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

Workshop 4: Heavy Industry Applications
Calgary, June 19-20, 2018

June 29, 2018

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Executive Summary

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1. Introduction

This report provides a summary of presentations and discussion from the fourth workshop associated with the Small Modular Reactor (SMR) Roadmap. The workshop was held in Calgary, Alberta on June 19th and 20th, 2018 and focused on Heavy Industry Applications. A list of participants at the workshop is included as Appendix A.

In the morning of the first day, John Barrett, President of the Canadian Nuclear Association, and Diane Cameron, Director of the Nuclear Energy Division at Natural Resources Canada, provided introductory presentations that offered context regarding nuclear energy in Canada, SMRs, and the SMR Roadmap. The remainder of this section summarizes some of the key messages from their presentations.

1.1 A Canadian Perspective on Energy

The International Energy Agency (IEA) has stated that the global demand for energy will increase by 30% by 2040. It has also stated that to meet the "2-degree scenario," installed nuclear capacity would need to be doubled by 2050. As such, there will be a need for additional clean energy generation.

Canada today has an impressive range of energy assets. For example, Canada is ranked:

- 2nd in free market holdings of oil reserves;
- 4th in crude oil production;
- 5th in natural gas production;
- 2nd in hydro-electricity production; and
- 2nd in uranium production.

Canada is also eighth in the world in power generated by wind, and in the past five years, solar power generating capacity in Canada has grown 2.5 times. Although power from renewable sources is growing quickly, it still provides a relatively small output overall. Further, there are challenges with storage of energy from these sources.

The federal government is thinking seriously about the future of energy. In 2016, Canada developed the Pan-Canadian Framework on Clean Growth and Climate Change (PCF). This was developed after signing on to the Paris Agreement in 2015, with input from the Provinces and Territories and through engagement with Indigenous peoples. The goal of the PCF is to meet Canada's emissions reduction targets and to grow the economy. It includes four pillars:

1) Putting a price on carbon;
2) Mitigation, including electricity interties;
3) Adaptation; and
4) Investments in clean technology and innovation.

In support of pillar #4, the federal government has made major financial commitments to clean energy innovation initiatives. Over $14 billion has been allocated to these initiatives in the most recent federal budgets (including $1.2 billion to revitalize Canadian Nuclear Laboratories at Chalk River).

In 2017, the Government of Canada also launched Generation Energy, which was tasked to help chart a pan-Canadian vision for energy. This involved a 6-month dialogue that reached over 380,000 people either in person or online. The initiative is led by the Generation Energy Council, which consists of 14 thought leaders in the industry. The Council will build on what was heard to develop recommendations for Canada's energy future; a report is due in the summer of 2018. Early results from this work indicated that a range of energy options need to be considered, and that nuclear has a role. Results from this work to date are available online at http://www.nrcan.gc.ca/20093.

1.2 Nuclear Energy in Canada

Canada is one of approximately six "Tier 1" nuclear countries, with its own domestic, commercialized reactor technology (i.e., CANDU). Canada has over 60 years experience in the nuclear industry with a mature full-spectrum supply chain. In all, 30 Canadian reactors are in operation, out of 446 reactors worldwide, representing 5% of the global installed nuclear capacity.

Nuclear is a pan-Canadian industry. In Ontario, Atomic Energy of Canada Limited (AECL) and Canadian Nuclear Laboratories (CNL), at the Chalk River Laboratories, have been undertaking "leading edge" nuclear research and development for over six decades. Further, Bruce Power operates the largest nuclear plant in the world, and with Ontario Power Generation (OPG), supplies over 60% of Ontario's electricity from nuclear energy. The Province of Ontario has recently committed $26 billion to refurbish the Province's nuclear fleet; this is one of the largest clean energy investments worldwide.

In the East, New Brunswick Power operates a nuclear plant at Point Lepreau. This plant generates approximately 33% of the Province's electricity. In all, nuclear energy provides 15% of Canada's electricity.

In Saskatchewan, uranium mining, milling, and processing activities are undertaken. Universities across Canada are also performing nuclear research and development, with research reactors in place in Saskatchewan, Ontario, and Quebec.

The sustainable development aspect of nuclear technology may be more important than power generation. Nuclear technology can help address 9 of the 14 United Nations Sustainable Development Goals.[1] Canada would not be able to meet its Paris commitments (and displace coal by 2030) without investments in nuclear power, as nuclear currently allows Canada to displace 50 tonnes /year in greenhouse gas emissions. Meeting these targets will require not just refurbishments, but also new builds.

Early results from the Generation Energy initiative (discussed above), indicated five overarching themes for nuclear in Canada moving forward. These themes include:

1) The Government of Canada is an important partner;
2) Nuclear energy is an important part of Canada's clean energy mix;
3) Lasting partnerships across the industry are important to bring the industry to the next level;
4) Next generation nuclear workers are diverse and passionate about environmentalism and climate change; and

[1] United Nations; "Sustainable Development Goals: 17 Ways to Transform Our World"; Retrieved June 2018 from: https://www.un.org/sustainabledevelopment/sustainable-development-goals/

5) The nuclear industry has a bright future, which could be guided by an overall strategy (but it needs to address some ongoing concerns about public confidence and costs).

1.3 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 is currently a large variation of reactor types under development within the industry, and large variations of designs within reactor types.

SMRs have the potential to be a clean, secure, and affordable source of reliable energy. The benefits of SMRS include:

- No Emissions: Like currently operating nuclear reactors, SMRs do not produce greenhouse gases in the production of electricity that contribute to climate change or air pollution.
- Hybrid Systems: Some SMRs can be integrated with renewable energy sources, like wind and solar, to create hybrid energy systems.
- Lower Costs: Factory fabrication and modular components can reduce construction costs and duration, and help lower costs by producing many similar units.
- Strong Safety Features: SMRs are just as safe as current nuclear reactors, and have new features that ensure designs meet stringent safety requirements.

1.4 Why SMRs in Canada?

The world is in the midst of something that has only happened a few times in history: a fundamental shift in the types of energy that power our society. The pace of that transition may vary from country to country, but it is underway and irreversible. SMRs and advanced nuclear reactors will have a role to play in this clean energy transition both domestically and internationally.

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:

- Canada has a world class and respected nuclear regulatory framework. All reactors in Canada are federally regulated by the Canadian Nuclear Safety Commission (CNSC). The regulatory framework in Canada differs from other countries. The robust yet flexible framework is able to accommodate new reactor designs, and has led several designers to engage in discussions with the CNSC. There are currently ten (international) designers who have had pre-licensing discussions with CNSC;
- An efficient gateway to the North American market;
- There is a pressing domestic need for the technology. Potential domestic applications are discussed in more detail in Section 1.5 below;
- An existing, capable, and established supply chain. Many countries have lost their supply chains, which is not the case in Canada; and
- A stable political system with a federal government that is committed to action on climate change.

However, the window for Canada to take action is accessible now, and is narrow. The SMR landscape is moving fast and there is a lot of interest worldwide. A lot of design work has taken place, and some of these technologies may now be ready in five to ten years.

1.5 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, that will involve 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 understand their perspectives on the unique requirements for each of the main applications/markets. Four workshops were 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 third workshop was held in Iqaluit on May 10-11, 2018, and focused on the energy needs of off-grid and remote communities.

The SMR Roadmap process also involved a series of engagements with Indigenous representatives. Engagement sessions were held in Saint John and Calgary prior to the workshops each city. Another engagement session is scheduled for the summer of 2018 in Ottawa.

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.

1.6 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.*

2. Presentations and Panel Discussions

The Heavy Industry Applications workshop included presentations from various stakeholders, and a series of panel discussions. Participants were invited to ask questions to the presenters or to provide general comments related to the content provided by the presenters. Generally, topics discussed involved the current nuclear industry, potential SMR applications, and the characteristics of a future pan-Canadian SMR industry. The following sub-sections provide a brief summary and excerpts from these presentations, as well as a summary of the panel discussions.

2.1 Nuclear Operations Today

Presentations on the current state of nuclear operations in Canada were provided by:

- Frank Saunders, Vice President, Nuclear Oversight and Regulatory Affairs, Bruce Power
- Paul Thompson, Senior Strategic Advisor, New Brunswick Power (NB Power)

Bruce Power has Substantial Expertise as a Nuclear Operator

Bruce Power is the largest private operator of nuclear power plants in Canada operating eight units leased from OPG. It produces approximately 30% of the electricity generated in Ontario. Its agreement with OPG is unique in that it is not only responsible for the operation, but also the refurbishment of these eight reactor units (Units 1 and 2 have already been refurbished; the other six units will be refurbished starting in 2020) through investments made by the Province of Ontario. These refurbishments are being undertaken so that its reactor operating life cycles will be extended into the 2060s.

Bruce Power is interested in adding SMRs to its asset fleet. Currently, nuclear is the second lowest cost source for on-grid applications, with hydro being less expensive. Not all reactors are very large, but the larger reactors tend to receive most of the attention. In fact, a CANDU reactor core can fit into the average meeting room. Currently, there is a research reactor with a 5MW core operating in the middle of a university campus in Ontario, and, generally, people on the campus are not even aware of it.

In terms of staff complement, the larger reactors require about 20 people on site at all times. With engineers and other support staff, the total required complement is around 500 positions. This still results in a fairly low overhead in comparison to the large output of these units (i.e. 800 MW). Further, these units can run for up to 80 years. They are also quite safe; even after a major accident there would never be a need to evacuate people (but we would anyway because the industry is very conservative).

NB Power: A Nuclear Operator in a Smaller Jurisdiction

NB Power employs approximately 2,300 staff and provides power to approximately 400,000 customers in New Brunswick. New Brunswick has a small and dispersed population, with industries in highly competitive markets. NB Power’s current generating sources are a mix of hydro, nuclear, coal, and other fossil fuels, with some of its power generating assets approaching the end of their life. The electrical grid in the Province is well distributed and interconnected with surrounding jurisdictions, which supports importing and exporting electricity from/to the United States.

NB Power has been operating a reactor at Point Lapreau since 1982. The unit was refurbished in 2012, so that it can remain in operation until the 2050s. Nuclear technology provides an advantage for energy rates, its helps the economy, and is environmentally friendly. It has also put New Brunswick "on the map" as being technically advanced in the nuclear space. This has opened a lot of opportunities to exchange information both domestically (across the supply chain) and internationally.

Many SMRs present a simpler reactor design. The science behind the technology is more sophisticated than previous reactors, so it has smaller physical dimensions. They also have a greater degree of passive safety features. Deployment would involve a standardized approach that would be established in collaboration with CNSC. The key objective to implementing SMRs is reducing greenhouse gas (GHG) emissions. Ultimately, SMRs could be adopted by utility companies or anyone else interested in owning and operating them for their own needs (e.g. heavy industry organizations).

Summary of Panel Discussion: Nuclear Operations Today

Question 1: OPG purchased Energy Alberta and considered moving nuclear power to Alberta. Could you discuss this experience?

- OPG was looking at putting 2 reactors in Peace River to supply the oil sands. At that time, these reactors would have produced 1500 MW of power, which is much greater capacity than is needed.
- The larger the plant you install, the more likely you will use electricity as the common currency.

Question 2: What challenges do you see being involved in introducing nuclear reactors to traditional non-nuclear environments?

- I do not see any technical challenges, as there are no differences in how they will operate in different locations.
- The major consideration that will require effort is having people within the jurisdiction understand and become comfortable with the technology. This will require Indigenous engagement, public consultations, etc. However, there are supports available that can be leveraged within industry and at the Canadian Nuclear Association (CAN).

Question 3: With respect to remote community applications, what are the key challenges related to having people available to work on these reactors?

- This will depend upon the size of the reactor and remoteness of the community. However, the expectation is that vSMRs will be used for these applications, in the range of under 2.5 MW.
- We will need to be aware of the key aspects required for remote deployment; some of these technologies are close to being ready. In fact, some of the reactors in this size are really "on/off" reactors, where very little knowledge is needed.
- However, you will always need to have some staff. But these reactors will largely be remotely monitored. Currently, it can be difficult to fully understand this because these designs and models are much different than today's large reactors.

Question 4: In terms of developing models and Indigenous involvement, we probably want to think about how Indigenous communities view the concept, particularly in deploying in remote communities. To what extent is the Roadmap considering this?

