NUCLEARENERGY INSIDER

FUTURE SMR DEPLOYMENT IN CANADA

A white paper in conjunction with

8th Annual

International SMR and Advanced Reactor Summit 2018

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Acknowledgements

This white paper was developed from a webinar featuring the following industry experts from Canadian Nuclear Laboratories:

Mark Lesinski
President and CEO

Corey McDaniel
Vice President of Business Development

Kathryn McCarthy
Vice President of Research and Development

Canadian Nuclear Laboratories
Laboratoires Nucléaires Canadiens

Introduction

As the nuclear industry faces commercial challenges in some of its more established markets, technology developers are increasingly focusing on the potential of small modular reactors (SMRs) to revitalize the sector's fortunes.

SMRs promise to overcome many of the concerns dogging larger nuclear projects, for example around cost, safety and deployment time. The main challenge for the technology is that it is still in its infancy.

While several viable SMR technologies are in the process of being commercialized, in practice developers are still keen to find markets that will be receptive to testing and deployment.

Frontrunners in this search include countries such as the US and the UK, but one market that has particular potential is Canada.

With a history of nuclear innovation and a benign regulatory environment, Canada has already taken a "small early lead in the race to commission the first commercial fourth-generation reactor in North America."

One of the key organizations involved in helping to sustain this lead is Canadian Nuclear Laboratories, Canada's premier nuclear science and technology organization, renowned for its Chalk River Labs research facility in Deep River, Renfrew County, Ontario.

To understand how SMR commercialization might move forward in Canada, Nuclear Energy Insider held a webinar with prominent Canadian Nuclear Laboratories executives. This white paper summarizes the main themes and messages from the event.

The Canadian market's suitability for SMRs

Canada's nuclear industry has been keen to promote SMRs for at least the last two and a half years, says Mark Lesinski, President and CEO of Canadian Nuclear Laboratories.

This enthusiasm has more recently crystallized around specific plans and proposals, some related to the fact that Canada has a number of sites that could be used for SMR deployment.

Canadian Nuclear Laboratories, for example, is scheduled to carry out remediation work on sites including:

- **Douglas Point Nuclear Generating Station**, Canada's first full-scale nuclear power plant and second CANDU (CANada Deuterium Uranium) pressurised heavy water reactor, which was built and owned by Atomic Energy of Canada Limited (AECL) but operated by Ontario Hydro until 1984.
- **Darlington 5&6**, Ontario, owned by Ontario Power Generation, which intends to give some proactive support to SMR developers to 2018, then shortlist some designs before selecting credible options about 2020 and having initial units operating about 2027.
- **Port Granby**, a federal government undertaking for the safe, long-term management of historic low-level radioactive waste situated at the south-eastern boundary of the Municipality of Clarington.
- **Whiteshell Laboratories**, originally known as the Whiteshell Nuclear Research Establishment, formerly an AECL laboratory in Manitoba, northeast of Winnipeg.
- **LaPrade**, a former heavy water plant in Quebec, adjacent to Canada's Gentilly reactors.

These "are licensed sites right now, and are locations that can also be repowered or used as demonstration locations," says Lesinski.

But of particular interest "because of their missions going forward," Lesinski says, are Canada's Chalk River Labs and the Centre for Nuclear Energy Research at the University of New Brunswick.

Chalk River, specifically, looks set to play a vital role in the development of SMR technology in Canada. The lab, the largest research centre of its kind in Canada, is active in nuclear science and technology, clean-up operations and infrastructure renewal.

The infrastructure renewal program is a CAD$1.2 billion initiative which is "the really exciting part of what's happening here," says Lesinski.

The investment shows "we're in it for the long haul," he says.

One of the strategic initiatives at Canadian Nuclear Laboratories is to develop advanced reactors and very small modular reactors. The organization is planning to demonstrate the viability of one or more SMRs at Chalk River by 2026.

Canadian Nuclear Laboratories is also aiming for Chalk River to become recognized as a world-leading hub for SMR testing, supporting multiple vendors and prototypes over the next 10 years.

Chalk River already has a pedigree in helping to bring new reactor designs to market.

The site has hosted more than eight reactor concepts since 1945, including iconic models such as the Zero Energy Experimental Pile, National Research Experimental, National Research Universal and Zero Energy Deuterium-2 reactors.

