# Canada's safeguards readiness for

# small modular and advanced reactors

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**Abstract**

The Canadian Nuclear Safety Commission (CNSC), as Canada’s safeguards regulatory authority, continues to ensure its readiness for the effective and efficient implementation of safeguards at small modular reactors (SMR). Canada has decades of experience in applying safeguards to CANDU reactors, uranium bulk handling facilities, and research and development, and hopes to leverage this knowledge in the application of safeguards for these novel designs and technologies. These efforts include its pre-licensing vendors design reviews, participation in the Member State Support Program task on safeguards-by-design for SMRs, and submission of preliminary design information for its first SMR. The CNSC has engaged with vendors, applicants, and the International Atomic Energy Agency to consider appropriate safeguards concepts, approaches, techniques, and equipment for these new designs. The paper will provide the status of SMR licensing applications in Canada, an overview of the CNSC’s engagement on safeguards-by-design in various forums, efforts to integrate safeguards with safety and security, lessons learned and remaining challenges.

## INTRODUCTION

The Canadian Nuclear Safety Commission (CNSC) is currently reviewing its first application in decades seeking a licence to construct a new nuclear power plant. It would also be Canada’s first non-pressurized heavy water nuclear power plant. This application, along with additional applications for licences to prepare nuclear power plant sites and other proposed projects, raises many regulatory challenges, including how to ensure that Canada’s safeguards commitments are addressed both effectively and efficiently when applied to these new reactor designs. The CNSC has initiated discussions on these safeguards considerations early in the design process with both vendors and the International Atomic Energy Agency (IAEA) to meet this goal. The paper will provide the status of SMR licensing applications in Canada, an overview of the CNSC’s engagement on safeguards-by-design in various forums, efforts to integrate safeguards with safety and security, lessons learned and remaining challenges.

## Setting the Scene

The Government of Canada has a long-standing political commitment to the peaceful uses of nuclear energy, dating back to the “Three-Power Declaration on Atomic Energy” in November 1945 with the United States and the United Kingdom [1]. At that time, Canada committed “to prevent the use of atomic energy for destructive purposes” and “to promote the use of recent and future advances in scientific knowledge, particularly in the utilization of atomic energy, for peaceful and humanitarian ends” but proposed the need for “effective safeguards” under an international organization [2]. These safeguards would play an important role in providing reciprocal and credible assurances to Canadian and the international community that nuclear material remains in peaceful uses. In 1968, Canada was one of the first countries to sign the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) which requires non-nuclear-weapons State Parties to accept safeguards and to bring into force an agreement with the IAEA. As a result, Canada brought into force a comprehensive safeguards agreement (CSA) in 1972 and an Additional Protocol (AP) to the agreement in 2000 (together, the “safeguards agreements”). The IAEA first drew its ‘broader safeguards conclusion’ for Canada that all nuclear material remained in peaceful uses in 2005 and Canada has maintained this conclusion every year since.

## Regulatory Environment

The CNSC is Canada’s nuclear regulator. Its mandate is to regulate the use of nuclear energy and materials to protect health, safety, security and the environment; to implement Canada’s international commitments on the peaceful use of nuclear energy; and to disseminate objective scientific, technical and regulatory information to the public [3]. Originally established in 1946 as the Atomic Energy Control Board, the CNSC is Canada’s sole safeguards regulatory authority and implements Canada’s safeguards agreements with the IAEA through its regulatory framework. These requirements are defined in the *Nuclear Safety and Control Act* (NSCA), and are implemented through associated regulations, licences and licence condition handbooks. Regulatory documents (REGDOCs), including REGDOC-2.13.1, *Safeguards and Nuclear Material Accountancy*, provide additional guidance to applicants and licensees on how safeguards are to be applied and requirements met.

As the nuclear regulator and the safeguards regulatory authority, the CNSC is responsible for ensuring that the Government of Canada is able to fulfil its safeguards obligations under the NPT. It achieves this goal by ensuring that the IAEA has the information and access it requires to perform its activities under the safeguards agreements. Cooperation between the CNSC and the IAEA, and with licensees/operators, play a vital role in this success.

In this role, the CNSC is responsible for assisting the IAEA in the development of a safeguards approach and associated measures for new facilities, ensuring the applicant/licensee has the program and procedures in place to implement the safeguards measures and monitoring their compliance. Overall, the CNSC is the facilitator and coordinator between the IAEA and the applicant/licensee and maintains the system of accounting for and control of nuclear material (SSAC) in Canada. While the CNSC supports the development of new safeguards equipment and techniques through its safeguards support program with the IAEA, it is up to the IAEA to develop and select the appropriate measures for the application of safeguards at new Canadian facilities.

## IAEA’s Safeguards Approach for Canada

The implementation of safeguards has evolved in Canada since 1972 from traditional (the measures in the CSA), to strengthened (the additional measures in the AP), through integrated (optimization of all available measures) and now State-level safeguards. The IAEA approved a revised State-level approach for Canada in 2016. This approach is based on several State-specific factors for Canada, such as:

* comprehensive safeguards agreement, additional protocol with the broader conclusion,
* large and complex nuclear fuel cycle but the absence of enrichment or reprocessing,
* robust and mature safeguards regulatory authority,
* the IAEA’s ability to implement certain safeguards measures, such as near real-time nuclear material accountancy and short-notice and unannounced inspections,
* the IAEA’s capability to remotely monitor some of its installed safeguards equipment,
* presence of resident inspectors at the IAEA’s Toronto Regional Office, and,
* cooperation from the safeguards regulatory authority and the operators to resolve implementation issues in a timely manner.

