Canada's Nuclear Regulator

The Canadian Nuclear Safety Commission's Strategy for

Readiness to Regulate Advanced Reactor Technologies

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The Canadian Nuclear Safety Commission's Strategy for Readiness to Regulate Advanced Reactor Technologies

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Executive Summary

The Canadian Nuclear Safety Commission (CNSC) is no stranger to regulating nuclear innovations. Since 1946, the CNSC has been regulating activities associated with the nuclear industry in Canada. In recent years, there has been a growing interest in new advanced reactor concepts (including small modular reactors) both within Canada and internationally.

The advanced reactor readiness report describes the CNSC's strategy for addressing the challenges of regulating advanced reactor technologies and prioritizing its regulatory efforts. The report outlines how the CNSC is prepared to address regulatory challenges like those presented by new technological advances in reactor designs, and new deployment and operational models.

This strategy includes three key elements that ensure readiness to respond to regulatory challenges through its three pillars for regulatory readiness:

- a robust and flexible regulatory framework
- risk-informed processes
- a knowledgeable and capable workforce with sufficient capacity and technical expertise

No matter the technology, it is the CNSC's role to regulate the nuclear industry and to ensure that the health and safety of the public and the environment are protected.

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The Canadian Nuclear Safety Commission's Strategy for Readiness to Regulate Advanced Reactor Technologies

1. Introduction

The Canadian Nuclear Safety Commission (CNSC) is continuing to implement a comprehensive strategy for establishing its readiness to regulate advanced reactor technologies[1], including small modular reactors (SMRs). This document provides an overview of that strategy and its primary components, and describes enabling priorities to further define where regulatory effort needs to be focused.

The regulatory readiness strategy aligns with the CNSC's mandate, vision, regulatory approach and philosophy, all of which are set out in REGDOC-3.5.3, *Regulatory Fundamentals* [1].

1.1 Background

The CNSC has noted a growing interest in new advanced reactor concepts both within Canada and internationally. These concepts are promising enhanced safety features as well as improved efficiency and economy to address traditional challenges faced by existing nuclear power plant designs. Some of the improved safety features being claimed include:

- the use of next-generation nuclear fuels with greater damage tolerance
- inherent safety characteristics in reactivity control
- passive safety functions that require limited or no human action during an external or internal plant event
- a reduced need for external power to support safety functions

Developers of these concepts are also proposing ways to further refine key construction and operational issues that have been highlighted by technology users. These proposals include:

- possible new manufacturing, such as 3D printing or modularity and construction practices
- new technologies to support efficiency in operation and maintenance, such as new methods for in-service inspection using robotics and other imaging technologies or 3-D printing for spare parts
- greater grid load-following, and the ability for the reactor facility to support the increased use of heat for cogeneration, district heating and other supplementary industrial processes not directly tied to reactor operation

[1] In this document, the term "advanced reactor technologies" includes any reactor facility that uses new technologies or concepts, including small modular reactors.

1.2 Objectives of the Regulatory Readiness Strategy

The strategy contributes to regulatory certainty by establishing the CNSC's technical readiness and informing the prioritization of regulatory activities, both of which help support the Commission's decision making. The strategy aims to communicate how the CNSC is preparing to regulate activities involving advanced reactor technologies. The strategy also supports the CNSC's mandate to disseminate technical, scientific and regulatory information.

2. Challenges

Advanced reactor technologies can differ significantly from Canada's current fleet of traditional water-cooled reactors, in terms of design, operation and deployment strategies.

The numerous departures from established technologies and deployment models pose new challenges with respect to effective regulation. Challenges include (without being limited to) different reactor concepts, new deployment models, new operating concepts, modularity in design, new types of fuel, and factory fabrication.

These multiple potential innovations, combined with limited operating experience with these new technologies, can introduce a number of regulatory challenges.

2.1 New technological advances

Many new reactor concepts use (or are based on) relevant operating experience and lessons learned from the previous generation of reactors; however, most advanced reactor designs employ a number of novel approaches simultaneously. Some new reactor designs vary from previous generations by incorporating technologies (e.g., greater use of automation and digital instrumentation) from other industries that are new to reactor designs.

New designs can also utilize different types of fuels or coolants, such as molten metal or helium, and make frequent extensive use of passive safety features.