The Canadian Nuclear Laboratories opportunity

As part of its aim to support SMR commercialization, in June 2017 the Canadian Nuclear Laboratories put out a request for expressions of interest related to the technology.

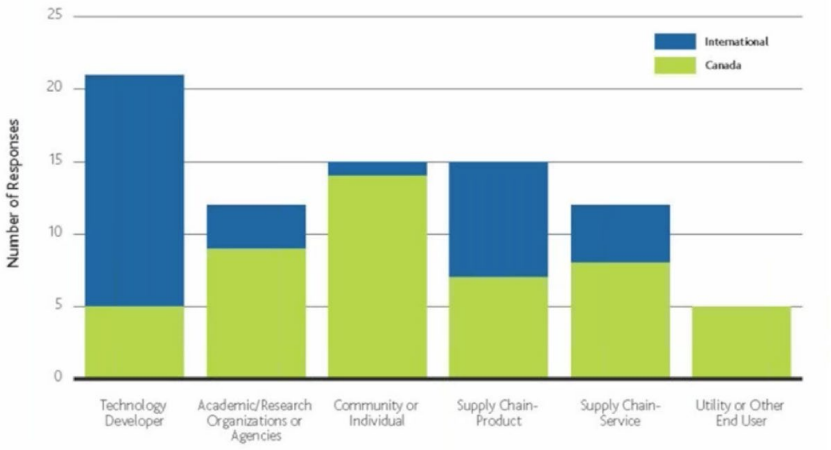
The call, which closed in August 2017, drew 80 responses, including 19 requests for potential SMR demonstrations at Canadian Nuclear Laboratories sites.

Of the 80 responses, 51 were from Canada, 11 were from the UK, nine from the US and nine from other markets, including Asia and South America. Canadian interest was from across the country, although 35 responses came from Ontario.

The responses came from a variety of stakeholders, with the largest group (accounting for 27.5% of the total) being technology developers, most of which were from outside of Canada.

Communities, individuals and supply chain representatives accounted for a further 37.5% of responses.

Responses by Stakeholder Group



Three key themes emerged from the call:

- SMRs were seen as being particularly attractive for remote, off-grid communities and industries operating in remote locations, such as mining.
- The development and deployment of SMRs would help Canada to combat climate change.
- Establishing an SMR industry in Canada would lead to economic benefits for the country.

All three themes are highly relevant to the Canadian market. Mining, for example, contributes $52.6 billion to Canada's gross domestic product and accounts for more than 20% of the country's goods exports.

Canada is also "a world leader in the fight against climate change," according to government sources.

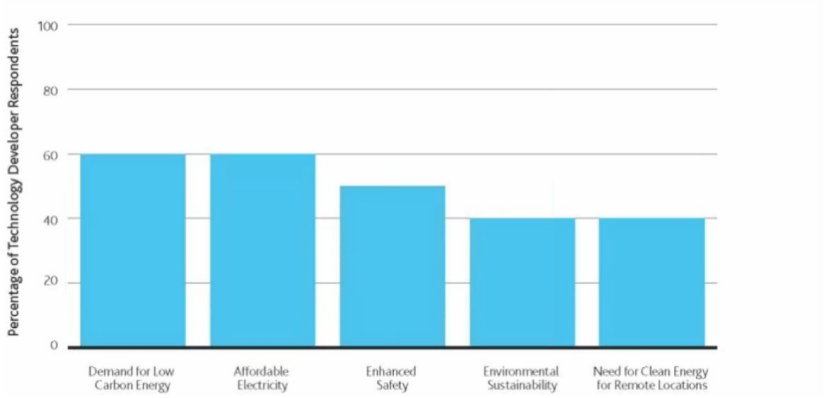
And as part of this leadership, the country is committed to commercializing low-carbon generation technologies that attract investment and deliver employment.

Besides nuclear, for example, Canada is currently among the leading nations worldwide pursuing the development of tidal stream technology.