- This is absolutely correct, as engagement early in the process is critical to success. This is why the Roadmap has included Indigenous engagement workshops (and one planned with Metis representatives).
- Results from these workshops to date have varied. In New Brunswick, being a smaller province, Indigenous representatives knew NB Power well and understood nuclear power, but historical context was also key. Some communities there were asking if it would be feasible to have an SMR in the community and to then sell power back to the grid.
- In Nunavut, where communities are more isolated and there is less coordination among communities, there was no experience with nuclear. As such, there is more need for capacity building and knowledge building. There is also more of a demand for community-based holistic energy planning (which could or could not include nuclear). There is also interest in various potential ownership models.
- In Calgary, much of the discussion was about economic development and ownership/partnership models.
- Overall, there is a need to establish more engagement and partnerships. Representatives also stated that they would like to meet with “power people.” To achieve this, NB Power has contracts to go out and speak with some communities in their province.
- We also need to get more Indigenous involvement in environmental programs, so that they include traditional knowledge.

Question 5: How many people (i.e. staff) will be needed for 50 to 100 MW reactors?

- This will depend on the size of the reactor. Also, electricity production is more complex than steam, which may have an impact on staff complement.
- Past experience demonstrated that a 25MW reactor required around 5 people per shift. However, staff complements could increase depending upon security requirements. Also, specialists will be required at the time of fueling. It would be expected that fuel would be brought in/removed from the site every 2 to 3 years.

Question 6: Does the capacity of a reactor impact the physical size of the reactor?

- This depends on the design; some are quite small and are designed to be scalable.
- Current reactors are in large vaults because of the amount of piping involved, not because of the size of the cores. These new reactors will not have the same level of, or need for, piping and valves.

Question 7: How would radioactive waste be managed for an SMR fleet?

- Current reactors do not produce a lot of volume of waste, but rather a lot of weight. This is because uranium is a very heavy element. In fact, the city of Toronto produces more waste per volume in one day than a reactor does in a year.
- Currently, waste is stored on site. However, you would not want to store this for the long-term in a small community. This requires more discussion to support a policy decision regarding how waste would be stored, and who would be responsible for dismantling the SMR at the end of its lifecycle.
- There is a panel scheduled within the workshop to discuss waste management (results are provided in Section 2.6 below).

2.2 Potential for Nuclear in the West

Presentations on the potential deployment of SMRs in the western provinces were provided by:

- Iain Harry, Senior Business Advisor, Innovation and Clean Energy, SaskPower
- Dale Friesen, Indigenous and Government Relations and Sustainability, ATCO

Evaluating SMRs as a Future Generation Option in Saskatchewan

SaskPower is a small utility company, with approximately 520,000 customers, responsible for power generation and distribution for Saskatchewan. From 1960 to 2012, the majority of its power generation came from coal. The original power plant was built beside the coal mine, and no other option could compete on cost.

In 2011, SaskPower started thinking about cleaner options more seriously. It has set aggressive clean energy goals for its operations. Specifically, by 2030, it is looking to double renewable generation capacity to 50% and cut GHG emissions by 40%. To accomplish these goals, SaskPower will most likely look to increase natural gas and wind generation, as well as introduce other sources (i.e., solar, biomass).

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. Further, the majority of its current assets are nearing the end of their lifecycles and will need to be replaced in the next 25 years. It is within this timeframe (i.e. post-2030) that SaskPower believes SMRs could be a viable option to meet these increasing demands and further reduce GHG emissions. However, to be viable, the cost of power from SMRs must be competitive with other non-emitting baseload options (e.g., hydro, wind + solar + capture). The following slide presents SMRs potential role in Saskatchewan's power mix.

In terms of challenges to SMR deployment, the technology is still in development, so it is not yet commercially available. There will be several first-of-a-kind (FOAK) risks related to regulations, scheduling, and financing. The volatility in the price of natural gas is also a risk, as it may not be a barrier in 2030.

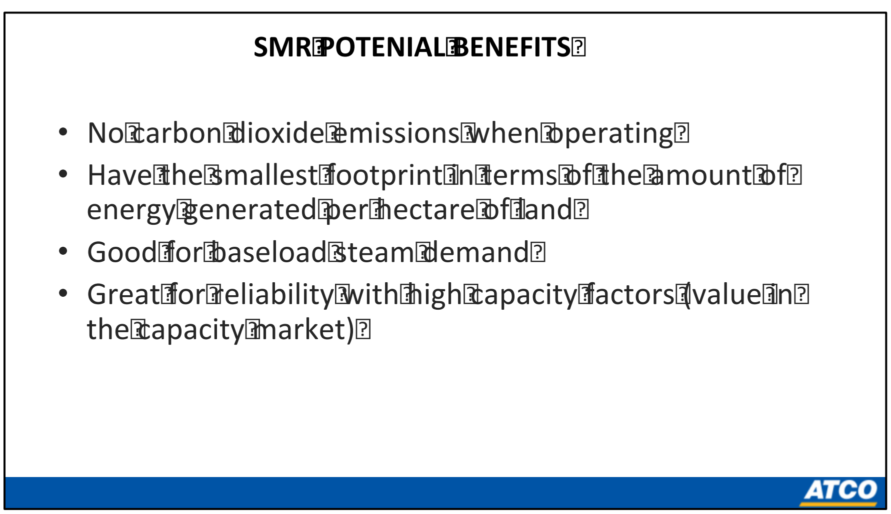
Also, the project schedule could be a challenge. Five years in the timeframe that SaskPower is looking at from making a decision about deployment. As such, if the technology cannot be ready within that timeframe, it will be difficult to convince decision-makers. Finally, public acceptance and building support will be a challenge as Saskatchewan is a traditional non-nuclear jurisdiction.

SMRs as an Option for ATCO

ATCO is family controlled business, with three main divisions: structures and logistics, electricity, and pipelines and liquids. The electricity division includes generation, transmission, and distribution. ATCO's electricity generation mix includes 75% natural gas, 23% coal (which is being phased out), and some renewables (e.g., wind, solar). They are currently working on a distribution line to Fort McMurray, and working with a number of Indigenous communities to establish equity distribution agreements related to the line.

Currently in Canada, there are 3 provinces that use coal: Nova Scotia, Saskatchewan, and Alberta. Ontario has now displaced coal, but they had nuclear and hydro to rely on as backup sources. Alberta is moving ahead on gas and renewables. However, renewables have a lot of challenges associated with them such as the poor efficiency of wind and solar, which would require load following (such as fast acting gas, hydro, or SMRs). A large power plant would not work well as a load following source for renewables.

The length of time to build after a decision is also a consideration. The impacts of Bill C-69 (the Impact Assessment Act and the Canadian Energy Regulator Act) could add another 2 to 3 years to a project schedule to receive regulatory approval. Also, election cycles can introduce risk, depending upon the political sensitivities associated with a technology option. The following slide demonstrates some of the potential benefits of SMRs from ATCO's perspective.



In terms of challenges, SMRs may be subject to some bias or public acceptance issues (i.e., "not in my back yard"). Also, the regulatory timelines must be short, and cannot be onerous. Finally, it is not clear yet how these projects would be financed (i.e., would a large bank want to be involved?).

Summary of Panel Discussions: Potential for Nuclear in the West

Question 1: Is the power line that ATCO is putting in place to Fort McMurray able to transmit power only to Fort McMurray or back as well? Could a larger SMR be placed in Fort McMurray to support the oil sands and feed electricity back on the grid?

- The new line can do both: take electricity from Edmonton to Fort McMurray, but also back as well. We would not anticipate a problem with 500 MW transmissions.
- A larger SMR in Fort McMurray is a potential opportunity. People have been weary about a nuclear explosion or incident potentially contaminating the oil sands, but this is a misconception.

Question 2: Considering that "first movers" realize economic benefits and Saskatchewan has oil sands and uranium mines, could Saskatchewan play a role as a first mover?

- This is true but it would not be successful public policy for the country. Saskatchewan is a strong advocate of a fleet-based approach, where one on-grid technology (potentially from one developer) has been selected with a pan-Canadian sharing of resources and risks. Though the technology may be different for other applications (such as heavy industry). We are less concerned about who is first, and more concerned about it being ready when we have the need (i.e., 2030s timeframe).
- Also, the oil sands in Saskatchewan are buried deeper than Alberta, and makes it more difficult to obtain. There would be more interest in supplying power to the uranium mines, as there is currently no power distribution there, which is an opportunity for SMRs.

Question 3: What is driving the emissions reduction timelines?

- Federal regulations that came into effect in 2015 states that coal power generation must cease by December 31, 2029.
- You are able to convert coal boilers to natural gas for 5 to 10 years of operations, which does provide some buffer.

Question 4: How does the political environments in Saskatchewan and Alberta impact your plans to reduce GHG emissions?

- The government of Saskatchewan opposes a carbon tax because of its impact on customers. However, it is still committed to reducing emissions. It plans to exceed emissions reduction targets by 2030, and is expecting additional reduction requirements after that.
- As such, Saskatchewan is looking for ways to get to 70% to 90% reduction by 2050.

Question 5: Considering the need for a fleet approach and common requirements, what are the general criteria or requirements for an on-grid application?

- In 2010, SaskPower was looking at nuclear power for baseload, and in particular at some larger designs. We were partly looking into this because Bruce Power was interested in building larger units in the province, but realized that it would not be feasible or economical to integrate a large unit if we were only serving our (relatively small) domestic market.
- Currently, SaskPower's plants produce 50 MW to 300 MW power per unit. The largest capacity plant is 300 MW and soon to be 350 MW. This capacity level would be our key restriction or requirement.
- In terms of design, in 2016, we were looking at light water designs because of potential risks and unknowns. We are now challenging that assumption and looking at other cooling types.

Question 6: What are the key challenges in becoming owners/operators of SMRs?

- The three key challenges would be:
    1) Acceptability
    2) Approval times (i.e. how long it would take to get through the regulatory cycle)
    3) Cost
- A fourth might be insurability.

Question 7: What would be the key challenges if those challenges (listed in Question 6 above) were addressed?

- If you can address those 3 challenges above, we (ATCO) would be very interested. We are very interested in SMRs but they have always been 10 years away. Now that they seem closer (maybe 5 years), we are interested.
- SaskPower does not see itself as a nuclear operator, as it does not have that expertise and does not have the time to develop it. Rather, we are interested in working with current nuclear operators.
- Other factors or challenges include: waste (what do you do with the waste and what is the cost associated with waste management?); how do SMRs compare to the alternatives (not necessarily natural gas); and whether they can survive election cycles.

Question 8: What initiatives have ATCO undertaken to influence the project list that are subject to Bill C-69?

- ATCO has met with several senior government officials (i.e. Deputy Minister, Associate Deputy Ministers, etc.) at the Privy Council Office, NRCan, and other federal departments in an attempt to influence the project list.
- The Acts that will follow Bill C-69 will essentially replace the environmental assessment requirements. The project list is the list of initiatives/projects that would be subjected to these Acts. The list has not yet been published, only issued as a discussion paper.
- Currently, any energy project generating 200 MW or above would be on the list, which is largely an arbitrary number. ATCO has suggested that that number be increased to 500 MW.
- There are also arguments that nuclear should not be subject to the same requirements, but rather what needs to be considered is its capacity to produce impact. SMR technology is not comparable to natural gas, wind, or solar.

Question 9: To justify investments into production facilities (i.e., factories), what is the size of the fleet that will be required?

- We need to model this to look at potential generation mixes.
- The fleet approach will simplify our procurement approach. As long as SMRs are competitive, there will be a strong argument to implement them.
- Not all renewable sources are equal. For example, solar is only 21% efficient, wind is 40%. You cannot rely on them; but if you build nuclear, you can rely on it. As such, we need to value renewables differently.

2.3 Oil Sands – Applications, Opportunities, and Challenges

Presentations on the potential applications, opportunities, and challenges of SMRs being deployed in the oil sands were provided by:

- Matt McCulloch, Director, Greenhouse Gases, COSIA
- Soheil Asgarpour, President, Petroleum Technology Alliance of Canada (PTAC)
- Axel Meisen, Senior Advisor, Alberta Innovates

Drivers and Challenges for Future Development in the Oil Sands

COSIA is a collaboration of ten companies who are responsible for 90% of oil sands production. These companies realized that they have a common objective of looking for ways to accelerate environmental performance, so these companies pooled their resources and intellectual property. COSIA's vision is "to enable responsible and sustainable growth of Canada's oil sands while delivering accelerated improvement in environmental performance through collaborative action and innovation."

