an SMR would need to assist in addressing may differ depending on the market size, anticipated growth, and potential export opportunities to neighbouring jurisdictions.
2. The **characteristics of current regional grids** may differ (e.g. energy mix, size of grid, use of renewables) and could impact how SMRs are integrated.
3. **Public opinion** towards nuclear may differ by region; possibly dependent on whether the region has had previous experience with nuclear technology.
4. The **risk appetite** of owners/operators may differ by region with some organizations willing to deploy a FOAK and others being more risk averse and waiting for an NOAK.
5. The **capabilities and knowledge** of owners/operators will differ by region, dependent upon whether they have prior experience in the nuclear space.
6. Some regions may require **fuel reprocessing**.
7. Each region will be focused on obtaining **regional economic benefits**.

Summary of Timeframe Considerations

The following are the key timeframe considerations reported back to the larger group after the roundtable discussion:

1. An agreement on a **pan-Canadian approach** is required by 2019, to deploy in the 2030 timeframe.
2. Timeframes associated with **government decisions and commitments** to reducing carbon emissions could impact the uptake of SMR technology.
3. A **review of regulations and standards** could take some time to ensure its appropriateness for SMR deployment.
4. If **recycled fuel** is required in some regions, the research and development required to offer a recycled fuel solution could take some time and potentially impact time to market.
5. **Public engagement** efforts could take time, and should commence soon.

3.2 Supply Chain Risks and Opportunities

Prior to the roundtable discussion related to supply chain risks and opportunities, presentations were made by the following:

- Neil Alexander, Principal Consultant, Bucephalus Consulting
- Ross Galbraith, Business Manager, International Brotherhood of Electrical Workers

- Ron Oberth, President and Chief Executive Officer, Organization of Canadian Nuclear Industries

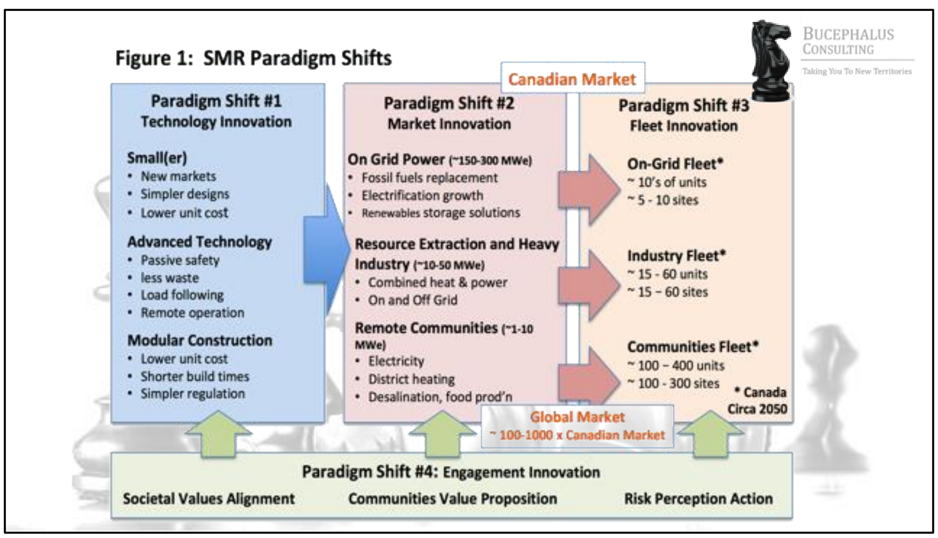
These presentations were intended to provide perspectives on various aspects of a future pan-Canadian SMR supply chain. The following provides a brief summary and excerpts from each presentation.