Respondents to the call identified five major benefits in adopting SMR technology compared to other generation technologies. In order of importance, these were:

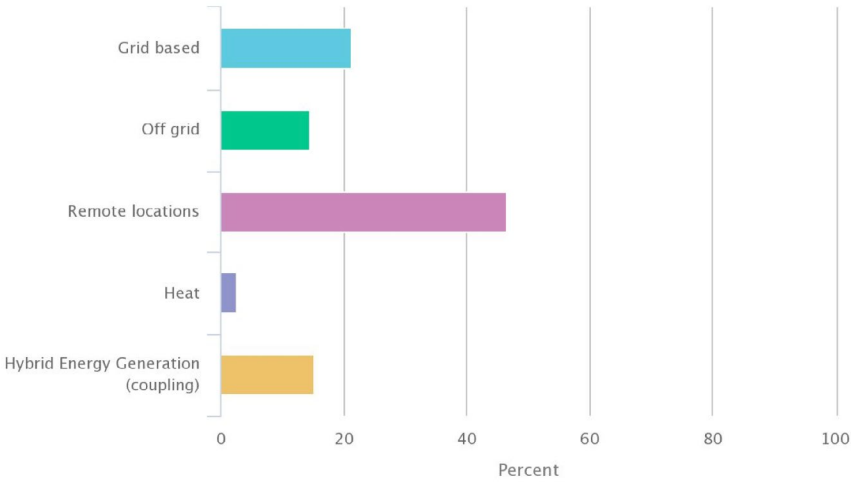
- Meeting demand for low-carbon energy.
- Providing affordable electricity.
- Enhancing energy security.
- Improving environmental sustainability.
- Delivering clean energy in remote locations.

Benefit of SMRs



Likely related to SMRs' potential importance for the Canadian mining industry, respondents to a New Energy Update poll rated delivering power in remote locations as the top application for SMRs in the country, cited by 47% of respondents.

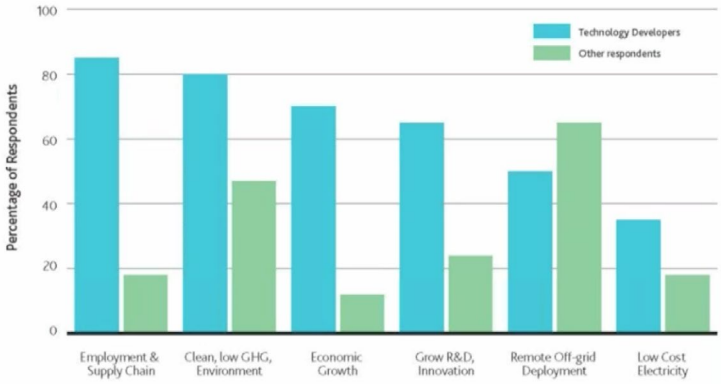
Which application(s) are SMRs most applicable to?



These advantages of SMR technology overall differed somewhat to the perceived benefits that SMRs could bring to Canada as a nation.

Here, technology developers argued in the Canadian Nuclear Laboratories call, the biggest advantage of commercializing SMRs would be in the creation of a supply chain and attendant employment opportunities.

Benefits of SMRs to Canada



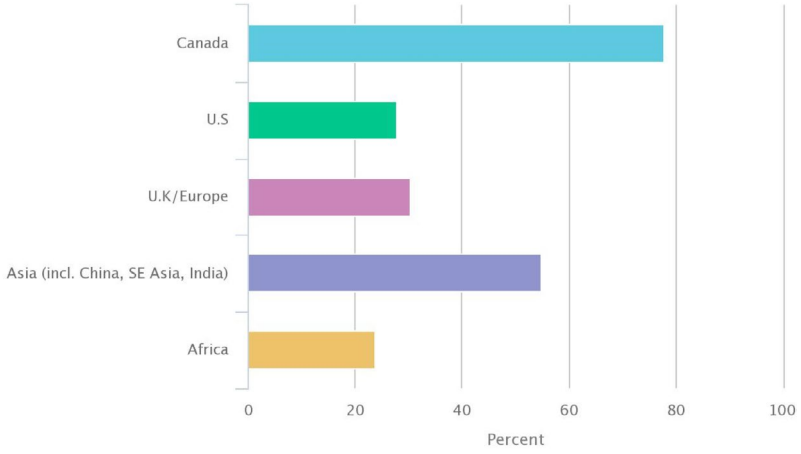
Perhaps surprisingly, the ability for SMRs to deliver low-cost electricity was rated rather poorly not just by technology developers but also by other respondents.

Industry attitudes towards the Canadian market

The capabilities at Chalk River, along with the regulatory climate and other factors, make Canada the most attractive market for SMR development worldwide, according to the poll carried out by Nuclear Energy Insider.

In the survey, 78% of respondents rated Canada as an attractive market for SMRs, significantly above Asia and Europe, the second and third-best rated markets, respectively.