2.2 Deployment and operational challenges

The proposed deployment and operational models for some of these new types of reactors are also very innovative. For instance, some reactor designers intend to suggest the use of fewer staff and eventual remote operation. Some of these new technologies have the potential to be ultimately transportable and even relocatable.

It has been raised that there is the potential for modular design and factory fabrication (including factory fuelling) of reactor fleets. This brings regulatory implications with respect to licensing and environmental assessment.

3. Pillars of the Regulatory Readiness Strategy

The CNSC has developed a strategy to address the challenges of regulating advanced reactor technologies and to prioritize regulatory efforts. The CNSC's regulatory readiness strategy for new advanced reactors is built upon three fundamental pillars (see figure 1):

1. a robust but flexible regulatory framework that provides a sound basis upon which regulatory decisions can be made and enforced
2. risk-informed processes by which the regulatory framework is applied
3. a capable workforce with sufficient capacity and technical expertise, operating within an agile work organization

A Small Modular Reactor Steering Committee (SMRSC) has been established to provide governance and to ensure that these pillars are appropriately balanced. The SMRSC will also ensure direct prioritization of the activities that will enable achievement of the priorities outlined in this document.

Figure 1: The three pillars of the CNSC's regulatory readiness strategy

3.1 The CNSC's regulatory framework

3.1.1 Background and evolution of the framework

The CNSC's regulatory framework for reactor facilities evolved from the operating experience and research and development activities associated with the development of large-scale water-cooled reactors, primarily of CANDU design. Early regulation of these reactors was mainly

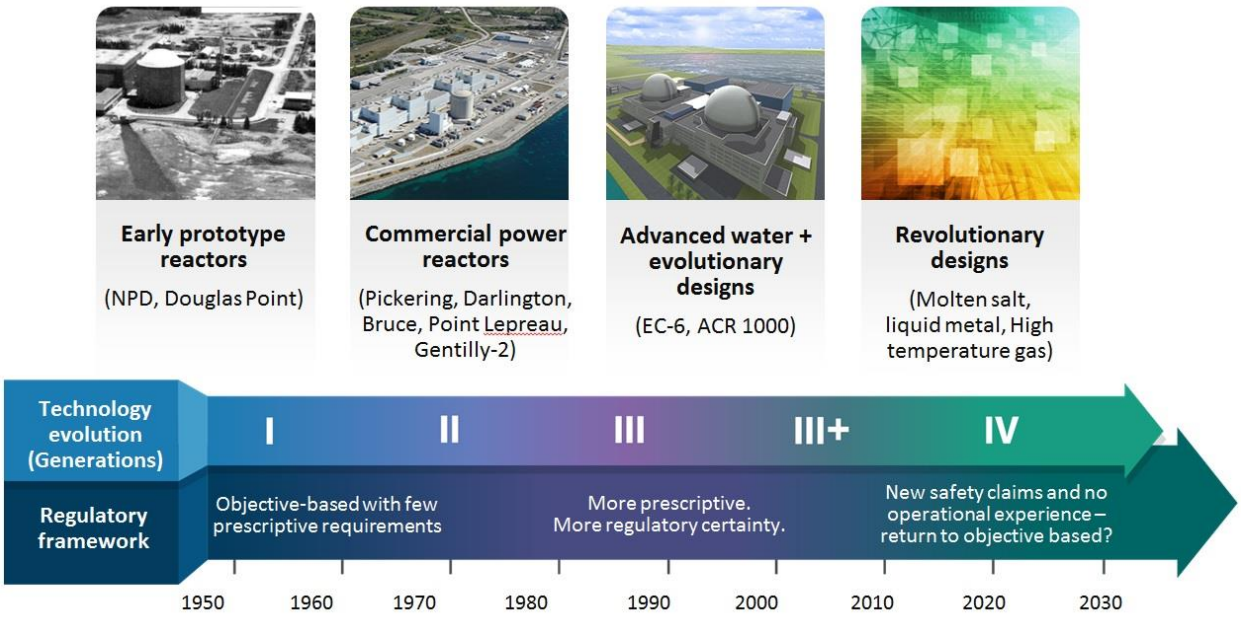
based on objectives and as new reactor generations were commissioned, the regulatory framework evolved accordingly. With operational experience, the framework eventually became more detailed and, in some cases, more prescriptive.