Fleet Deployment of SMRs will require a Paradigm Shift

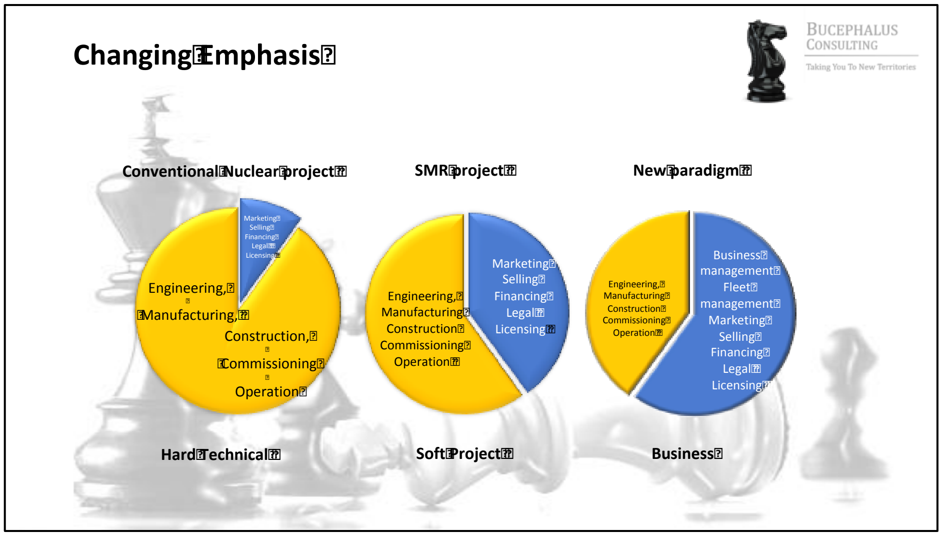
The world is vastly different than when the first reactors were built. Internationalization is taking place in the nuclear industry. Before supply chain issues can be resolved, a vision for SMRs needs to be defined. The supply chain will differ depending upon the vision and model employed.

Currently, there is no demand for SMRs, but there is an opportunity for them. In order to seize the opportunity, Canada should be looking to build a fleet of reactors, first for use in Canada and then for deployment internationally. Orphaned plants will not yield the benefits from an economy of scale. There needs to be consideration for how SMRs will be linked together as a fleet; this differs to how reactors are currently managed.

Successful deployment of a fleet of SMRs will require a new paradigm and changing emphasis from traditional reactor development. This involves innovative shifts in technology, market, fleet, and engagement. If Canada wants to succeed in this initiative, it will have to plan now for these paradigm shifts. Planning for the deployment of only a few reactors will not garner success. The slide below illustrates these paradigm shifts.



Historically large-scale reactor projects have been dominated by hard technical costs in engineering, engineered components, and construction. In SMR projects, engineering design will be removed and the costs of components will be lower, while front-end costs of putting the project together, environmental assessment, and gaining approval will not scale proportionally. As a result, the value will be more closely related to soft project skills. Specifically, this will require more focus on financing, building social acceptance, and growing the market. This will involve more business-oriented issues, rather than project issues. Success will not arise in selecting the right technology, but establishing the circumstances for its success market. The slide below illustrates these changes.



A critical success factor for a Canadian SMR program will be regarding how and when the first SMR factory gets built and when the First Dozen of its Kind (FDOAK) is built and deployed. Many questions still need to be considered including: Who will be involved as investors (i.e. government, industry)? When will there be sufficient orders to create a business case? Where is the optimum location for the factory (i.e. near the FOAK, near the primary market, etc.)?

Canada is accustomed to owning the nuclear technology; however, this possibly will not be the case for SMRs. There will be a large number of entities involved, and each will have different view of their role. There will be a need to define expectations and roles of vendors. There is significant benefit for Canada and Canadian companies to be engaged early in the process. Further, Canadian companies gaining experience with the regulatory process early in the deployment process is of value. Involvement early in the process will enable Canada to establish skills that can be mastered and potentially exported.

A Key Aspect of the SMR Supply Chain will be Human Resources

Generally, it is a best practice for an industry to send early signals to organizations that provides labour of their needs. Typically in these instances, the organizations will respond to meet the need as best they can.

For larger initiatives, project labour agreements can be effective. In these instances, the proponent is working with one labour supply entity. Provisions for diversity and inclusion (e.g. Indigenous employment) are often included into these agreements, which can lead to training opportunities. Further, apprenticeship and journey people provisions are often included in these agreements as a means to lower costs and provide additional training/exposure opportunities.

It will be important to identify the resource requirements for the SMR industry for the future. This would not only be to inform labour suppliers, but to also coordinate with other industries (e.g. Irving in New Brunswick) and ensure that a right-sized workforce is available when needed. This will require communication to ensure that other regional initiatives (where there could be an overlap in schedules) are not competing for resources.

As "baby boomers" are retiring, workforce demographics are changing. Unions are looking at hiring more apprentices. Traditionally, the focus has been on trade skills, but in recent years, there has been a shift in focus towards softer skills such as communicating and problem solving. This is so candidates are better able to adapt to ongoing technology changes.