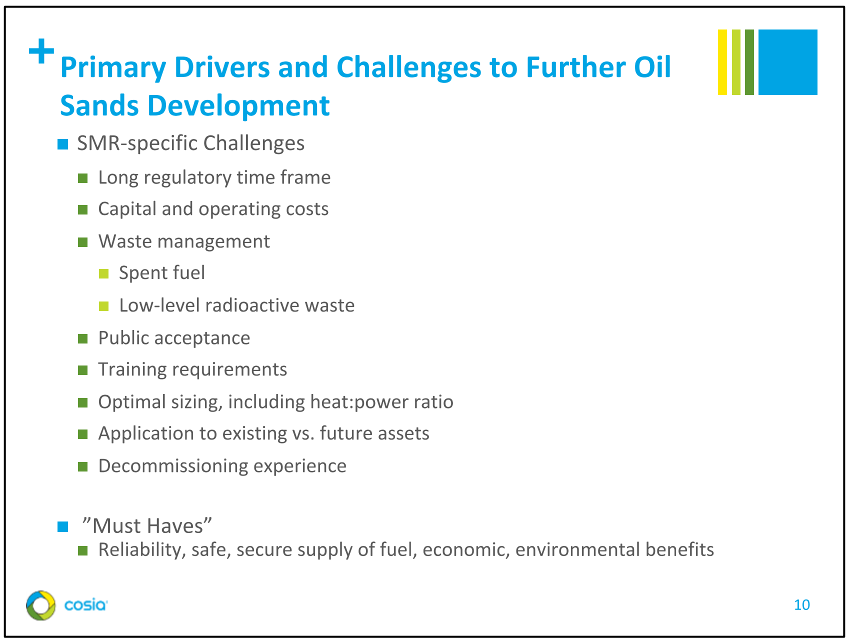
Canada has an estimated 1.75 trillion barrels of petroleum reserves, 97% of which are contained in Alberta's oil sands. Currently, Canada's oil sands production is about 2.65 million barrels per day. There are two methods of bitumen extraction: surface mining and in-situ. Deposits located at a depth of less than 75 metres can be surface mined. This represents about 20% of total recoverable assets. The remaining 80% is too deep to be mined and can only be extracted in-situ (using steam). Regardless of the method of extraction, the bitumen is then upgraded. Upgrading is a process by which bitumen is transformed into a lighter and sweeter crude by fractionation and chemical treatment. This improves the quality of the oil, reducing viscosity and sulphur content. All of these activities result in direct GHG emissions as demonstrated in the table below.

Activity	GHG Direct Emissions
Mining Production	Fugitives from tailings ponds
	Flue gas from gas/natural gas combustion (steam generated / co-gen)
	Diesel-fired mining trucks
In-Situ Production	Flue gas from natural gas + associated gas combustion (steam generation)
Upgrading	H2 production (steam-methane reforming)
	Flue gas from fuel gas/natural gas combustion (steam generation + furnaces + co-gen)

The primary drivers to further oil sands development are: economics (recovery technology application for existing and new assets and improving upon existing recovery processes); and reducing GHGs, improved tailings management, reducing land impact, and water use and impact. The following are the key challenges for further oil sands development:

- Oil market strength and market access;
- High costs associated with existing and new assets – cost competitiveness;
- Uniqueness of assets – leading to high integration costs;
- Regulatory costs;
- Increasing GHG regulatory stringency - carbon competitiveness;
- Environmental trade-offs;
- Public acceptance;
- Potential for new technology putting assets at risk; and
- Timeframes for new technology development and deployment.

In terms of the potential deployment of SMRs in the oil sands, the following slide presents SMR-specific challenges.



PTAC has Studied the Potential Use of Nuclear in the Oil Sands

PTAC is an industry association focused on significantly improving the environmental, safety, and financial performance of the Canadian hydrocarbon energy industry through the facilitation of innovative and collaborative research and technology development. It has a unique innovation ecosystem with over 200 members representing industry, government, and regulators. In its over 20 years of experience, PTAC has launched over 600 projects.

Beginning in 2006, there was interest in researching a solution for near-zero emissions for oil sands production. In response, a consortium was established that included NRCan and Alberta

Innovates. PTAC launched a project to assess the potential application of nuclear technologies for oil sands production. This project included a phased approach with the following phases:

- Phase 1: Evaluate nuclear technologies for oil sands applications;
- Phase 2: Study of application of high temperature gas reactors to in-situ operations;
- Phase 3: Detailed engineering studies; and
- Phase 4: Implementation of field pilot tests.

As part of this project, six workshops were held in June of 2017 with stakeholders to see if nuclear would be a viable solution from a technical and cost-competitiveness (i.e., with natural gas) perspectives. The following slides present the results from the study.

PTAC PETROLEUM TECHNOLOGY ALLIANCE CANADA

Study Results

- NPPs with water cooled reactors have thermal capacities exceeding energy requirements of evaluated options.
- Water cooled reactors not hot enough to generate steam for SAGD.
- High Temperature Gas Reactors (HTGRs) could meet technical requirements for three (3) scenarios considered, but are not currently commercialized.
- Among the considered technologies are the Pebble Bed Modular Reactor (PBMR), Toshiba 4S, and the General Atomics High Temperature Gas Reactor (GA-HTGR).

PTAC PETROLEUM TECHNOLOGY ALLIANCE CANADA

Study Results Cont'd…

- The introduction of nuclear energy into oil sands will be a lengthy and expensive process
- Timing is likely to be post-2035.
- Project duration, including site selection, environmental assessment, licensing and construction, could span 15+ years.
- A practical way of utilizing the existing commercial NPP designs for use in the oil sands would be to adopt a 'utility' approach for the delivery of energy (in the form of steam and electricity) to multiple oil sands facilities, and for providing electricity to the Alberta power grid.

Some of the key challenges that were identified for deployment of nuclear in the oil sands included price (with respect to competitiveness with natural gas), safety, and operating in a remote area. The report from this study can be obtained from PTAC's website at: https://www.ptac.org/.

Alberta Innovates has Studied the Potential Use of SMRs in the Oil Sands

Alberta Innovates is a research organization that funds research in the public and academic sectors, and also undertakes research itself. It recently launched a project with the Pacific Northwest National Laboratories to undertake research on SMRs and their potential use in the oil sands. The study was undertaken with two objectives:

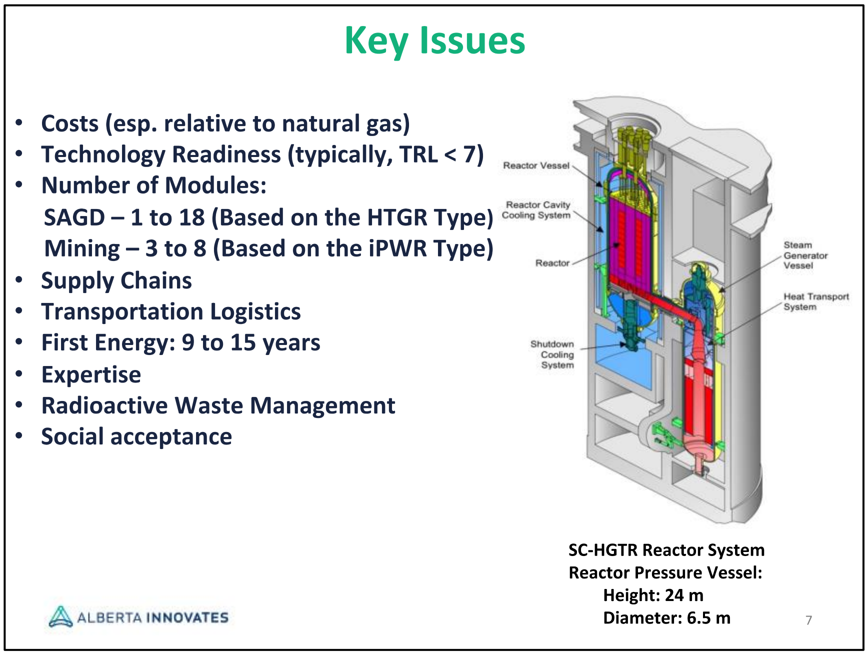
1) To gain a comprehensive and neutral understanding of SMRs; and
2) To assess whether SMRs are able to meet typical generation requirements of:
   - Steam in oil sands mining and in-situ oil recovery;
   - Electricity in oil sands mining and in-situ oil recovery; and
   - Hydrogen in oil sands upgrading.

Specific technical requirements were established based on COSIA data, and natural gas was used as a cost comparator at $3.25 per GJ. The study involved assessing 26 different reactor designs and types. These designs were assessed with data available in the public domain. A ranking methodology was developed to determine the “most promising” technology based on the data available. Where data was not available for particular design, it received a lower ranking.

In terms of results, for in-situ applications, high temperature gas cooled reactors (HGTRs) were selected as a comparator because they are able to generate the high-pressure steam required for in-situ extraction. In comparison with natural gas, the HGTR technology was identified as being more costly ($128/MWh for HGTR vs. $72/MWh for natural gas).

There were similar results for mining applications, where integral pressurized water reactors (iPWRs) were selected as a comparator because vendors are making major investments in these designs, the designs are well advanced, and sufficient information is available on them in the public domain. Again, in comparison with natural gas, the iPWR technology was identified as being more costly ($105/MWh for iPWR vs. $72/MWh for natural gas).

The slide below presents some of the key issues of SMR deployment in the oil sands identified by the study.



While SMRs have come a long way, there are still important challenges that need to be addressed. The final reports from this study can be obtained from Alberta Innovates website at: http://www.ai-ees.ca/wp-content/uploads/2016/12/SMNR-Final-Report-11-10-2016.pdf and http://www.ai-ees.ca/wp-content/uploads/2018/04/SMNR-Phase-2-Final-Report-04-12-2018.pdf.

Summary of Panel Discussions: Oil Sands – Applications, Opportunities, and Challenges

Question 1: What year were both studies undertaken?

- The PTAC study was completed in 2016.
- The Alberta Innovates study was completed in 2017.

Question 2: The common theme in both studies appears to be the relatively low price of natural gas and the inability to predict that price over the long-term. Did either study look at a threshold price for natural gas? Did you introduce any sensitivity for natural gas? What about for the carbon? These appear to be the two key variables.

- For the Alberta Innovates study, the estimates are not absolutely correct. There may be some uncertainty (+/- 40%). Our comparisons include costs for the N+1 reactor, not the FOAK.
- For the PTAC study, natural gas was fixed at $6/MCF. This is where the solution would make it competitive for large-scale 3000 MW reactors. We did not really look at the carbon tax, as it was not really sensitive to carbon pricing.
- Once we have mass production of SMRs, then the cost reductions are realized. Regardless, we do not expect gas prices to move much, most likely remaining close to $3 per kGJ for some time.
- Also, you do not want to overlook the insurance costs. You cannot take this for granted, and it requires close attention.

Question 3: Did you send out a request for information (RFI) for some of the costs used in the studies, as some of these are known now?

- This leads to the next steps. The logical next step is to ask for specific estimates. We are really waiting for progress to be made on the Roadmap, as this will add tangible context.
- In discussions with oil sands producers, they are really most concerned with the price of steam.

Question 4: Then the question becomes: what type of steam is required, what quality, and for how long? The operators need a customer, and right now that is not coming.

- The cost of replacing what the producers have in place now will be substantial. Generally, the case to make for SMRs needs to be an economic case. If you are in a position to make that case, then the industry will be interested in learning more.
- However, just because we have an economic case, does not mean it creates a business case.

Question 5: Natural gas and carbon costs are a factor, but learning could also be considered a factor. What assumptions did you make for Nth of a kind (NOAK)? Do you see faster learning rates influencing costs?

- The assumptions made in the Alberta Innovates study are listed in the reports. We did not test a lot of assumptions around fluctuating natural gas prices and learning from NOAK.
- Learning rates from FOAK to NOAK are in the public domain and were used. Costs in the study were not related to FOAK.

Question 6: Have you thought about policy levers at a federal or provincial level to incentivize someone to be the first to "jump in?"

- Policy makers were invited to all the workshops included in the PTAC study. However, the Province of Alberta does not have experience with nuclear.
- The federal government has experience with water-cooled reactors, but would need to go through a learning curve for some of the other design types (e.g., pressure cooled).

Question 7: What are the factors/criteria that are most important to oil sands producers? The technology and economics working groups (as part of the SMR Roadmap) may be interested in hearing about this.

- You need to put yourself into the mindset of an oil sands producer. The main benefit of SMRs is GHG emissions. But at what cost?
- This is not just about SMRs, but also about all options available to producers.
- Also, timing is an issue. It seems like SMRs have always been a decade or more away.

Question 8: What are the oil sands emission requirements (approaching 2030)? Is this an issue? If so, what other options do you have to reduce CO_2?