As current regulatory instruments are based on operating experience with water-cooled and CANDU reactors, the strict application of related requirements to advanced reactor technologies may pose challenges. The CNSC may therefore need to adapt its regulatory framework to align with the new technological reality, returning to more objective-based regulation until it develops more regulatory instruments to address advanced reactor technologies.

With this in mind, the CNSC's regulatory readiness strategy includes the application of a risk-informed approach to decisions, and to assessing alternative approaches to meeting current requirements.

Figure 2 illustrates the parallel between the evolution of reactor technologies and that of the CNSC's regulatory framework over time.

Figure 2: Evolution of reactor designs and the CNSC's regulatory framework



3.1.2 Structure of the regulatory framework

The CNSC's regulatory framework consists of the *Nuclear Safety and Control Act* (NSCA) and other laws passed by Parliament that govern the regulation of Canada's nuclear industry (see figure 3).

Figure 3: Elements of the CNSC's regulatory framework

In addition to the NSCA and the regulations made under it, the CNSC has developed regulatory documents, which are a key part of its regulatory framework for nuclear activities in Canada. They provide additional clarity to licensees and applicants by explaining how to meet the requirements set out in the NSCA and the regulations made under it. Regulatory documents are organized into three key categories: regulated facilities and activities, safety and control areas and other areas of regulatory engagement.

The CNSC maintains an efficient and streamlined regulatory framework by making appropriate use of industry standards. These include standards created by independent third-party standard-setting organizations, such as CSA Group, the American Society of Mechanical Engineers, the International Commission on Radiological Protection and the Institute of Electrical and Electronics Engineers. Industry or international standards may be referenced in CNSC regulatory documents.

More information about the CNSC's regulatory documents and CSA Group nuclear standards can be found on the CNSC's regulatory documents Web page.

Although developed principally for water-cooled reactors, the CNSC's regulatory framework was designed to be flexible and can be applied to different reactor technologies as required, although clarification and guidance may be needed when applied to new advanced reactor technologies.

As part of an initiative to identify opportunities for improvement to the regulatory framework, the CNSC consulted with stakeholders by publishing discussion paper DIS 16-04, *Small Modular Reactors, Regulatory Strategy, Approaches and Challenges* [2]. The feedback received on the

discussion paper was captured in a What We Heard Report [3]. The feedback received was that with some updated guidance and interpretation of requirements, the CNSC's regulatory framework would generally able to facilitate CNSC staff's review of a licence application for an advanced reactor technology.

3.1.3 Graded approach and alternative approach to requirements

The CNSC regulates using a risk-informed approach, which is long-established and forms the foundation of its regulatory activities. The CNSC sets requirements and provides guidance on how to meet them, and the applicant or licensee may put forward a case to demonstrate that the intent of a requirement is addressed by other means. Such a case must be demonstrated with suitable supporting evidence.

CNSC staff consider all relevant guidance when evaluating any proposal submitted. This includes application of the graded approach, and consideration of alternative means of meeting requirements.

The graded approach is a systematic method or process by which elements such as the level of analysis, the depth of documentation, and the scope of actions necessary to comply with requirements are commensurate with:

- the relative risks to health, safety, security, the environment and the implementation of international obligations to which Canada has agreed
- the particular characteristics of a nuclear facility or licensed activity

In addition, as outlined in section 11 of REGDOC-2.5.2, *Design Requirements for New Nuclear Power Plants* [4], the CNSC will consider alternative approaches to requirements of nuclear power plant design when :

1. the alternative approach would result in an equivalent or superior level of safety
2. the application of the requirements in this document conflicts with other rules or requirements
3. the application of the requirements in this document would not serve the underlying purpose, or is not necessary to achieve the underlying purpose

Any alternative approach shall demonstrate equivalence to the outcomes associated with the use of established requirements.

This does not mean that the requirements are lessened or waived; rather, it is an indication that the regulatory framework provides the flexibility needed for licensees to propose alternative ways to achieve the intent of the requirement(s). The Commission is always the final authority on deciding whether requirements have been met.

This flexibility allows CNSC staff to review modern and innovative nuclear reactors without having to entirely redesign the regulatory framework.

Depending on the extent of change in the new technologies, it may become necessary to establish more technology-specific guidance and review processes or procedures to ensure continued flexibility and consistency in application. In the long term, some requirements may also benefit from adaptation to more closely align with new reactor technologies being proposed.