Engaging with Potential SMR Suppliers Early will be Important

The Organization of Canadian Nuclear Industries (OCNI) represents a broad range of Canadian nuclear suppliers, of which the majority of members are small to medium enterprises (SMEs) comprised of anywhere from 50 to 100 staff. The flexibility of these small suppliers will be valuable to SMRs. Currently, suppliers and the supply chain will be engaged and committed for approximately the next 15 years with scheduled refurbishment and major component replacement projects. However, openings will emerge around the year 2027, which fits well for the SMR timeframe, as demonstrated in the slide below.

Technology selection needs to be undertaken in collaboration with suppliers. This assists suppliers to understand the supply needs. This also assists in accurately quantifying costs, as any costs without supplier input are essentially marketing numbers. It is highly recommended that SMR designers host supplier workshops to initiate this collaboration, as was recently done by NuScale in Oregon.

The Canadian on-grid SMR market may be too small to sustain a dedicated supply chain. The Canadian SMR technology selection parameters should also consider global export opportunities as well.

Again, these presentations were intended for information purposes and to promote discussion in the subsequent roundtable. Participants were then asked to discuss the following questions (at their respective table) and report back to the larger group:

- **What would be the elements of a strategy to ensure the viability of a Canadian SMR supply chain? (How do we ensure that Canada plays a leading role in global SMR supply chains?)**
- **What would be the two principal elements of that strategy?**
- **What would be the respective roles of industry and government in the strategy?**

The following provides a summary of the results from these discussions.

Summary of SMR Supply Chain Strategy Elements

The following are the key strategy elements for a future SMR supply chain reported back to the larger group after the roundtable discussion:

1. Timely government decisions and actions in support of a **national strategy** for SMRs is needed to advocate the merits of the program, remove national and international barriers, and set relevant policy (e.g. fuel).
2. **First to market** by either being the first to supply or demonstrate an SMR.
3. Training programs and facilities to establish a **skilled workforce** with appropriate soft and technical skills.
4. A **competitive advantage** that is difficult to achieve and replicate (i.e. cost, unique technology, functionality, etc.).
5. Clearly **defined sharing of risk** related to a FOAK so suppliers fully understand the level of risk they would need to incur.
6. **Timelines** for SMR design and development are defined so suppliers can sufficiently plan, required facilities can be built, and an adequate workforce can be secured.
7. An effective **national research and development program** anchored within the Canadian Nuclear Laboratories (CNL).
8. A **fleet business model** with a centralized supply chain, where all vendors are “on the same page.”
9. A reliable and assured source/supply of **fuel**.
10. **Innovative manufacturing** techniques as a means to lower costs.
11. **Regulations and standards** that support off the shelf components.

In terms of the **roles of government** in the strategy, participants provided the following responses:

- Making timely strategic decisions to support policies and programs;
- Aligning and revising policy as needed;
- Providing funding;
- Establishing international agreements to support export opportunities;
- Engaging the public to obtain social acceptance;
- Clarifying and establishing rules and regulations (e.g. waste disposal, transportation between provinces, etc.); and
- Developing an adequate workforce.

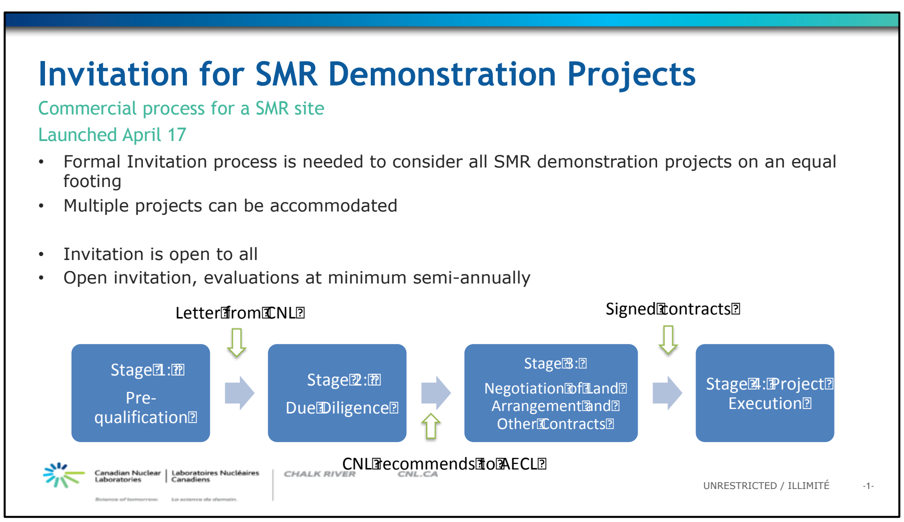
In terms of the **roles of industry** in the strategy, participants provided the following responses:

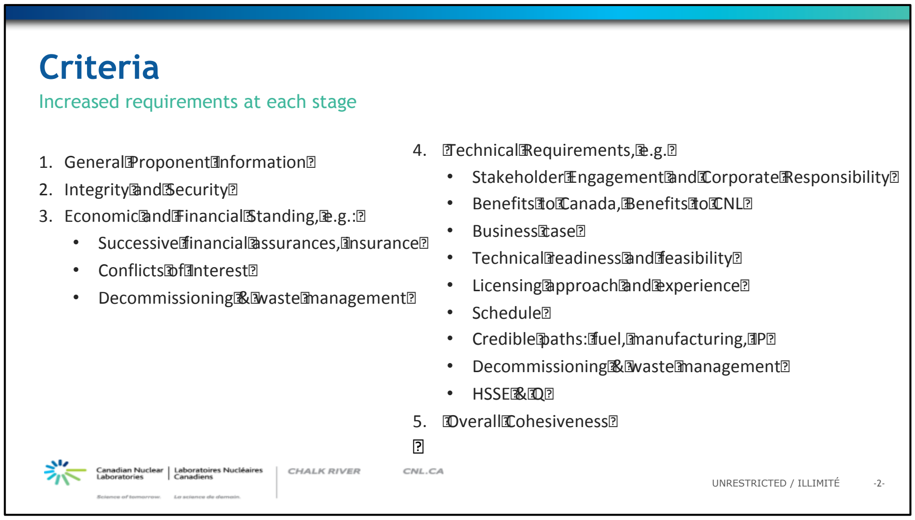
- Establishing a viable economic/business model;
- Providing funding;
- Designing technical aspects; and
- Developing an adequate workforce.

Participants also noted that **academia** would have a role as a partner to both government and industry within this strategy.

3.3 SMR Characteristics Needed to Meet On-Grid Requirements

Prior to the roundtable discussion related to SMR Characteristics needed to meet on-grid requirements, Bronwyn Hyland, Program Manager of Small Modular and Advanced Reactor Technologies at the CNL, and Co-Chair of the Technology Working Group provided a brief overview of the invitation for SMR demonstration projects process recently launched by CNL. The following slides provide details on the process and criteria that will be used to assess applicants.





After providing the overview of the CNL process, Ms. Hyland presented participants with a draft On-Grid Characteristics Framework (“framework”). The framework is intended to capture a range of potential characteristics for an on-grid SMR, and to label the characteristics under specific categories and levels of need.

The framework listed various categories related to a future on-grid SMR as column headings including: National Research and Development Support; Fuel; Operational Aspects; Deployment; Safety; among others.

Row headings within the framework listed the levels of need of the characteristic included:

- Mandatory (i.e. characteristics the SMR must have);
- Desirable (i.e. characteristics that would be nice to have);
- Exclusion (i.e. characteristics that the SMR must not have); and
- Comparison (i.e. characteristics that could be used to evaluate one SMR design over another).

A number of SMR characteristics were pre-populated in the draft framework for validation and discussion purposes. Participants were then asked to consider the following questions (at their respective table), to fill in the framework with relevant characteristics under the appropriate categories and levels of need, and to report back to the larger group:

- **What mix/formula of SMR characteristics would optimize the meeting of both these requirements (on-grid application and supply chain)?**
- **Can the structure/concept of the framework be improved?**

Each table provided a marked up copy of the framework that captured the key characteristics discussed. These results are amalgamated into the On-Grid Characteristics Framework provided in Appendix C. The following presents some key themes identified throughout the discussion and report back.

National Research and Development (R&D) Support

There was a general consensus that a rigorous national R&D program is required, which should involve CNL, industry, academia, and other partnerships. There was also recognition that this program would be needed to support the lifecycle of SMRs. It would not just be needed for the design of the initial technology but also to understand, review, and solve issues as they arise.

Supply and Nature of Fuel

Many participants noted that the ability to obtain fuel from multiple sources should be a mandatory characteristic, or at least highly desirable. Further, there was a range of views related to the potential level of enrichment of the fuel. Many in the industry believe that highly enriched uranium (i.e. > 20%) is not permitted, but this is incorrect. In Canada today, there are systems and processes in place that require highly enriched uranium. However, it is highly unlikely than any new technology would require this level of enrichment. As such, any enrichment above 20% could be considered undesirable. Regardless, participants provided varying views as to whether less than < 5% enrichment should be considered a desirable or a comparator.