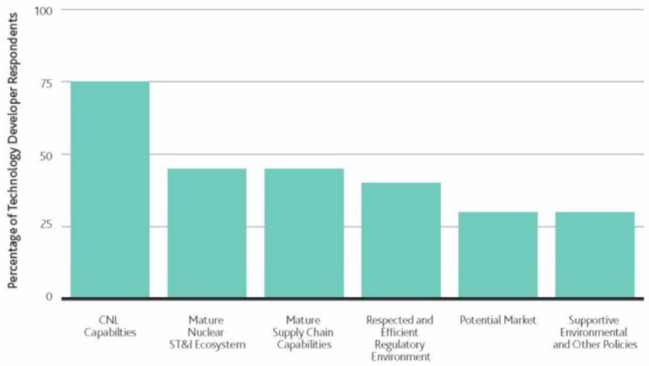
Which markets are most attractive for SMRs?



The Canadian Nuclear Laboratories call offered further insight into why industry players might prefer Canada to other potential SMR markets.

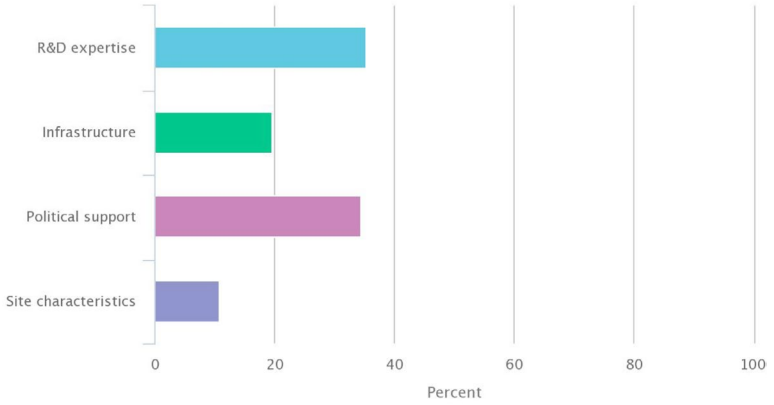
The chief factor was the capabilities of the Canadian Nuclear Laboratories itself, followed by the presence of mature nuclear supply chain and science and technology ecosystems.

Why Canada?



Building on this finding, the Nuclear Energy Insider poll revealed that the main reasons developers might be attracted to the Canadian Nuclear Laboratories for demonstration projects was the strength of the labs' research and development, and its support for SMRs.

What makes CNL most attractive for siting an SMR demonstration?

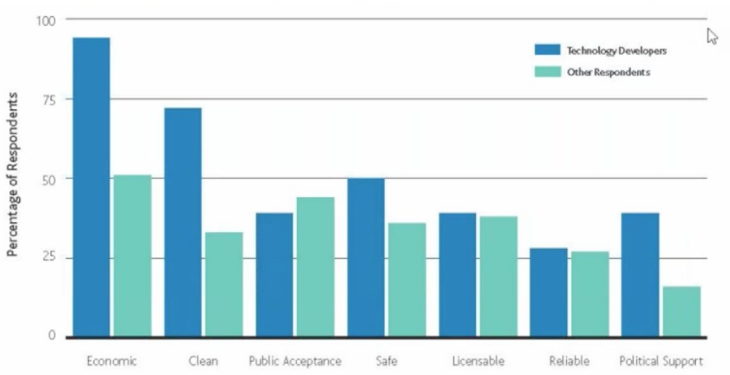


The right environment for SMR development

The Canadian Nuclear Laboratories call for expressions of interest yielded valuable information on the factors that could stimulate or hold back SMR deployment.

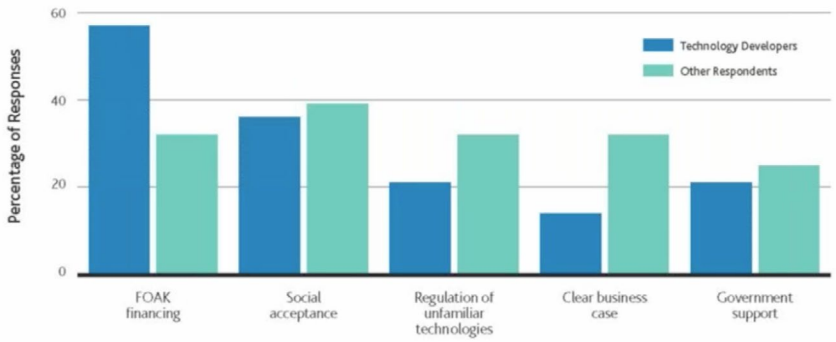
The main requirement cited by developers and non-developers alike was, perhaps unsurprisingly, the availability of positive economic factors. Developers also acknowledged the need to deliver clean, safe technologies.