It is important to note that the flexibility of the regulatory framework does not imply reduction in safety, but rather consideration of alternative approaches and grading, which ensure an equivalent or superior level of safety. Grading may result in more stringent application/enforcement of some requirements.

3.1.4 Enabling priorities for the regulatory framework

The regulatory readiness strategy includes the following enabling goals with respect to the regulatory framework:

- complete the improvement actions identified as a result of the What We Heard Report (potential amendments to security regulations and regulatory documents, application of the graded approach, further clarity on the approach to licensing SMRs, etc.)
- continue to articulate the objectives behind existing requirements, in order to ensure consistent interpretation of the regulatory instruments and to increase overall clarity of the regulatory framework
- establish a mechanism to document lessons learned, to capture feedback and to identify which regulatory requirements and documents may need adjustment

3.2 Risk-informed processes

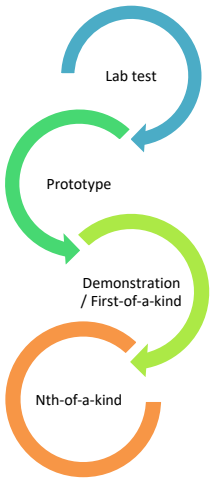
To ensure that the regulatory framework is properly applied to new advanced reactor technologies, adequate processes are required. The processes associated with licensing and compliance need to be adaptable to each specific facility, and must be applied through a risk-informed approach based on the complexity, novelty and risk associated with the facility or activity.

3.2.1 Development lifecycle of a new reactor

The development lifecycle of an advanced reactor (or any other innovative technology) typically goes through a set of product development phases, which follow the well-known technological readiness scale[2] (see figure 4).

[2] The technological readiness scale is a scale of product development developed for NASA and the U.S. Department of Energy. This scale is now used in many technological development applications, including the Government of Canada's Innovation and Skills Plan (https://www.ic.gc.ca/eic/site/080.nsf/eng/00002.html).

Figure 4: Development lifecycle of a new technology



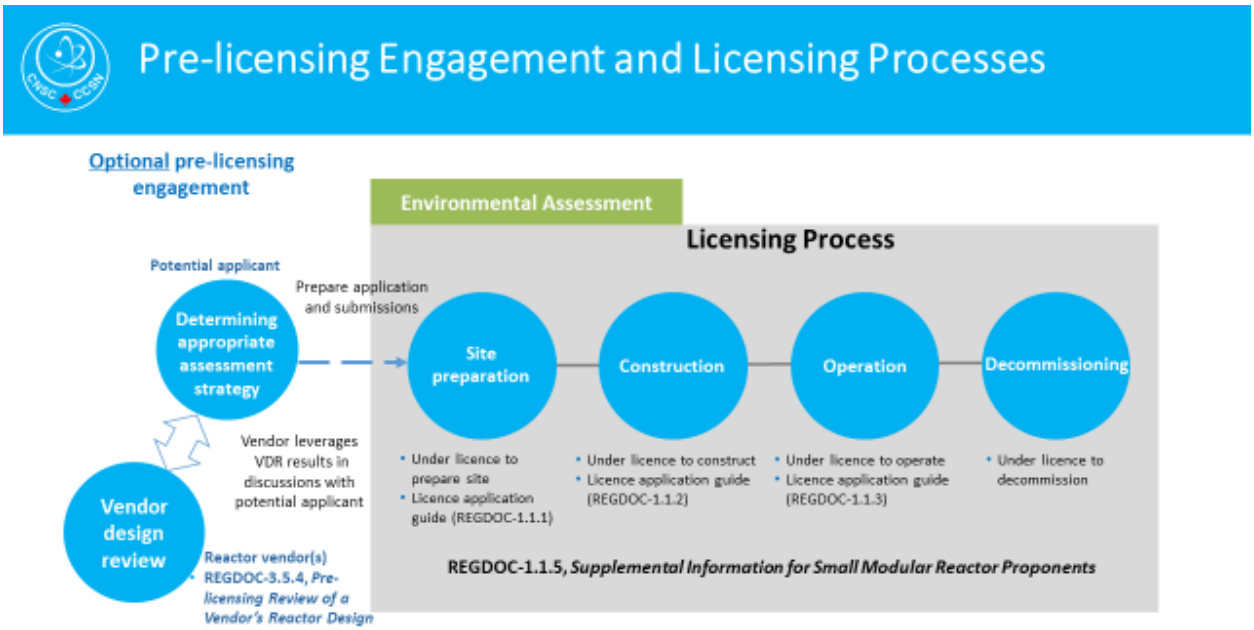
Once the development of a new reactor nears completion, it is expected that a demonstration or "first-of-a-kind (FOAK)" reactor will be constructed. The FOAK may need special construction and design adjustments to enable inspection, testing, or other means to substantiate safety claims. It is also expected that safety margins may need to be adjusted to compensate for the potential insufficient experimental data when licensing reactors that use new technologies. The pre-licensing processes can help in improving efficiencies in the licensing of new advanced technologies, particularly if the technologies are in the early phases of the development scale.