- Producers are looking at other options. There are other options to produce steam that could help with economics, but there is no "silver bullet." Most likely, there will be a portfolio of solutions.
- There are different sources of power and different ways to get steam. For example, we are looking at extracting CO_2 from methane, as well as ways to drive down the cost to capture carbon.

2.4 Mining – Applications, Opportunities, and Challenges

Presentations on the potential applications, opportunities, and challenges of SMRs being deployed at mining sites were provided by:

- Vic Pakalnis, President, MIRARCO
- Benjamin Escobar, Projects and Procurement, McEwen Mining

SMRs and Their Application to Remote Mining Operations

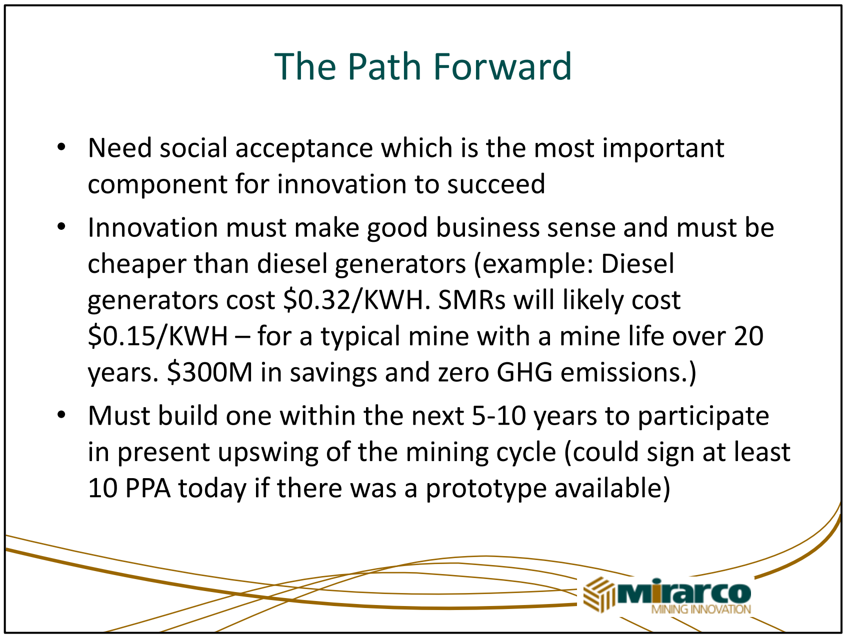
Established in 1998, MIRARCO (Mining Innovation Rehabilitation and Applied Research Corporation) develops innovative solutions for the mining industry and its challenges. It is a not-for-profit corporation that operates with support from the private and public sectors. MIRARCO is engaged in five core research domains: geo-mechanics research; safety research; decision support software; sustainable energy solutions; and climate adaptation.

The Canadian mining industry directly employs over 373,000 staff in Canada (with another 190,000 indirect positions), with more than 3,700 companies providing goods, services, and expertise in the industry. It also contributes 19% of Canada's total export value, and is the top employer of Indigenous peoples with 12,700 direct jobs.

The SMR Roadmap has to "go through" the mining industry. Energy costs are the mining industry's primary challenge. Currently, diesel is the only reliable power source, and it ranges in cost from 32 to 35 cents per kWh, and 78 cents per kWh in the arctic. Costs associated with SMRs are in the range of 15 cents per kWh. Deploying SMRs could potentially reduce operational costs on average by $300 million per mine.

There are three substantial initiatives currently being undertaken by the federal government: the Arctic Policy Framework (and mining is a big industry in the north); the SMR Roadmap; and consultations on a Canadian Minerals and Metals Plan (where federal and provincial ministers are asking the public for input). All of these initiatives are coming together at the same time, which presents a great opportunity for SMRs.

The mining and nuclear industries have a lot of similarities, and both have largely been vilified historically. Specifically, there are a lot of misconceptions about safety. However, mining actually has a lower injury rate than the health care industry. The public needs to hear more about safety in the nuclear industry; more effort needs to be dedicated to communicating this. The following slide presents some of the key steps that need to be taken in order for SMRs to be successfully deployed in mining sites.



Without social acceptance, SMRs will "sit on the shelf." They need to be "sold" properly, information needs to be provided properly, and the right people need to be talking about them. Finally, timing is critically important; mining runs in ten-year cycles. A solution needs to be ready for the next mining cycle (in the next five to ten years). Finally, if the mining industry can help demonstrate that SMRs are feasible, then potentially other heavy industries will be interested.

SMRs Could Present New Opportunities for the Mining Industry

McEwen Mining is a mining company whose operations include exploration, development, and production. Its projects are located in Canada, the United States, Mexico, and South America.

The most significant challenge to pursuing a mining opportunity is a lack of energy at the site. If an SMR with an output capacity of 10 MW to 15 MW could be placed at these remote locations, then this would create opportunity for some projects that are currently not feasible because of energy restrictions. For example, the energy costs for a specific gold mine in Mexico are going up to almost 40 cents per kWh. In another example, a silver mine in the same region of Mexico is 14 kilometres from the closest power source. The costs to connect to this power source would be close to 20% of the total capital costs for the project. As such, if SMRs could be placed on site in these locations, this would open a lot of opportunities for the mining industry.

Summary of Panel Discussions: Mining – Applications, Opportunities, and Challenges

Question 1: We want to leverage our current supply chain and investments in AECL. How do we seize the opportunities to develop, demonstrate, and deploy in Canada? Also, how do we access international markets? What are the challenges and similarities? Are there factors we need to keep in mind?

- When Canadian mining companies have an innovative solution, other countries tend to notice and want to become involved. For example, there are 20 South American companies coming to Canada soon to look at our supply services technologies. We have a great opportunity to become a leader in this area and to help companies get away from diesel.
- It would have to be proven here in Canada first for any of the countries in South America to be interested. The regulatory processes will be easier to get through elsewhere, but we need to make sure it is safe here first.
- For Latin America, you need to build trust with governments and in the communities. People are still apprehensive about nuclear even though reactors have been in operation there for 25 years; they have heard stories of disasters. You need to change their perceptions and inform them that nuclear is safe.
- The CNA has done a lot of studies on public opinion related to nuclear. Results indicate that there is a large gender gap, and differences regionally depending upon experience. Some people do not know much about nuclear and their default position is to oppose it.

Question 2: What is diesel actually used for in mining operations?

- It is used for generating electricity to break down the rock, milling, and all other operations. Not much of it is used to power trucks, except in open pit mines.
- In the case of underground mining, more companies are getting away from diesel, and using more direct electricity (for ventilation systems, milling and smelting, etc.).

Question 3: How do you deal with tailings? How could SMRs help deal with tailings?

- There are a lot of metals in the tailings. If there was a way to get those metals out and to store them more efficiently, it would help. We are working on various technologies to help with this. In order to remove the water from the tailings, you need electricity.
- If low cost energy solutions were available, there could be other technology/options available to reprocess the tailings.

Question 4: What is the size of power generation in MW in the north for mining operations?

- The larger mines have around 30 MW per site and the smaller around 5 MW.
- The life cycles of the mines vary as well. Some are 10 years, and some are 150 years in the case of Sudbury (but this is unique). Generally, the life cycle is between 20 and 30 years.
- The total power consumption in the north would be approximately 30 MW x 40 mines.

Question 5: COSIA and PTAC have been mandated to pull together industry to meet objectives. How about if the mining and oil sands industries commit to a partnership as part of this Roadmap? This would create a joint venture so that we are leaders in this area.

- This is a great idea. However, COSIA is much better funded and well organized.
- We need to get the "nuclear people" more visible, and maybe combining forces would accomplish this.

Question 6: What would a mining SMR look like? What would be its characteristics? Is there a way to use direct heat in mining operations?

- It would need to be about 5 MW to 30 MW of output and "walk away" safety (i.e., "set it and forget it").
- Currently, all energy used on site is electrical. We are looking for ways to further electrify mines (e.g., use of electric vehicles).
- Crushing rocks takes a significant amount of power, and requires massive equipment that uses a lot of energy but is only 3% efficient. Instead of looking for slightly more efficient technologies, we need to look for new solutions.

Question 7: What are the challenges related to transportation and getting the SMR to the site?

- They need to be able to be moved in and out either by trucks, ice roads, planes, etc. We may have to fly them in by Hercules aircraft if the docks are iced-in in the north, which will increase costs. The ice road season is only five to six weeks in duration and shrinking with climate change.
- SMRs would give the mining industry a solid power generating foundation, which can then be supplemented with other sources.
- Currently, the mining industry is interested, and there are opportunities for power purchase agreement (PPAs), but we need to "de-risk" an SMR project with government support.
- Insurance may be an issue, depending upon designs and developers. If government can purchase the first one, it could lead to a "cottage industry." The fuel operations would remain at Chalk River, but the rest could be built anywhere.

Discussion Point: In many African countries, their regulatory bodies do not have the capacity to work on advanced reactors such as SMRs. As such, significant capacity would need to be developed in countries we are looking to export to.

- We need to develop a standard SMR design here in Canada that is proven and safe. Regulations are one way to ensure safety, but it also depends on how we deploy the technology. It should be considered a standard piece of equipment. If our regulatory framework ensures its safety here, it would be safe elsewhere. SMRs should not be site-specific.
- We do need to help other countries on the public policy side, but we should not be shipping technologies that are not safe. The whole nuclear expertise in Canada should be part of the package that we are selling.

Discussion Point: There is an assumption that the host country has to regulate, and we need to change these presumptions. We need to engage at a government-to-government level, with a focus on climate change. This cannot be industry led.

- Our message should be that if we want to change the planet, we need to change the way we are thinking worldwide.

2.5 SMR Research and Development

Presentations on current SMR research and development initiatives were provided by:

- Cory McDaniel, Vice President of Business Development and Commercial Ventures, Canadian Nuclear Laboratories (CNL)
- Steve Bushby, Senior Director, Commercial Oversight and S&T Integration, Atomic Energy of Canada Limited (AECL)

Investments in CNL Demonstrate a Federal Commitment to SMRs

CNL is Canada's premier nuclear science and technology organization. It is a world leader in developing peaceful and innovative applications from nuclear technology through its expertise in physics, metallurgy, chemistry, biology, and engineering.

CNL is consistently looking to work with other national labs that are studying ways to use nuclear technology for more than just electricity generation. NuScale in the United States is working on its first SMR design that is grid-scale, and that could be used in an integrated system. This design will not only create electricity, but also generate heat.

The federal government has committed $1.2 billion for new CNL infrastructure. This will include establishing the CNL Clean Energy Research Park (CERP) that will be tasked with solving the technical challenges to demonstrate and deploy an affordable, low-carbon energy system to power the needs of diverse communities and applications. A key building block for this initiative will be a new global hub at CNL for SMR research and technology.

CNL is dedicated to having a demonstration reactor on site by 2026. In April 2018, CNL launched an Invitation for SMR demonstration projects. The invitation process is multi-phased and open to all SMR designers. The purpose of this process was so that CNL could better understand and assess the credibility of the designers and their current technologies, with the ultimate goal of having one (or more) designs being demonstrated at a CNL site. Thus far, CNL has received four applications (three in Phase 1 and one in Phase 2), and they are aware of two other designers that intend to apply.

AECL Has Undertaken Initiatives to Better Understand SMR Research and Development Needs

AECL is federal crown corporation mandated to enable nuclear science and technology, and fulfill Canada's radioactive waste and decommissioning responsibilities. AECL delivers its mandate through a long-term contact with CNL for the management and operation of its sites. It also administers a $76 million federal science and technology program. Ultimately, AECL's role is to ensure that there is enduring capability in nuclear science and technology, and that it supports ongoing and future needs.

In the summer of 2017, CNL launched a Request for Expressions of Interest (RFEOI) process. This involved asking proponents their views on research and development needs for SMR implementation. The needs identified were not around a specific technology. Rather, all respondents identified fuel and materials research as integral for the evolution/licensing of advanced reactors designs. The vendor design reviews being undertaken by CNSC are also helping identify some of the gaps in terms of research and development.

In terms of human capital, Canada has a strong knowledgebase across the industry. There are people in place keeping existing reactors operating, and developing new reactors types. There is a misconception that you need to be a nuclear physicist to work in this industry. Although those are needed, specialists are also needed in other areas such as chemists, materials engineers, etc. Canada also has an excellent "pipeline" that it can leverage, with a number of universities conducting nuclear research. If there is a need for capacity building, the capabilities exist for Canada to respond.