Load Following Design

Many participants stated that the operational design needs to allow for up to 50% load following. However, load following may have a different meaning depending upon the market. Load following essentially provides flexibility to the operator. Regardless, the anticipated costing structure for SMRs will require no more than a 50% capacity factor for seasonal load following. This is because fixed costs will continue to remain regardless of the output being produced, and marginal costs will not be as high as traditional fossil fuel plants.

Potential Changes to the Framework

Participants recommended a number of potential changes to the framework. This includes adding several new categories/columns such as federal government, international market, economic/social, community engagement/social responsibility, and insurance. These columns are included in the results in Appendix C.

Participants also stated that some categories or individual characteristics could be considered more important than others. Currently the framework does not capture these differences. Participants recommended potentially introducing a weighting system. They further suggested that the framework could be changed into a checklist that could be used to review different technologies, and that the weighting system could be integrated.

It was also noted that some characteristics may be unique to, or would differ for, different Provinces/markets. The framework currently does not enable a means to differentiate these characteristics. In these instances, participants highlighted these characteristics (and they have also been noted in Appendix C).

Appendix A: List of Participants at the On-Grid Applications Workshop

Appendix B: List of Steering Committee Organizations

The following organizations are represented on the SMR Roadmap Steering Committee:

- New Brunswick Power
- New Brunswick Department of Energy and Resource Development
- Qulliq Energy Corporation
- Ontario Ministry of Energy
- Ontario Power Generation
- Bruce Power
- SaskPower
- Northwest Territories Department of Infrastructure
- Alberta Ministry of Energy
- Alberta Innovates
- Non-voting: Atomic Energy of Canada Ltd.
- Non-voting: Natural Resources Canada

The Steering Committee is also served by the following non-voting co-chairs:

- Diane Cameron, Director, Nuclear Energy Division, Natural Resources Canada
- Phil Carr, Roadmap Facilitator, Strategic Review Group/Canadian Nuclear Association

Appendix C: On-Grid Characteristics Framework

	National R&D Support	Fuel	Operational Aspects	Deployment	Safety	Supply Chain
Mandatory	National laboratory - Can't rely exclusively on an R&D program elsewhere (e.g. in vendor home country) Verify credibility of R&D on fuel within the context of national labs and the research community as a whole (e.g. academia, partnerships) Ongoing Canadian support throughout the operating life of the plant (i.e. ability to understand and solve issues) Rigorous R&D program	Security/diversity of supply ~~Credible~~ Qualified fuel manufacturing technology - Fuel design has undergone irradiation testing for reactor use for early deployment (2030)	Scalable for different markets/sites – Plant minimum ~~100~~ 50 MW, max ~300MW* - Scalable or modular? Offering different sizes loses fleet economics Simple ease of operation - Organizational resilience to technology Load following capability / flexibility* - Able to integrate with renewables & support daily and seasonal load swings > 85% CF* < 2% Forced Loss Rate* Central support for technical, O&M, training to support fleet model Expected plant life > ~~60 years~~* (commensurate with viable economic life cycle with consideration of O&M, refueling, and decommissioning) - May also include refurb	2030-2035 Within political timeframes - Integrate with renewables Transportable (logistics and regulatory) Time to market	Gen IV passive safety - At least 7 days, without operator action for severe accidents Fire and safety resistance built into design Reasonable EME strategy Minimal plan boundary & EPZ > flexible siting for a variety of locations	Central manufacturing Realistic manufacturing technology allowing for high likelihood for supply and manufacturing in Canada and various provinces
Desirable	Strong pan-Canadian and international networks (e.g. universities) National lab involvement	< 5% enrichment* (could go up to < 10%) As a commodity Capable of manufacture and supply in Canada Multiple fuel sources/suppliers Accident tolerant Designed for reprocessing over time	> 90% CF* Small O&M staff levels - O&M costs comparable to current nuclear plants, per electricity output Dual cycle electrical steam, desalination, etc.	Not FOAK* - Decision to COD < 10 years - LTC to COD < years Canadian supply chain Deployment in 2025	Complete walk away Black Start capability Economical passive safety	Canadian manufacturing opportunities (all or some of the supply chain) - Pan-Canadian/Regional shared benefits
Exclusion / Undesirable	National security legislation Proprietary IP that negates ability to perform R&D in Canada	> 20% / 19.75% enrichment impractical	< 50% load following capacity factor			
Comparison	Degree to which increases innovation in Canada Incremental IP held in Canada	< 5% enrichment (comparator rather than a desirable)	# of staff Ability to load follow (may only need up to 50% capacity) Black start		Plant boundary & EPZ Remote monitoring and shutdown 7 days without operator action (comparator rather than mandatory)	Canadian capacity/expertise (hard to replicate and "sticky")