3.2.2 Pre-licensing processes

As shown in figure 5, the CNSC has established two pre-licensing processes to engage stakeholders early in the technology development and licence application processes:

- Vendor design review [5] is a process typically requested by the technology developer (vendor).
- The process for determining an appropriate application assessment strategy for a novel nuclear technology (aka the "four-step process") is intended for potential licence applicants considering building and operating reactors based on vendor designs (this process is outlined in REGDOC-1.1.5, *Supplemental Information for Small Modular Reactor Proponents* [6]).

Figure 5: Optional pre-licensing engagement processes



Vendor design review (VDR)

Once a design is sufficiently developed with a good conceptual outline of the safety aspects of the proposed reactor, the technology developer (vendor) may choose to participate in an optional VDR process, which is explained in REGDOC-3.5.4, *Pre-licensing Review of Vendor's Reactor Design* [7]. A VDR is a service provided by the CNSC, and would typically take place before a licence application is made. It is cost-recovered, where the vendor can choose to apply the process.

A VDR involves a systematic evaluation of 19 topical areas to allow early identification and resolution of potential regulatory or technical issues early in the design process, particularly those that could result in significant changes to the design or to the safety analysis. The review can be performed in three phases of increasing depth.

The VDR process offers a unique opportunity to examine the design challenges that are anticipated for future SMR licensing. In addition to providing vendors with a greater understanding of CNSC requirements, the insights gained through VDRs will effectively inform several aspects of the CNSC readiness strategy, such as:

- opportunities to improve the CNSC's regulatory framework
- implications for future licensing stages for the respective reactors
- training of the CNSC's workforce in the respective technical aspects of licensing

Process for determining appropriate licensing strategies for novel nuclear technologies

Proponents who intend to build and operate a vendor's design can choose to engage in the pre-licensing process for determining appropriate licensing strategies, in order to anticipate the potential regulatory implications on the licensing process for the proposed concept.

This process ensures that a risk-informed approach is systematically and consistently applied in the development of a licensing strategy for an innovative activity or facility that uses technology that is new to Canada.

The process to determine appropriate licensing strategies can be carried out before any licence application is made. It begins by way of early CNSC engagement with a potential new reactor applicant to reach a common understanding of the nature of the proposed design and approach to operation. Information acquired through a VDR can also be very useful to this process, and can be used in the licensing process at the applicant's discretion.

The process begins with a high-level analysis of the proposed project, including scoping of applicable regulations and regulatory processes. Applicable regulatory documents and practices, with recommendations on their risk-informed applications, are also identified. In some instances, such as the testing of a thermalhydraulic loop without the use of any nuclear substances, it may be determined that a licence under the NSCA is not required.

The outcome of this process is an appropriate risk-informed strategy, which the CNSC will ultimately use in developing supplemental guidance for an applicant on how to prepare a licence application for the given project. The process is expected to be iterative, with several interactions between the CNSC and the applicant before the strategy is complete.

3.2.3 Issue resolution processes

Technical assessment process

CNSC staff have developed a comprehensive technical assessment process, which provides guidance on how to effectively and consistently provide technical conclusions and recommendations to support regulatory positions. This core process will be used in regulating all aspects of each new advanced reactor facility for the lifecycle of that facility. If necessary, this process may be used in conjunction with the New Build Technical Sub-Committee assessment.

New Build Technical Sub-Committee assessment

The New Build Technical Sub-Committee provides a mechanism for interpreting requirements, addressing policy considerations and significant departures from past Canadian regulatory practices due to advanced designs and modes of operation, etc. The committee ensures a rigorous approach to, and proper documentation of, any technical issues and recommendations, and also ensures that the review process remains rigorous and balanced.