AECL also participates in the Generation IV International Forum on behalf of Canada. This is an international collaboration, involving 12 countries and the European Union, focused on developing the next generation of nuclear reactors with improvements in safety, economics, sustainability, and proliferation resistance.

Summary of Panel Discussions: SMR Research and Development

Question 1: What is the opportunity to collaborate with other like-minded countries?

- AECL leads a lot of the international collaboration efforts related to the nuclear industry. We have agreements in place with other countries; we are on the "same page" as the United States (US) and the United Kingdom (UK).
- In the early 2010s, the US initiated development by funding a specific vendor, and they have just committed another $64 million to that vendor. The UK has had several starts and stops regarding SMRs.
- Generation IV came from the need for advanced reactors, but these countries realized that they cannot accomplish this alone. There is a possibility for a similar forum for SMRs. It seems that governments want to take some sort of action, but are unsure what actions to take. The dynamic needs to change from talking about doing something to taking action.

Question 2: Collaborating internationally could be a catalyst for SMR development and deployment. Is that something that we are currently weaving into the narrative of the SMR Roadmap?

- Participating in a collaboration first requires a nuclear collaboration agreement including a non-proliferation policy. Only Global Affairs Canada can enter into these agreements. When that is in place, a memorandum of understanding (MOU) that focuses the collaboration can be established. The MOU focuses the collaboration (between government-to-government, industry-to-industry, and regulatory-to-regulatory) and keeps the highest levels of government informed.
- Most of Canada's current collaboration efforts are with the International Atomic Energy Agency. It includes 162 countries and the majority of the work focuses on negotiating standards (i.e., around safety, security, etc.).
- With respect to SMRs, Canada is in a very fortunate spot. We have a world-class regulator and labs, and a stable government committed to reducing GHG emissions. We also have a lot of international advantages as the UK has experienced several starts and stops, and the US regulator is not viewed as being ready. As such, Canada is in the position where it can be selective on whom in chooses to collaborate with. We should be looking to anchor the research and development and the supply chain in Canada to the greatest extent possible.

Question 3: How ready is the supply chain considering that it is based on CANDU technology? Also, what are the opportunities for capital cost reductions? Finally, by selecting SMR designs at Chalk River (CNL), how does this fit into the fleet approach?

- CNL has enough land locations to host several applicants. We are just assessing and making recommendations on which designs should be demonstrated. Any could be demonstrated at a CNL site, regardless of technology. Also, these designs will not end up being government owned like CANDU. Rather, CNL is supporting the deployment of these designs.
- With respect to the fleet approach, that is really for the utilities and the markets to decide. AECL and CNL do not have the funding to build these reactors. The demonstration projects are to inform only.
- In terms of the supply chain, the capabilities are there and the supply chain is ready. In fact, it is already starting to supply non-CANDU customers. It also has the competency and opportunity to look at other manufacturing processes (e.g., the use of 3D printing).
- In terms of who will fund SMRs, the Roadmap is part of three concurrent initiatives. The other two are: a design review process being undertaken by CNSC and the CNL demonstration. These three initiatives collectively are looking at the viability of various business models. There may be several different technologies that are viable, each with its own business model.

Question 4: Would it be possible to receive research and development support from outside of Canada? Also, is it possible to have a demonstration site that is more reflective of an application (i.e., oil sands environment)?

- CNL works closely with other national labs, particularly the US and the UK. Expertise related to different technologies resides in specific national labs, and we share expertise as needed.
- We proposed demonstrating the technology at CNL because we have the expertise and can act as the operator.

Question 5: How do you evaluate the importance of the vendor and alignment with market need?

- CNL will not select a technology. There was no funding tied to the expressions of interest or the demonstration application process.
- Vendors need to demonstrate how they would make their model financially viable.

2.6 Regulatory Context and Waste Management

Presentations on Canada's regulatory framework and waste management requirements were provided by:

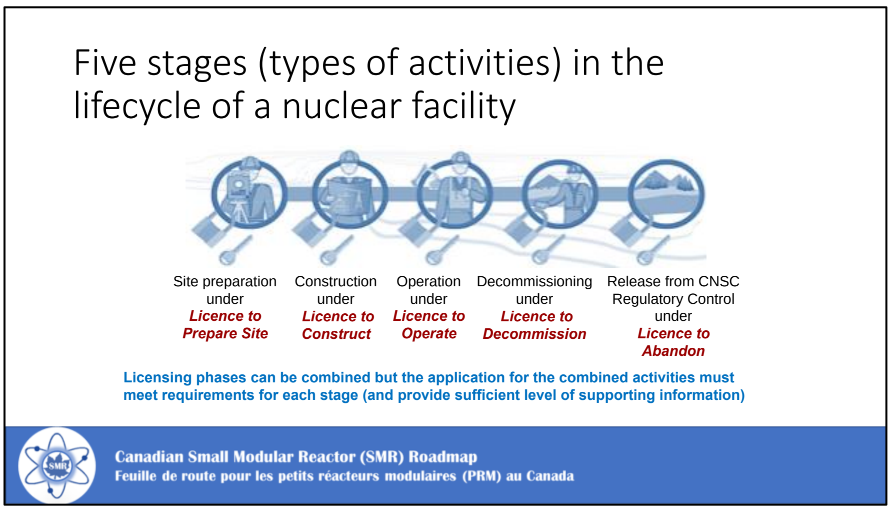
- David Train, Manager, Regulatory Affairs, Ontario Power Generation
- Christian Carrier, New Major Facilities Licensing Division, Canadian Nuclear Safety Commission
- Paul McClelland, Director, Waste Management and Technical Support, Atomic Energy of Canada Limited

Readiness of Canada's Regulatory Framework for SMRs

All nuclear activities require some form of license in Canada. A different license is required for each distinct activity including mining, refining, construction, deployment, etc. At the highest level of the regulatory framework, the Nuclear Safety and Control Act forms the legal framework for nuclear activities. This Act establishes the CNSC, and enables it to issue licenses and penalties for non-compliance. Below the Act are:

- Regulations that set out general obligations as well as specific requirements (e.g. security, transportation, type of nuclear material);
- Licenses and certificates that set out the name of the entity, the duration of the license, and the specific activities that the entity is licensed to undertake; and
- Regulatory documents that provide more prescriptive requirements and guidance on a specific subject area or set of activities.

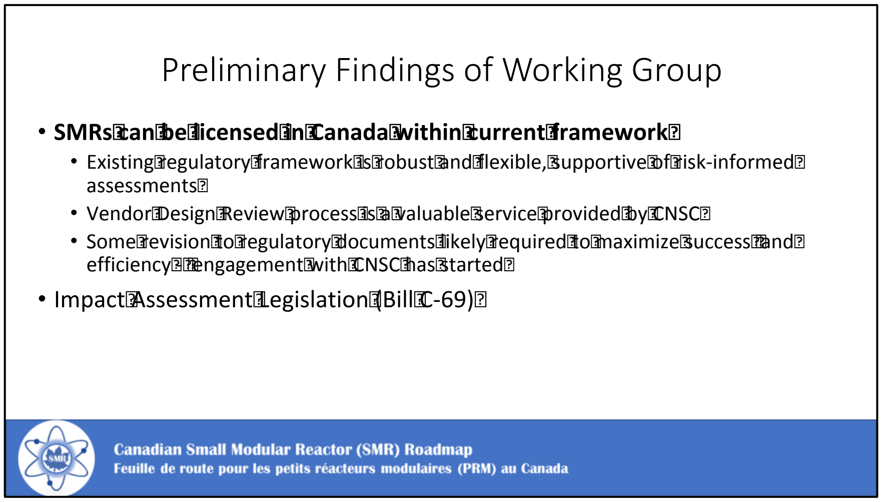
A series of licenses are required for the lifecycle of a nuclear facility. Generally, there are five stages of licensing, which are outlined in the slide below.



As an entity moves through the stages, the information required to obtain a license is more detailed. Once an entity gets to the operations stage, it has to demonstrate that the facility is built and staffed, and convince CNSC that it is safe and ready to operate. CNSC does not license a design; it licenses the use of a technology at a specific site.

Each stage requires an application, which also requires public and Indigenous engagement sessions, and full public hearings. This is to enable an open and transparent process. Once a license has been issued, the CNSC's focus shifts to compliance to ensure that the licensee is abiding by the conditions of the license. The CNSC employs inspectors to undertake compliance activities.

The Regulatory Readiness Working Group, as part of the SMR Roadmap, has been mandated to "identify potential barriers and challenges to the deployment of SMRs under the current regulatory framework." Its key activities are to conduct an analysis of the current regulatory framework, identify any gaps in the framework for SMR deployment, and identify any areas that may lead to excessive regulatory costs or burdens for deployment. The following slide presents some preliminary findings from this work:



There are some areas of the framework where revisions will be required, and initial discussions with CNSC have taken place. A more significant area of concern is Bill C-69, which is the proposed new impact assessment legislation. This would involve more than just an environmental assessment, but also a project's potential socio-economic impacts. Currently, all nuclear facilities would be subject to the new legislation, which is in contrast to other power generation projects where output criteria have been established (e.g., only hydro facilities with an output of 500 MW). If all SMRs are subject to the new legislation, it could add significant delays to deployment schedules.

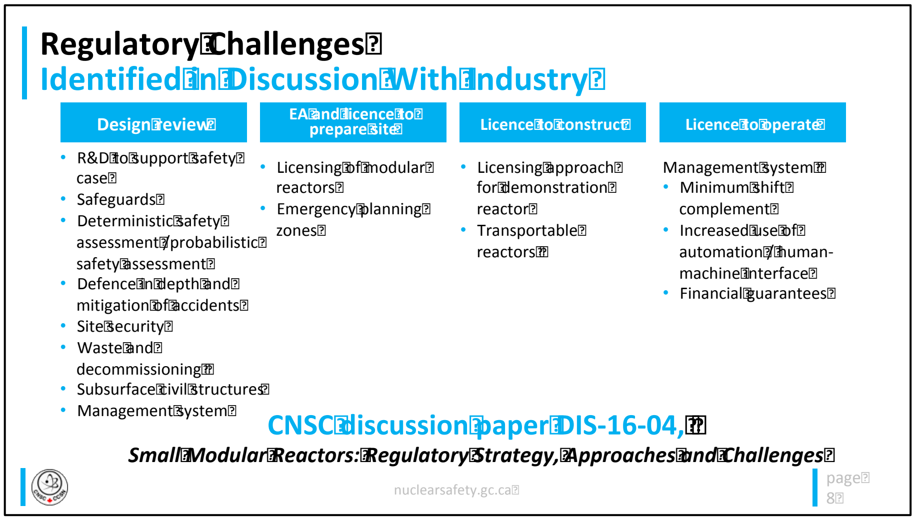
Readiness for Regulating Advanced Reactor Projects

The CNSC's mandate is to: 1) Regulate the use of nuclear energy and materials to protect the health, safety, and security of Canadians and the environment; 2) Implement Canada's international commitments on the peaceful use of nuclear energy; and 3) Disseminate objective scientific, technical, and regulatory information to the public. As such, it is the responsibility of CNSC to regulate any new nuclear facilities including SMRs.

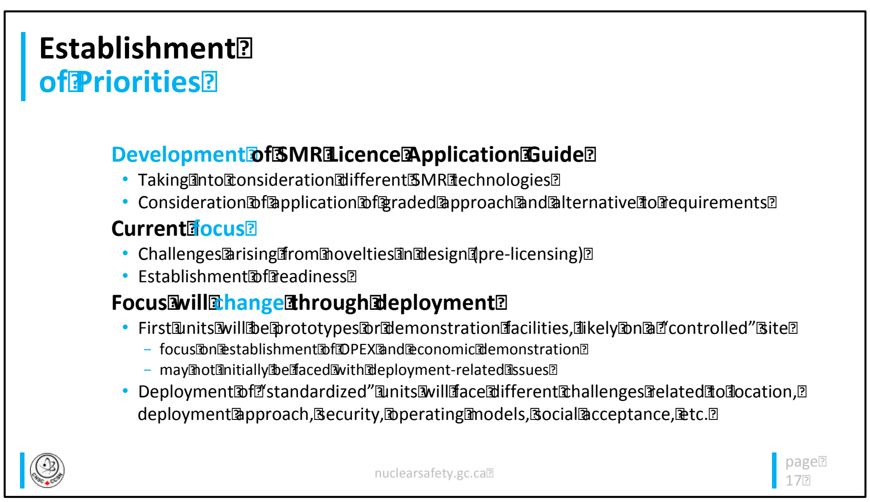
There is significant interest in SMRs in Canada from utilities, and federal and provincial governments. The CNSC launched a vendor design review (VDR) process, where applicants are proposing their designs. Thus far, ten applications have been received. The CNSC is also having initial licensing discussions with a number of these designers. These are informal discussions to identify any significant issues early on that could arise in the regulatory process. This also provides CNSC with useful information on potential technologies to support building internal capacity.