Black font denotes original characteristics presented for validation to workshop participants
Red font denotes new or revised characteristics and other content (e.g. columns, titles, etc.) provided by workshop participants
* Denotes attributes that may be specific to a market or province

	Other	Licensing	Financial	Waste	Federal Government	International Market	Social / Economic	Community Engagement / Social Responsibility	Insurance
Mandatory	Good potential for export opportunities Easily shipped to remote locations by ship, rail, or truck Flexibility of siting locations (brownfield, greenfield, water regimes)	Licensable in Canada Safeguard application must be practical	Financial strength - Competitive with backstopped renewable Low upfront capital cost (#s for FOAK and NOAK) Low LUEC (#s for FOAK and NOAK) – must be close to gas	Spend fission product storage on site Ability to mesh with existing plans Coordination/engagement with NWMO regarding waste, core storage, cool down, transport (time and volume), etc.	High level of safety and security - Compliance with proliferation resistance High level of economic benefits - Positive measurable economic and employment impacts (e.g. jobs, GDP) - Proportional benefits to Canada relative to risk/cost sharing (including supply chain, R&D, IP, value chain, etc.) Low environmental impact - Support/compliment uptake of variable/renewable generations - Support climate change initiatives	TBD	TBD	TBD	TBD
Desirable	Water usage/consumption, desirable to be no greater than a comparable sized unit for natural gas or coal Flexible cooling options, water, air, water/air hybrid Minimize use of toxic materials Radioisotopes Cobalt 60 capability		Should compete with gas Lifecycle of fuel (is an economic concern)	No high level waste stream Burn CANDU spent fuel Recycle used CANDU fuel (Desirable rather than a comparator)	Support international relations Success of CNL Canadian leadership in SMR technology Enhance Indigenous partnerships Export opportunities / market diversification Support provinces and territories move from fossil fuels				
Exclusion / Undesirable	> ~300MWe				Vulnerable / National interest				
Comparison				Recycle used CANDU fuel					

Black font denotes original characteristics presented for validation to workshop participants
Red font denotes new or revised characteristics and other content (e.g. columns, titles, etc.) provided by workshop participants
* Denotes attributes that may be specific to a market or province

Appendix D: List of Presenters at the On-Grid Applications Workshop

The following provides a list of topics presented and presenters at the On-Grid Applications workshop.

Introduction and Approach to the SMR Roadmap:

- Diane Cameron, Director, Nuclear Energy Division, Natural Resources Canada

The Status of Small Modular Reactors & CNL Invitation for SMR Demonstration Projects:

- Bronwyn Hyland, Program Manager of Small Modular and Advanced Reactor Technologies, Canadian Nuclear Laboratories and the Co-Chair of the Technology Working Group

SMRs in Canada: Readiness of the Regulatory Framework:

- Robin Manley, Vice-President of Nuclear Regulatory Affairs and Stakeholder Relations from Ontario Power Generation, and the Co-Chair of the Regulatory Readiness Working Group

Spreading the First-of-a-Kind Risk for On-Grid:

- Nicolle Butcher, Vice President of Strategy and Acquisitions from Ontario Power Generation, and the Chair of the Economics and Finance Working Group

SMR – Public and Indigenous Engagement:

- George Christidis, Director of Government Affairs from the Canadian Nuclear Association, and the Chair of the Indigenous and Public Engagement Working Group

Waste Management Working Group Update:

- Derek Wilson, Chief Engineer and Vice-President of Contract Management at the Nuclear Waste Management Organization, and member of the Waste Working Group

On-Grid Requirements:

- Brett Plummer, Vice-President and Chief Nuclear Officer, NB Power
- Iain Harry, Senior Business Advisor, Generation Asset Management and Planning, SaskPower

Supply Chain Risks and Opportunities:

- Neil Alexander, Principal Consultant, Bucephalus Consulting
- Ross Galbraith, Business Manager, International Brotherhood of Electrical Workers
- Ron Oberth, President and Chief Executive Officer, Organization of Canadian Nuclear Industries