3.2.4 Enabling priorities for risk-informed process

The regulatory readiness strategy includes the following enabling goals with respect to processes:

- optimize CNSC processes to respond to the challenges posed by new reactor technologies
- ensure that pre-licensing engagement and technical assessment processes remain fit for purpose
- confirm that the different issue resolution processes align with current challenges
- establish processes to assess alternative approaches for meeting regulatory requirements
- Identify and correct any gaps in the suite of processes available to regulate new advanced reactors

3.3 Workforce capability and readiness

The importance of adequate nuclear knowledge and supporting organizational arrangements merits special attention in the readiness strategy. The CNSC needs to manage and allocate resources effectively, recognizing that the variability of reactor technologies coming onto the licensing horizon will present new and unique challenges that may stretch resources.

3.3.1 Technical capability

To be able to adequately evaluate each application and safety case, CNSC staff must have technical proficiency that is aligned with new technological advances. Some of the key competencies for evaluating applications and safety cases for new technologies do not significantly differ from those required to address traditional water-cooled reactors. However, the CNSC recognizes that new and different competencies may also be needed to address advanced reactor technologies.

To further support the CNSC's technical capability, the readiness strategy includes making sure that technical resources are kept abreast of the upcoming challenges, that specific training requirements are identified, and that training is developed and delivered to appropriate staff and management in a timely manner. The development of the Capability for Nuclear Safety Project is an important part of ensuring staff's technical capability. The lessons learned and feedback from the VDR process will also provide significant input.

Capability for Nuclear Safety Project

The CNSC's Capability for Nuclear Safety Project encompasses the workforce capability to evaluate and regulate nuclear safety for both existing reactor technologies and new reactor technologies, with a focus on new reactor technologies. This project is taking stock of the CNSC's current resources, identifying gaps and providing resolution actions. With a clear picture of the current workforce's baseline capability, the anticipated requirements for technical knowledge can be identified. Ongoing evaluation of resourcing needs will enable continued building on the baseline capacity, which in turn will allow the CNSC to meet growing resourcing demands and to regulate highly specialized technologies over time.

Feedback obtained from vendor design reviews

The VDR can drive the direction of staff training by identifying issues or details that extend beyond staff's current technical capability. Knowledge or technical gaps will be resolved through a variety of responses, such as developing and delivering specialized training to CNSC staff, hiring specialist consultants, initiating research and development activities, partnering with other organizations, and ensuring that resolutions are captured as part of the CNSC's knowledge management activities.

3.3.2 International cooperation

Strong international collaboration is a critical part of ensuring that the CNSC's workforce is ready and able to regulate advanced reactors. Technology and modelling capabilities are developing increasingly quickly, and vendors are also becoming more diverse. By pooling resources with its international counterparts, the CNSC will be better prepared to face the challenges associated with regulating advanced reactor technologies. Other jurisdictions around the world are adapting their licensing frameworks, and while these frameworks are not identical to the Canadian context, the CNSC can build on lessons learned from the international work in this realm.

International cooperation also provides a forum for establishing technical links, which can lead to sharing of research, assessment results and training opportunities. This sharing of knowledge among regulators provides the potential to reallocate resources to focus on other aspects of the regulation process.

Many international forums are actually in place to promote such information sharing. For example, the Nuclear Energy Agency, a specialized agency within the Organisation for Economic Co-operation and Development, has several groups looking at advanced reactor technologies. For example:

- The Working Group on the Regulation of New Reactors (WGRNR) is examining the licensing aspects of new advanced reactors. To date, the WGRNR has focused on new large-scale projects, but its mandate will include SMRs in the future. The group organizes workshops to share experiences among regulators on some important aspects

of new reactor licensing, such as commissioning activities and organizational oversight. It also conducts surveys to document practices on specific topics across member countries.

- The NEA Working Group on the Safety of Advanced Reactors (WGSAR) provides a forum to exchange and elaborate on safety requirements for new types of technologies. The first technology that the WGSAR evaluated was the sodium fast reactor.
- The International Atomic Energy Agency (IAEA) also conducts several activities that foster exchange and cooperation with respect to SMR technologies. For example, in March, 2015 the IAEA established the SMR Regulators' Forum for Member States and other stakeholders to discuss and share SMR regulatory knowledge and experience – thereby providing support to regulators establishing regulatory controls for advanced reactor technologies.