Requirements for SMR Deployment



Also unsurprising was the fact that developers believed the biggest hurdle for SMR deployment was gaining funding for first-of-a-kind technologies.

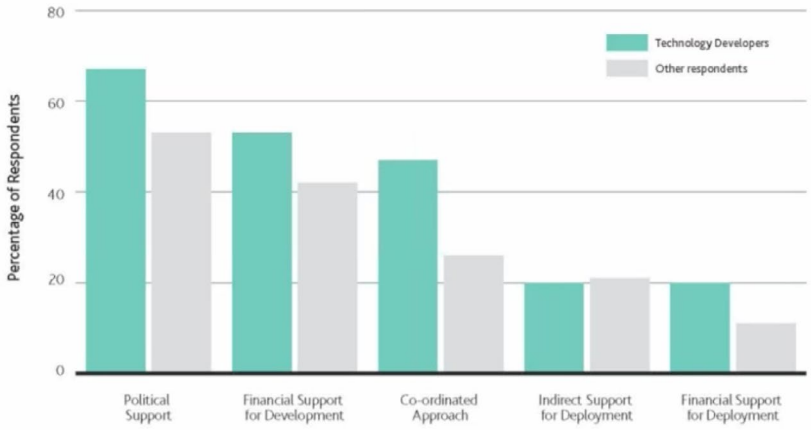
Challenges for SMR Deployment



All stakeholders were keen to emphasize the need for political and financial support in bringing technologies to market. A third requirement from government was for a coordinated approach to SMR commercialization.

In practice, says Kathryn McCarthy, Vice President of Research and Development at Canadian Nuclear Laboratories, this might translate into government backing of a single technology family, such as is the case with France's focus on pressurized water reactors.

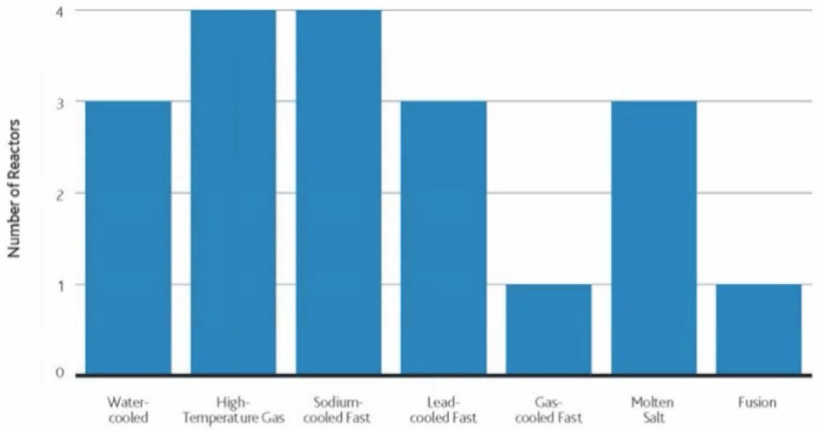
Roles for Government



Potential SMR technologies

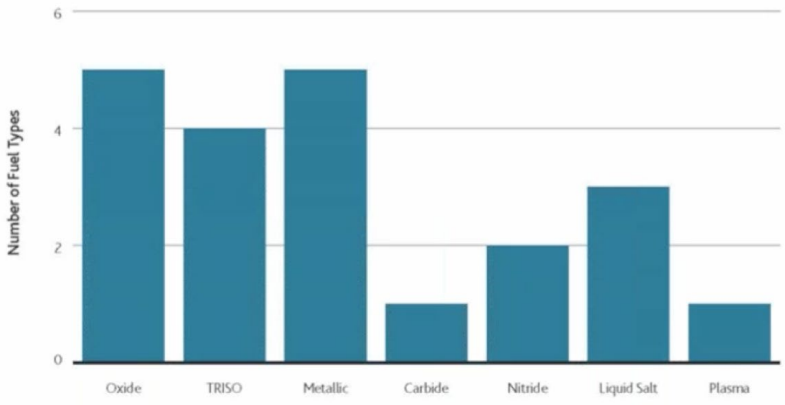
Respondents to the call put forward a wide range of potential SMR technologies for commercialization, with high-temperature gas and sodium-cooled fast reactors leading the way and one respondent even proposing a fusion design.