The SMRs being proposed are quite different from traditional on-grid facilities. These designs are much smaller physically, with outputs up to around 300 MW. There are also different coolants being proposed, different business models, some requiring fuel in liquid form, and some not needing containment. There are different ways to demonstrate safety. Regardless, the CNSC believes that the regulatory framework is ready for SMRs.

In March 2016, the CNSC undertook a series of industry discussion and developed a paper that set out the key regulatory challenges identified through these discussions. The slide below presents these key challenges.



In preparation for regulating SMRs and advanced reactors, the CNSC has established a strategy for readiness that involves increased regulatory certainty, establishing technical readiness, establishing priorities, and increasing awareness. Activities underway include reviewing current processes to ensure risk-informed resource allocation for licensing and compliance, and assessing the need for new processes (e.g., readiness of workforce capacity, capacity for vendor inspection, documenting lessons learned, etc.). CNSC is also involved in a number of international collaborations as a means to inform and exchange information with other countries facing similar challenges (e.g., IAEA SMR Forum, the Working Group on the Regulation of New Reactors). Finally, CNSC has also established its priorities to prepare itself for regulating SMRs and advanced reactors, which are outlined in the slide below.



Challenges and Opportunities Related to Waste Management for SMR Deployment

In Canada, under the Federal Radioactive Waste Policy Framework, the federal government has the responsibility to develop policy, regulate, and oversee producers and owners to ensure that they comply with legal requirements, and that they meet their funding and operational responsibilities in accordance with approved waste disposal plans. 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.

The majority of the used nuclear fuel produced in Canada is from nuclear power plants. The used fuel is stored at the site of generation. The Nuclear Waste Management Organization (NWMO) is in the process of establishing a permanent repository for used fuel with deep geological disposal. However, the repository is not expected to be operational until 2043, so operators will have to continue storing on-site for some time. SMRs are expected to produce very small amounts of used nuclear fuel relative to current nuclear power plants.

Low and intermediate level waste (L&ILW) is also currently stored at the site of generation, or in centralized waste storage facilities. The two organizations with the highest volumes of L&ILW (OPG and AECL) have disposal projects in the regulatory decision phase. Other organizations (i.e., SMR operators) will not have access to these facilities. Producers of very small volumes (hospitals and universities) have existing arrangements with CNL to take their waste. Again, SMRs are expected to produce very small amounts of radioactive waste relative to current nuclear power plants

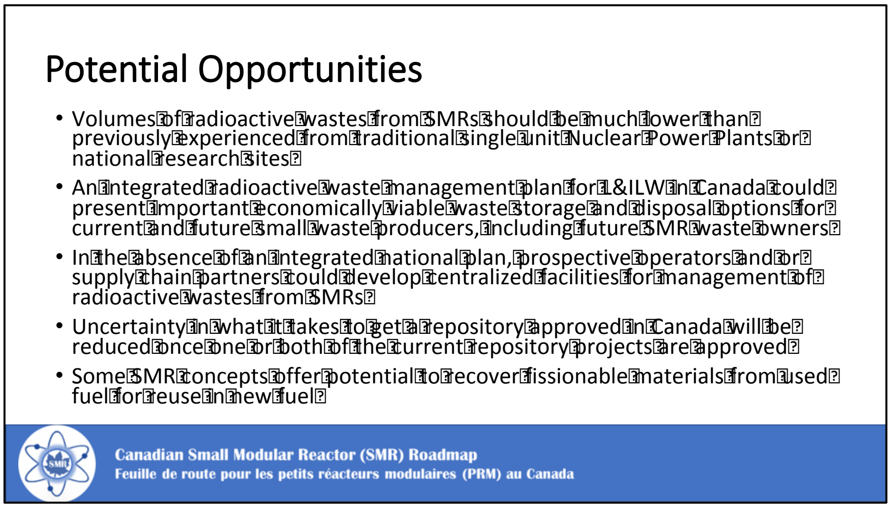
The Waste Working Group, as part of the SMR Roadmap, has been mandated to “identify waste disposal and storage considerations for Canadian SMR applications.” The working group has identified a number of challenges related to used fuel and L&ILW. The table below presents these challenges:

<table>
<tr><th>Used Nuclear Fuel</th><th>Low and Intermediate Level Waste</th></tr>
<tr><td rowspan="3">1) NWMO’s disposal approach is developed around CANDU fuel bundles
• Determining an acceptable waste form for SMR fuels will have to be developed in conjunction with NWMO for each new fuel type
• This could take many years and different fuel types will have different considerations
• Practical challenges associated with how many different fuel types are assessed for compatibility</td><td>1) Unlike for used nuclear fuel, there is no established strategy for disposal of L&ILW from SMRs</td></tr>
<tr><td>2) Consistent with other producers of modest volumes of L&ILW SMR vendors and/or operators may need to develop disposal capacity on their own, or in partnership with others</td></tr>
<tr><td>3) Alternatively, efforts at integrating radioactive waste management plans across the industry could lead to disposal solutions for SMR operators</td></tr>
<tr><td>2) NWMO’s repository will not be available for decades, so interim storage capacity will be required, either onsite or centrally</td><td>4) In the interim, SMR vendors and/or operators will need to develop L&ILW storage capacity on their own, or in partnership with others</td></tr>
<tr><td>3) Used fuels may need to be stored on site before they are safe to transport</td><td></td></tr>
</table>

Other more general challenges identified by the working group included:

- Will custom methods be required to be developed for transportation of radioactive wastes from SMRs?
- Are there special considerations for characterization of wastes from SMR technologies that would be particularly different than for other radioactive wastes?

Finally, the working group also identified a number of potential opportunities related to waste management and the deployment of SMRs. These are presented in the slide below.



Summary of Panel Discussions: Regulatory Context and Waste Management

Question 1: If the time required to license an SMR becomes prohibitively long, then it will not become a viable option. Are there aspirations to cut current timelines? How is this progressing?

- The timelines are documented in the regulatory documents. It provides assumptions of around 9 years, with construction licensing taking 6 years. Different licenses will be required throughout this process (i.e., site preparation, construction, operation, etc.).
- It is anticipated that FOAK will take a longer time for construction, but NOAK should not take as long once building and operating experience has been established.
- The hard regulatory timelines are really anchored to the public consultation processes.

Question 2: What is the typical timeframe for a license? Also, used fuel from SMRs is expected to be less than from traditional nuclear plants, but if you have multiple SMRs is the waste any less?

- The license’s timeframe were once three years in duration, then in the last decade we moved to five years because operators were always renewing. We have now changed them to ten years in duration.
- In terms of used fuel, the more SMRs you add, you would eventually get to the same amount that is produced by a larger facility. However, the volumes are less today than in the past. Storage can be expensive, so operators are always looking for efficiencies.

Question 3: With respect to Bill C-69, are there any thoughts about the size of nuclear projects that will be on the project list? What are the key environmental impacts from these projects?

- Currently, there are specific criteria for certain power generation plants, such as anything above 200 MW electric for a hydro-electric plant, but the reasons for this are unclear.
- If all nuclear projects are on the list, then it will hinder the potential success of an SMR industry. The industry needs to make a case for what would be reasonable criteria for a nuclear project. However, if you have six or seven SMRs on a site, then it begins to look more like a power plant. Perhaps remote communities and heavy industry application should be exempt from the list.

Discussion Point: If it takes a long period of time to receive regulatory approval, the mining industry will not be interested in SMRs. Regulatory certainty and timelines need to be addressed. This will be dependent on the approach taken by each province. We need to ensure the safety of these reactors, but in a sensible and reasonable manner.

2.7 Economics and Finance

Presentations on the economic and financial considerations of SMRs were provided by:

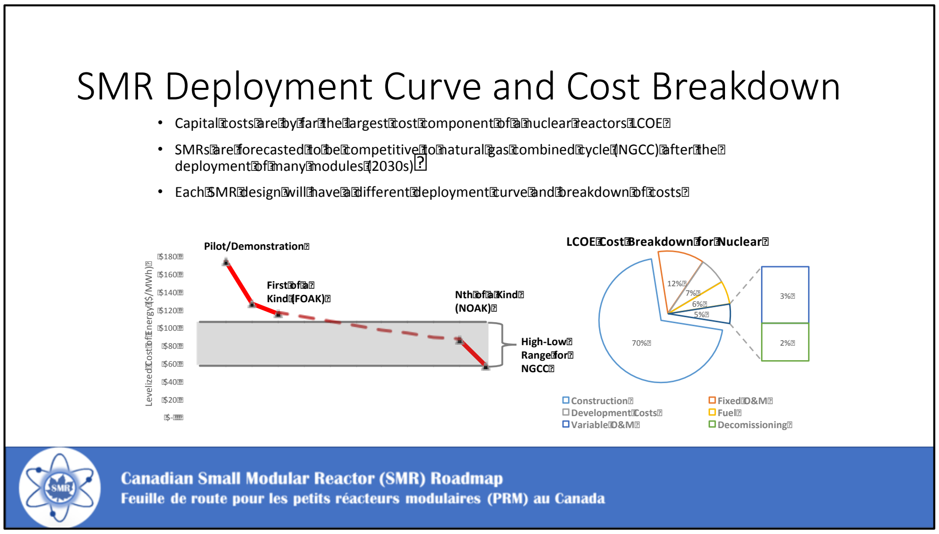
- Milt Caplan, President, MZ Consulting Inc.
- Paul Murphy, Director, Gowling WLG

Policy Levers and Economies of Series Required to Keep Costs Competitive

The Economics and Finance Working Group, as part of the SMR Roadmap, has been mandated to “provide insight into indicative pricing for breakeven analysis and to understand the key economic drivers for profitability for each of the three development areas (i.e., on-grid, heavy industry, and remote applications).” Key activities undertaken by the working group included a detailed literature review, identifying key economic drivers, assessing cost estimates of SMRs to competing technologies, and providing insights into SMR development paths and macroeconomic implications. Some of the findings and results from this work are discussed below. The data used to undertake this work was from the public domain.

Based on the working group research, it was found that SMRs are likely to lose economies of scale at the level of the individual project. As such, methods have to be established to make SMRs disruptive without economies of scale. A key factor for SMRs to achieve cost competitiveness is through economies of series, as was the case with large nuclear. That is, to deploy multiple units from the same manufacturing facility with a standard design so that capital costs can be reduced through learning, standardization of parts, skills, operations, fuel, decommissioning, etc.

Pilot or demonstration plants for SMRs will have high capital cost and will be uncompetitive relative to conventional generation technologies. The following slide demonstrates the SMR deployment (from pilot/demonstration to NOAK) and cost breakdown.



FOAK SMRs (as of what is known today) are not cost competitive compared to natural gas combined cycle ($105/MWh vs. $66/MWh). Policy tools are needed to reduce the overall levelized cost of electricity (LCOE) such that they can become competitive. Some policy tools that could be considered include: 1) Production tax credits; 2) Loan guarantees; 3) Advanced cost recovery models; and 4) Power purchase agreements for resiliency.

Further, industry input will be required to make key decisions related to economics, financing, and the overall business model. Specifically, some of the key questions that heavy industry needs to provide input on are:

- How does the industrial sector assess energy options for its projects?
    - Key drivers such as schedule, project economic life, capacity factors, etc.
    - Assess available cost estimates of SMRs to competing technologies.
- What business models are applicable to industrial applications?
    - Who will mining companies see as the energy project proponents?
- How will benefits of SMRs be defined?
    - Carbon intensity, job creation, etc.
- What outcomes are required for companies to move forward?

The Importance of Establishing a Robust Business Case for SMRs

With respect to implementing larger reactors, there are three main challenges: resources development, public acceptance, and financing. Some of these challenges, and their severity, may change for SMRs.

It may be challenging to sustain an SMR industry by servicing just a domestic market. As such, the industry may have to pursue international markets. Further, there could be a significant “first mover” advantage if international markets are pursued. However, government support – both domestically and in the exporting country – needs to be sustained to keep those markets open. Nuclear deals are typically entered into bi-laterally between governments. As such, strong cooperation between these governments is needed, as well as a compelling business case. It is also important to structure SMRs as part of broader bi-lateral deals between governments (involving several sectors).