Bilateral cooperation with other nuclear regulators also provides opportunities to share insights and solutions for meeting new regulatory challenges. The CNSC has initiated cooperation with both the UK Office of Nuclear Regulation and the U.S. Nuclear Regulatory Commission.

3.3.3 Workforce organization

The CNSC's current technical support organization model has been in place for many years, ensuring that technical reviews are conducted and communicated to the appropriate internal licensing division and to the Commission, eventually supporting licensing of prescribed activities. The VDR and pre-licensing application processes enforce strict project management controls for estimating, planning and executing safety reviews. Similarly, the licensing process is project-managed to ensure proper allocation of resources at all stages. CNSC staff have already developed comprehensive project management plans for assessing applications for a licence to prepare site, and is creating plans to manage other licensing phases for advanced reactor projects.

These processes and organizational models will be reviewed regularly to ensure their continued effectiveness in addressing the regulatory challenges of new advanced reactor technologies.

3.3.4 Risk-informed resource allocation

The risk-informed approach that the CNSC applies to all regulatory activities will also be used to allocate resources and prioritize tasks with respect to regulatory readiness for advanced reactor technologies.

3.3.5 Enabling priorities for workforce capability

The regulatory readiness strategy includes the following enabling goals with respect to workforce capability:

- encourage international cooperation in the exchange of best practices on the safety assessment of new reactor technologies
- ensure appropriate workforce training on new reactor technologies

- ensure that the workforce organization can support the review and assessment of new reactor technologies
- continue to evaluate resourcing needs and build on baseline workforce capacity to meet increasing resourcing demands and highly specialized technologies over time

3.4 Strategy governance – SMR Steering Committee

Governance of the CNSC's regulatory readiness strategy for advanced reactor technologies is led by the Small Modular Reactor Steering Committee (SMRSC). The SMRSC ensures that each element of the strategy receives appropriate attention and that proper oversight of all related functions is established.

The SMRSC:

- makes high-level decisions regarding the CNSC's regulatory position on SMRs
- provides guidance and senior management support with respect to resource requirements
- identifies issues that require approval or attention of the CNSC's Executive Committee or Commission
- monitors progress against planned activities, and tracks other performance measures
- escalates issues to the New Build Technical Sub-Committee where necessary
- becomes aware of and removes obstacles to progress

The SMRSC is chaired by the CNSC's Executive Vice-President and Chief Regulatory Operations Officer.

3.5 Communication

Governance of the CNSC's regulatory readiness strategy for advanced reactor technologies is led by the Small Modular Reactor Steering Committee (SMRSC). The SMRSC ensures that each element of the strategy receives appropriate attention and that proper oversight of all related functions is established.

4. Conclusion

The strategy outlined in this document demonstrates the CNSC's readiness to license new advanced reactor technologies, which include SMRs. The CNSC's regulatory framework is adequate for licensing these new technologies, as it provides the flexibility to adjust processes in order to meet new or unique technical challenges. Robust, risk-informed processes, a highly capable workforce, and effective governance of this strategy will ensure that the CNSC continues to meet its mandate.

5. References

1. Canadian Nuclear Safety Commission (CNSC), REGDOC-3.5.3, *Regulatory Fundamentals*, Ottawa, Canada, 2018
2. CNSC, DIS-16-04, *Small Modular Reactors: Regulatory Strategy, Approaches and Challenges*, Ottawa, Canada, 2016
3. CNSC, What we Heard Report–DIS-16-04, Ottawa, Canada, 2017
4. CNSC, REGDOC-2.5.2, *Design of Reactor Facilities: Nuclear Power Plants*, Ottawa, Canada, 2016
5. CNSC, Webpage, Pre-licensing Vendor Design Review, Ottawa, Canada, 2019
6. CNSC, REGDOC-1.1.5, *Supplemental Information for Small Modular Reactor Proponents*, Ottawa, Canada, 2019
7. CNSC, REGDOC-3.5.4, *Pre-licensing Review of a Vendor's Reactor Design*, Canada, 2018

6. Additional information

More detailed information is available in the following documents:

- Report of the Standing Committee on Natural Resources, 5th Report, 42nd Parliament, 1st session:
- *Government of Canada Response to the Fifth Report of the Standing Committee on Natural Resources*