Proposed SMR Demonstration Reactors



There was similar diversity in the range of fuel stocks proposed, with five proposals each espousing oxide and metallic fuels and four respondents choosing tristructural-isotropic (TRISO) particles.

Fuel Types for SMR Deomstration Reactors



Current status of the market

Of the 22 technology vendors that answered the Canadian Nuclear Laboratories call for expressions of interest, three are intending to proceed directly to the deployment of commercial units and the remaining 19 are planning to carry out testing.

Canadian Nuclear Laboratories has already signed non-disclosure agreements with 18 SMR vendors, and has memorandums of understanding with seven and master task agreements with eight.

The lab has signed four contracts for work and has another 22 under discussion.

The first contract was with Terrestrial Energy, which in June 2017 announced it had commenced a feasibility study to explore siting the world's first commercial Integral Molten Salt Reactor at a Canadian Nuclear Laboratories location.

Canadian Nuclear Laboratories is opening up its sites for inspection, and Corey McDaniel, Vice President of Business Development, says vendors are being encouraged to engage early in conversations.

"With the very sharp interest in SMRs at Canadian Nuclear Laboratories, you don't want to be the 23rd or 24th person in the door," he says.

Conclusions

While many countries still see SMRs as a generation technology that might have potential in the distant future, Canada and Canadian Nuclear Laboratories clearly see it as a near-term industrial opportunity.

The information gleaned in the Canadian Nuclear Laboratories call for expressions of interest, and backed up by Nuclear Energy Insider research, shows Canada is very much seen as being at the vanguard of moves to make SMRs a commercial reality.

This attitude is reflected in the work being carried out by Canada's nuclear regulator, the Canadian Nuclear Safety Commission (CNSC), which is leading the worldwide development of SMR regulation.

The CNSC has already made it clear that Canada's regulatory framework is largely open to SMRs. "Existing regulations under the Nuclear Safety and Control Act are already suitable for regulating activities involving the use of SMR technologies," it says.

Against this backdrop, there is every reason to expect Canada to lead the development of an increasingly vibrant and significant SMR industry in the 2020s.

8th Annual

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This whitepaper was produced in conjunction with the 8th Annual International SMR and Advanced Reactor Summit (March 27-28, Atlanta), the largest event of its kind in the world.

In March 2018, over 350 senior representatives from around the world will unite to develop siting, supply chain and construction strategies to reduce Nth of a kind deployment costs in SMR and advanced reactor technologies.

Now in its 8th year, there's no better place to hear from the biggest names in next generation nuclear power … here's just a glimpse of who you'll meet at the summit in 2018:

Edward McGinnis
Acting Assistant Secretary of Energy
US Department of Energy

Julian Gadano
Undersecretary for Nuclear Energy
Ministry of Energy and Mining, Argentina

Congressman Randy Weber (R-TX)
US House of Representatives

Glenn Jager
Chief Nuclear Officer
OPG

Mark Lesinski
President and CEO
Canadian Nuclear Laboratories

Mike Rencheck
CEO
Bruce Power

Vic Pakalnis
President and CEO
MIRARCO Mining Innovation

Vonna Ordaz
Acting Director – Office of New Reactors
US NRC

Jose Reyes
Chief Technology Officer
NuScale

Ray Rothrock
CEO
RedSeal

- Get to grips with SMR and advanced reactor technologies' applicability to emerging markets, allowing you to develop deployment and supply chain strategies for the future
- Understand how the licensing framework of global regulators are being adapted to accommodate next generation nuclear technologies, enabling you to best prepare your license application
- Pave the way for the global deployment of SMR and advanced reactor technologies, by learning from your peers from developers, end users, supply chain companies and government officials, to overcame major obstacles
- Discuss the state of SMR and advanced reactor financing including investment, structured financing and government loan assistance to ensure the efficient use of project funding in the future
- Evaluate the potential of new technologies and methods such as additive manufacturing, modular construction, robotics and automation, that could lead to reduced costs in Nth-of-a-kind deployments

Nuclear Energy Insider are proud to be partnering with Canadian Nuclear Laboratories, the Nuclear Energy Institute and UxC for the summit.

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