In terms of financing, even though SMRs are not based on new technology, it will not matter to investors. They will want to see the technology demonstrated in the manner that it will be used. Investors will have a different perspective than engineers; they will be very conservative with anything new.

Investors will also be looking for a business plan that sets out the revenue streams. It is not just thinking about the technology, but also what is being sold to the market. Traditionally, the large reactor projects have gone over budget. Demonstrating a plan that involves constructing several of the same units repeatedly, thereby achieving efficiencies and gaining experience will be of interest to investors. Any model demonstrating shorter construction times, scalability, and lower costs will be of interest to them.

Desalination is also a big advantage that SMRs possess. There is not a lot of attention being placed on power and water in the same solution. This can help overcome some the historical biases related to nuclear. This functionality should be stressed in any business plan.

Government support and public policy could change some of the economics related to SMRs. However, government needs to articulate the rationale for supporting this technology. For certain applications such as remote communities, this will not be difficult. However, in other instances, it may be viewed as corporate assistance, which may not be viewed positively by the electorate. Also, it will be important for the Canadian Infrastructure Bank to support nuclear. There are significant barriers to entry in the nuclear industry that will not change, so government needs to step in.

Summary of Panel Discussions: Economics and Finance

Question 1: In terms of “framing” the work of the working group, and in consideration of the oil sands, would you change the comparator to natural gas co-generation?

- That is exactly the type of input the working group is looking for. We need the appropriate comparators and benchmarks.

Question 2: When calculating the costs, what are the appropriate assumptions for natural gas and the carbon tax?

- The correct approach would be to show a range. We have used Energy Outlook documents, and international and Canadian based studies that predict these costs. But even the assumptions in these studies change from year-to-year. For example, the US price assumption for national gas recently fluctuated 14% in one year. The best approach is to pick a base price based on the markets and then show a range. No one can really predict these costs in the future.
- However, if electricity is being used as an input into an industrial process, and if you can provide a consistent price from SMRs for 20 to 40 years, then many producers would be interested in locking in at that price (because it is assured to be consistent over the long-term).

Question 3: How does one go about getting certainty for a fleet order in order to take advantage of economies of series? What is the threshold of orders before a vendor develops a factory? How do these orders play out and how should government provide certainty?

- The supply chain will not expand capacity because the work is not yet assured. This may be an area for government to intervene. We want to capitalize on Canadian content, so we may need to invest in capacity and manufacturing space.
- In terms of the approximate size of the fleet, you need to find ways to do this in segments. Emphasis should be placed on the market side and market needs.

Question 4: There is a constant debate about whether it is better to “pick winners” or allow the market to select winners. What is your perception of this?

- I would suggest some sort of stage-gated process so developers can prove certain abilities before proceeding with them.
- In terms of international competition, some think of SMRs as commodities but they are different. You need to think that you are selling a package (i.e., regulatory approvals, expertise, etc.). In terms of market timing, you need to drive a developer into the market quickly or the market will pass them by.
- Military procurement is a good example for SMRs. There are not 50 vendors designing aircraft carriers. Funding is provided through the development process, and industry and government have to work together. Exporting then becomes a dialogue between two governments.

Question 5: With respect to fleet deployment and the notion of NOAK, this seems to be constrained to a domestic market, but it also seems like we need to consider international markets as well. Is it possible to look at jurisdictions where CANDU reactors are already deployed? Also, we talk about how we need to be the first movers, but who is “we?”

- It is not about selling to the same countries that we have already sold CANDU reactors to. We are one of the few countries that have successfully deployed a fleet. Both OPG and Bruce Power have learned a lot through their multiple unit development, so they have a lot of lessons learned that could be shared.
- NOAK can mean different things in different scenarios. For example, the first in a new country may be a NOAK in another because of location risk and uncertainty.

Question 6: A number of different scenarios have been discussed related to FOAK and a demonstration project, but we have not heard anything credible around building a factory. What are your views?

- It depends what you define as a factory. Currently, there are vendors who are building modules that can be used in SMRs. Certainly for on-grid applications the entire SMR might not be built in a single factory.
- The market has to take the lead. Quality requirements for nuclear are significantly higher. FOAK includes buying new machinery and equipment, and you reduce those costs through additional orders and customers.
- Also, do you want this to be an exclusive Canadian platform, utilizing only the Canadian supply chain? Industry may not care about this, but government might, so this should be factored in to any manufacturing solution.

Discussion Point: From an operator's perspective, we know how to undertake the process to deployment. The challenge is: where do we get the funding and value for this to happen? This needs to be driven by the customer, with specifications. Once a customer comes forward, everything else will fall into place. Currently, lots of people seem interested, but no customers have come forward. Once a customer comes forward with terms and specifications, then we can have discussions with government, industry, etc.

Question 7: Who is going to build the factory?

- The supply chain currently exists for a FOAK. There is a belief that industry will come with orders after the FOAK is built. If the order book after FOAK is 20 to 30, supporting 10 years of business, then there will be no issues around building a factory.
- There are divergent views about building the factory. The first is that the FOAK is built and then the market follows (which is able to sustain a factory). The second is that the market will follow at a much slower pace, where demand will never be enough at any given time to facilitate building the factory.

Discussion Point: Uncertainty in the construction process is removed as it becomes better known. The remaining uncertainly is then related to the design. With respect to investment, we need to create confidence in investors and customers. We need customers; there is interest but with certain caveats that need to be factored. For example, we cannot ask the customers to go through the regulatory process. This would be a "showstopper." From a manufacturing perspective, this will require substantial investment.

Discussion Point: Both the oil & gas and mining industries build their sites using a modular approach. However, these are typically unique and "one-offs." A FOAK needs to be modular like the planned build in order to demonstrate economics and stability. Manufacturing techniques need to be proven.

Question 8: Do we let the market dictate the model or do we implement a strategy? Should we do some benchmarking (i.e., UK, elsewhere)?

- The UK is changing the rate structures and rates. If we can play a bigger role and keep it on track, there could be a huge benefit to ratepayers.
- The traditional utility market usually has a single customer who is close by and known, and creates jobs in that jurisdiction. The heavy industry sectors have a large and more international view, so there is not as much concern with the use of international suppliers. These expectation needs to be understood.
- Once the initial SMRs are deployed, the need for government supports will change. You need support for a point in time, and then is should go away or be reduced.

2.8 Engineering, Procurement, and Construction

Presentations on the capabilities of Canada's engineering, procurement, and construction (EPC) firms in support of SMRs were provided by:

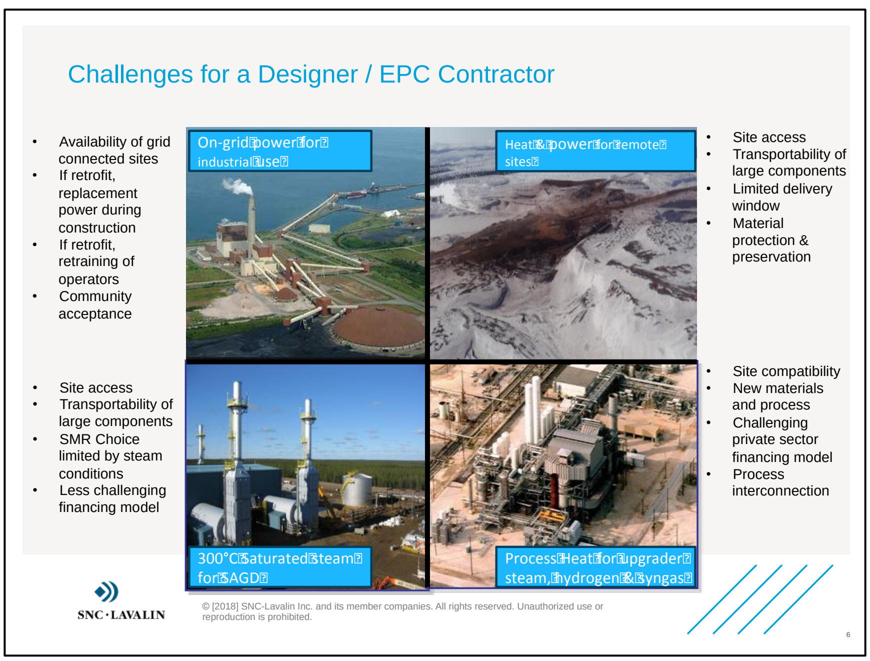
- Justin Hannah, Director, External Relations, SNC-Lavalin
- Jim Sarvinis, Managing Director, Power, Hatch Ltd
- James Gandhi, Director, Business Development, Aecon Nuclear

SNC-Lavalin Has Had Preliminary Discussions with SMR Designers

SNC-Lavalin employs over 50,000 people, with offices in over 50 countries. In 2011, it purchased CANDU and the CANDU energy division from AECL, which made it the original equipment manufacturer (OEM) of CANDU reactors. In July 2017, it also purchased Atkins, an engineering firm with expertise in nuclear technology. Further, recently SNC-Lavalin has re-structured its organization so that the nuclear division has its own sector group. The company employs 3,700 staff in its nuclear operations worldwide (with approximately 75% located in North America). All of these actions demonstrate the importance of nuclear moving forward to the company and its senior management team.

SNC-Lavalin possesses end-to-end capabilities across all reactor types including SMRs. It is different than other EPC firms in that it looks to fill gaps in all stages of a nuclear lifecycle. This helps enable smaller technology developers, who may need additional capacity. The company has reached out to several of the developers that are involved in CNSC's design review process, and are exploring how it can support them. It may even become an OEM for some of these designers. Some of the designers are relatively small, and some designs are still in the pre-conceptual stages (i.e., looking at materials, etc.). There are around 50 to 70 SMR designs being developed, with many in the pre-conceptual stages. Getting these to the development stage could take five to seven years.

There are three or four main categories that SMRs could fit within, depending upon the application. These include on-grid power (i.e., utilities), heat and power for remote sites (i.e., mining), steam-assisted gravity drainage or in-situ (i.e., high pressure for oil sands), and industrial processes (i.e., bitumen upgrading). Each category will have its own challenges from a designer and EPC perspective. These are presented on the slide below.



In its work with SMRs, SNC-Lavalin has identified some common themes that are challenges or uncertainties for SMR developers. These include:

- Technology gaps: Some of the technical concepts have been around for some time. Moving these past the concept stages to an actual design will take significant effort;
- Regulatory challenges: It is important that vendors go through at least two stages of the CNSC's design review process so that their designs can be challenged and reviewed beforehand.
- Underestimate costs to market: This is the largest challenge. All costs are currently based on estimated models, and the vendors are underestimating. The designs need to be completed to obtain cost certainty.
- Underestimate time to market: This needs to be streamlined (e.g., 5 to 10 years). All regulatory requirements need to be known early on.
- Uncertainty over target markets: Canada is a small market, so global markets have to be pursued to sustain the industry. The market is not expanding and the competition is intense. The Canadian value proposition needs to be defined.

Hatch Ltd is Able to Bridge the Gap Between Heavy Industry and Nuclear

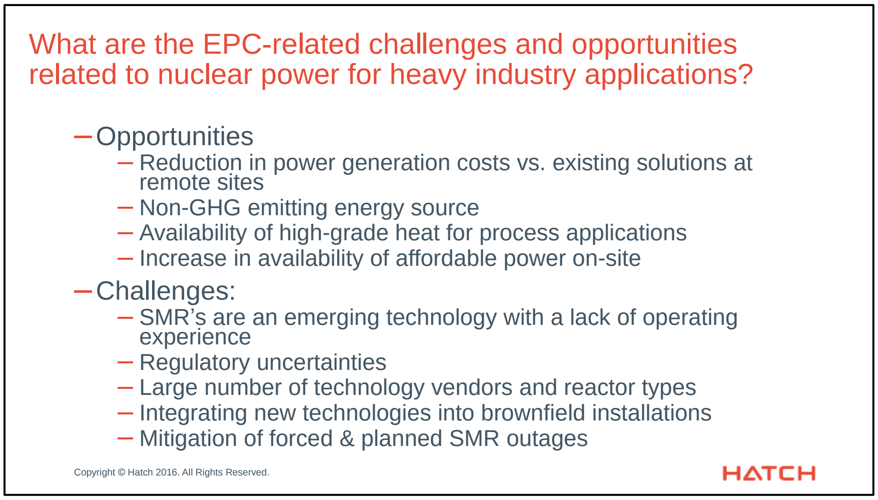
Hatch Ltd is a professional services firm combining engineering and technical acumen. It is a private, employee-owned firm, specializing in three main business units: metals, infrastructure, and energy. It works with a number of oil and gas, and mining industries, with northern remote locations. Its involvement is largely in project execution and as a solution provider for large projects, from the conceptual stages to execution and turnover. Its services do not just include technical analysis, but also advice on capital and finance costing and business models.

Currently, most of the power stations in place are diesel based. However, the company is "technology agnostic," as it does not look to promote one technology over another. It looks for the best-fit technology for its clients based on need. One aspect that it considers is the technology readiness level, in terms of how ready is a technology to deploy and how ready is the company who is selling the technology. There are a lot of competing technologies (e.g., diesel, natural gas, renewables, SMRs, etc.), but they may not all work in every market. At some sites it may not be feasible to have SMRs as the only power option, and a backup option may be needed, which could be diesel.

EPC vendors, like Hatch Ltd, can help bridge the gap between heavy industry and the nuclear sector. It can assist in understanding the nuclear specific project requirements and their potential impact on project timelines. It can also assess the viability for deployment of SMRs for specific projects or applications. Some of the common key considerations in an SMR assessment for heavy industries would include:

- Ability to load follow;
- Requirements for backup power/fueling outages;
- Ease of integration with other power generation technologies (e.g., renewables, diesel) for brownfield sites;
- Type of utility/Independent Power Producer (IPP) model in place; and
- Potential for security/workforce integration with the site.

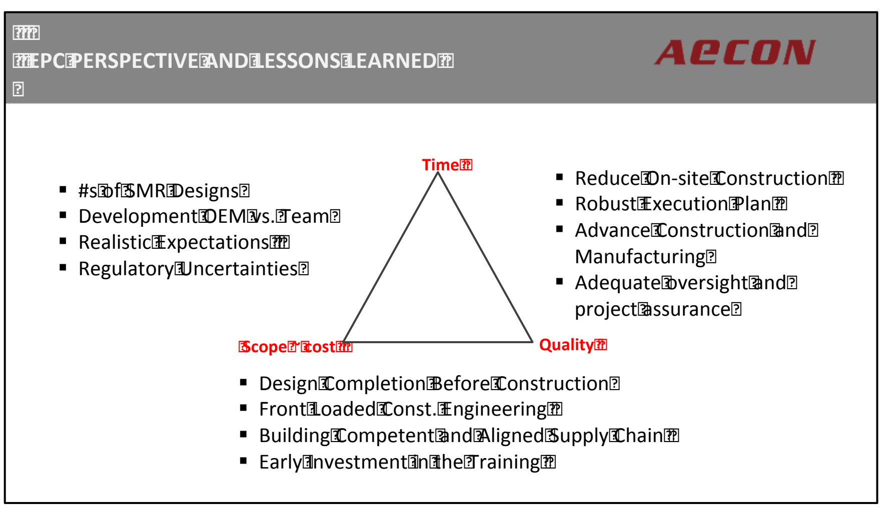
Other considerations would include environmental assessment, community engagement, project execution logistics, project management, labour force planning and mobilization, transportation logistics, and site security. There are a number of EPC-related challenges and opportunities for nuclear power in heavy industry applications that have been identified by Hatch Ltd. These are presented on the slide below.



Lessons Learned from Aecon's Experience in Nuclear Project Execution

Spanning five decades and more than 400 nuclear energy projects, Aecon Nuclear's portfolio of building, refurbishing, maintaining, and decommissioning nuclear power facilities reflects a record of project success that ranges from small but essential maintenance contracts to major construction endeavours. Aecon supports clients with expert project management and trades working to Aecon's most exacting standards, based on the nuclear industry's fundamental principles of safety, reliability, quality, and predictable performance.

Currently, international partners such as the US are saying that with our supply chain that if Canada is unable to get SMRs "off the ground," then no country can. Every project has the same three constraints: time, cost, and quality. Historically, the nuclear industry has been focused on quality, but this is changing as the Darlington refurbishment project is 60% complete and is on time and budget. The following slide demonstrates the relationship with those three constraints and how it relates to SMRs.



A high quality FOAK needs to be built, but the key performance indicators (KPIs) associated with the FOAK should not be the benchmark. Also, the notion that they must be 100% modular should be challenged, as there has to be some level of flexibility in design, but regulations need to allow for this. Currently, most of the designs are proven, but if a new component is connected it then has to go through the regulatory process again. This is cost prohibitive. However, the regulators and OEMs are all learning at the same time.

The client-base needs to be convinced that SMRs are what they need. Most OEMs are small and have not previously built a reactor. Perhaps they should look to work with SNC-Lavalin or others, as this may help get through the regulatory process. They will also need EPC expertise for construction engineering at the same time as the design work is being undertaken.

Summary of Panel Discussions: Engineering, Procurement, and Construction

Question 1: How do you suggest getting designers and fabricators together? How do these alliances happen in the marketplace?

- The obvious method is through early engagement, and engagement through the supply chain to maximize Canadian benefit.
- We need to focus of three or four designs. Potentially one for each category or applications.
- Some EPCs can only really partner with one designer, and they will select who that is based on market intelligence and who they think has the best chance of being successful. Early on AECON would invest in-kind. It is too early to provide funding, and this may change once they have successfully gone through CNSC's design review.
- From an engineering perspective, you have to have experience in building in the environment that the site is at (e.g., permafrost in remote locations).

Question 2: How do you get a customer when the customer does not understand nuclear? What will the Roadmap say about this? How do we make this process work?

- We need to start looking at more detailed scenarios for deployment and set out what those might look like. We have identified several issues, but we need to start grouping them into scenarios. There are definitely distinct applications that do not compete with each other. The scenarios should be anchored to these applications.
- Suncor (and other heavy industry firms) need to provide us with their requirements, schedules, risks, etc. The EPCs have to take care of the gaps. The designers are not in a position to connect interested end users with a vendor. Organizations like SNC-Lavalin can bridge those gaps.
- In the old model, AECL was the "one stop shop," but that has changed. The end users, delivery, and technology are different.
- There are currently several companies engaging with the vendors. It is important to review them (i.e., CNL demonstrations, CNSC design review) to ensure that they are able to produce what they claim.
- The focus should be on "Team Canada." We have to create a supply chain with a constructor, engineer, and OEM and together move in one direction. We should pick an OEM move forward with it.

Question 3: Where does a demonstration fit on the lifecycle of a nuclear plant? Also, is "EPC capabilities" included in the CNL demonstration criteria?

- You have to undertake all the activities before a demonstration (i.e., developer, designer, EPC contractor, and operator).
- The CNL process is very thorough and its criteria does include EPC capabilities.

Question 4: If we are looking at markets outside of Canada, is this a network that gets leveraged into other markets?

- Yes, we can leverage a lot of the same networks used for design and engineering here and then easily re-locate talent to other countries. We can also leverage digital technologies as a way to collaborate remotely.
- SNC-Lavalin is a global company that formed its own internal SMR team that engages with vendors to explore scenarios, provide advice, etc. We are always looking to engage with other groups. We have had internal discussions to consider experiences from other regions and jurisdictions (e.g., US and UK).
- For any technology-based business, key components in the design are manufactured in their own country with their own supply chain. This is done to reduce risk. Canada has a framework in place through the Canadian Commercial Corporation where the manufacturing can be done here, and exported through them.

Question 5: The success or failure of a FOAK deployment depends upon whether it is a viable solution, but it is difficult to understand what solution is needed without the input of a customer, as we do not know the requirements. We need to know what is needed to develop a solution and gain confidence. Could you comment on this challenge?

- We need to identify the key technical aspects to demonstrate and to prove the technology, and move ahead with the project. Vendors are interested in hearing about needs. It is still in the early stages of their designs. If there was a specific need, they could probably still incorporate it into their designs.
- We also need to understand the risk of a design or solution not working in a particular application.

Discussion Point: We need a paying customer. Currently, we have only heard of one interested customer willing to provide funding. However, if we put this together properly, this industry could be much larger than just mining. As such, what would a "Team Canada" look like? Perhaps it should involve setting up a joint venture among the EPCs. Government certainly has a role as well. However, we need to start taking action to gain "first mover" benefits.

Discussion Point: The Roadmap should not be defining who is on Team Canada, but rather it should set out a process to select the organizations that would be involved. In fact, there could be a Team Canada for each application.

Discussion Point: The oil and gas sector is quite conservative. They will want to see a demonstration working in their environment (or one very similar) before committing. The designs have to be driven by end user requirements.

Discussion Point: Every organization needs to start thinking about what their roles will be (i.e. federal government, provinces, CNL, EPCs, etc.). It is not anyone's role to select a technology. The government is already playing the role of determining a vision. Government could also be the initial procurer (e.g., business park). A joint venture is a possibility, but we would need a developer, engineer, fuel development, etc. We also need to determine who will act as the operator.

3. Summary of Roundtable Discussions

The Heavy Industry Applications workshop also included a roundtable discussion used to collect input from participants. Specifically, participants were asked to consider the following with other participants at their respective table:

> **Consider and discuss the range of factors that affect electrical power (and related) decision-making for heavy industry applications, and have your table rank the relative importance of the 3 most important risks/uncertainties associated with nuclear (on a scale from 1 to 5, where 1 is the most important and 5 is least important). Where "important" is defined as "affecting industry's decision to actively invest in nuclear as a power option."**

Each of the tables was then asked to report back to the larger workshop group in only a few words for each risk/uncertainty that was identified. The following presents the results from the roundtable discussion.

Rank	Risks / Uncertainties		
1	Financing	Public acceptance (safety demonstration, environment)	Regulatory approvals less than 5 to 10 years total (C-69, CNSC, Prov.)
	Indigenous partnerships and economic development	A reason to change from the status quo	Demonstrating technical feasibility
	Competitive price with respect to natural gas	Availability of viable technology	
2	Regulatory risk	Economics (reliability demonstrated, potential alternatives	Cost competitiveness
	Predictable and acceptable timelines	Social license acceptance	Time to market / Regulatory timeframes on par with competitors
	Validation and certainty of cost	FOAK risk	Time to deployment including regulatory schedule
3	Costs (regulatory timeline and carbon costs)	Demonstration (including $ for demo)	
4	Public acceptance and government commitment	Regulatory approval (timelines, certainty)	Life of local market demand (properly matching user requirements)

5	Public confidence		

Appendix A: List of Participants at the Heavy Industry Applications Workshop

The following presents the participants at the Heavy Industry Applications Workshop:

TBC

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: List of Presenters at the Heavy Industry Applications Workshop

The following provides a list of topics presented and presenters at the Heavy Industry Applications workshop.

Introduction and Approach to the SMR Roadmap:
- John Barrett, President, Canadian Nuclear Association
- Diane Cameron, Director, Nuclear Energy Division, Natural Resources Canada

Nuclear Operations Today:
- Frank Saunders, Vice President, Nuclear Oversight and Regulatory Affairs, Bruce Power
- Paul Thompson, Senior Strategic Advisor, New Brunswick Power

Potential for Nuclear in the West:
- Iain Harry, Senior Business Advisor, Innovation and Clean Energy, SaskPower
- Dale Friesen, Indigenous and Government Relations and Sustainability, ATCO

Oil Sands – Applications, Opportunities, and Challenges:
- Matt McCulloch, Director, Greenhouse Gases, COSIA
- Soheil Asgarpour, President, Petroleum Technology Alliance of Canada
- Axel Meisen, Senior Advisor, Alberta Innovates

Mining – Applications, Opportunities, and Challenges:
- Vic Pakalnis, President, MIRARCO
- Benjamin Escobar, Projects and Procurement, McEwen Mining

SMR Research and Development:
- Cory McDaniel, Vice President of Business Development and Commercial Ventures, Canadian Nuclear Laboratories
- Steve Bushby, Senior Director, Commercial Oversight and S&T Integration, Atomic Energy of Canada Limited

Regulatory Context and Waste Management:
- David Train, Manager, Regulatory Affairs, Ontario Power Generation
- Christian Carrier, New Major Facilities Licensing Division, Canadian Nuclear Safety Commission
- Paul McClelland, Director, Waste Management and Technical Support, Atomic Energy of Canada Limited

Economics and Finance:
- Milt Caplan, President, MZ Consulting Inc.
- Paul Murphy, Director, Gowling WLG

Engineering, Procurement, and Construction
- Justin Hannah, Director, External Relations, SNC-Lavalin
- Jim Sarvinis, Managing Director, Power, Hatch Ltd
- James Gandhi, Director, Business Development, Aecon Nuclear