While the IAEA’s overall inspection effort in Canada was significantly reduced under integrated safeguards and the State-level approach, Canada continues to receive the third most IAEA inspection effort amongst all States [4]. Some Canadian facilities and sites are the largest under safeguards – measured by the amount of nuclear material or throughput – in the world.

Safeguards measures continue to evolve to ensure that they can be applied both effectively and efficiently in Canada. As part of the revised State-level approach for Canada, the IAEA is pursuing an equipment-based approach for the verification of spent fuel loadings and transfers at the CANDU stations to complement the existing approach of unannounced inspections. With the introduction of new facilities and designs, the overall State-level approach and specific safeguards measures are expected to be adapted to meet the new safeguards challenges.

## Canada’s Current and Future Nuclear Fuel Cycle

The CNSC regulates and the IAEA applies safeguards to Canada’s once-through natural uranium fuel-cycle. The fuel-cycle includes uranium mining and milling; uranium refining, conversion and fuel fabrication; nuclear power generation; and waste management. This cycle is complemented by nuclear research and development activities and other locations that possess smaller quantities of nuclear material (i.e., Locations Outside Facilities) or perform nuclear-related manufacturing activities.

Nuclear power plants have been generating electricity in Canada since the early 1960s using CANDU (Canada Deuterium Uranium) pressurized-heavy water reactor designs. There are currently seventeen operating CANDU units in Canada at three multi-unit stations in the province of Ontario and a single-unit station in the province of New Brunswick. At the multi-unit stations, there are two units undergoing refurbishment and two units in safe storage prior to future decommissioning. About 15% of Canada’s electricity is derived from nuclear power with the majority being generated from hydro sources [5].

Utilities and developers have made a number of applications and announcements for new nuclear power projects in Canada [6]. As Canada’s first potential small modular reactor (SMR) project, Ontario Power Generation (OPG) holds a licence to prepare site for their Darlington New Nuclear Power Project (DNNP) at the existing Darlington CANDU site. OPG has applied to the CNSC for a licence to construct a single GE-Hitachi BWRX-300 (300 MWe boiling water reactor design). The CNSC is reviewing the application and the first public hearing of the Commission is scheduled for October 2024.

The CNSC is also reviewing two applications for licences to prepare site [6]. First, Global First Power has proposed to build Ultra Safe Nuclear Corporation’s micro-modular reactor (10-45 MWth high-temperature gas-cooled reactor design) at the Chalk River Laboratories site in Ontario as part of a demonstration project. The environmental assessment is underway and documentation is expected to be submitted to the CNSC in 2024. Second, New Brunswick Power has proposed to build ARC Clean Energy’s ARC-100 (100 MWe sodium-cooled fast reactor design) at the existing Point Lepreau CANDU site. The CNSC is currently reviewing the application.

Several additional projects have been announced by proponents without an application to the CNSC. This includes OPG’s three additional BWRX-300 units as part of the DNNP at the Darlington site [7]; the Province of Ontario and Bruce Power’s consideration of new reactors at the existing Bruce CANDU site to generate an additional 4800 MWe of electricity [8]; SaskPower’s consideration of deploying two BWRX-300 SMRs at one of two potential sites [9]; and additional proposals from new and existing operators at both new and existing sites. These projects are in addition to on-going projects and proposals for refurbishment of the existing CANDU fleet.

## Anticipated Safeguards Challenges

While the consideration of safeguards measures for new small modular and advanced reactors in Canada are still in the early stages, several safeguards implementation challenges have been identified. Any proposed design will likely depart significantly from the safeguards approach at the existing CANDU facilities. The introduction of novels designs and fuels pose a challenge in implementing existing safeguards measures and techniques for the regulator, industry, and the IAEA [10]. These new features of various SMR designs may include the use of low enriched uranium (LEU) fuel, non-itemized reactor facilities (e.g., pebble-bed and molten salt), sealed cores, and sodium coolants. Further, novel methods of deploying and using these types of reactors pose a challenge in implementing existing safeguards approaches. These new methods include remote locations, long operating cycles, fleet approach, non-power applications (e.g., district heating) or even transportable/floating reactors. The CNSC has decades of experience in applying safeguards to CANDU reactors, uranium bulk handling facilities, and research and development, and hope to leverage this knowledge in addressing these novel safeguards challenges.

The early identification of these challenges, especially those relating to the development of new equipment, is critical for the successful implementation of safeguards in the future. The Canadian Safeguards Support Program (CSSP) provides support for the implementation of Canada’s safeguards obligations and provides resources and assistance to the IAEA in order to ensure the successful application of safeguards in Canada and the peaceful use of Canadian-exported nuclear material, technology, and equipment [11]. Originally established in 1977, one of its early tasks was to assist the IAEA in the development of a safeguards approach for the nascent CANDU reactors including equipment for the monitoring and verification of spent fuel movements through the onload facilities. While the CSSP may be able to support the development of new safeguards measures and technology, both sufficient time and resources will be needed to meet these safeguards challenges for new designs.

## Safeguards Regulatory Readiness for SMRs

“Safeguards and Non-proliferation” is one of the CNSC’s fourteen Safety and Control Areas (SCAs). Each SCA includes technical areas and topics, which are selected based on the specific class and activity risks [12]. The SCAs are sorted into three functional areas: management, facility and equipment, and core controls and processes, with “Safeguards and Non-proliferation” falling into the third category. The SCAs framework is used in the CNSC licensing and compliance processes to systematically ensure that applicants and licensees are meeting CNSC requirements and expectations.

The CNSC licensing process for new nuclear facilities typically requires separate applications, CNSC staff reviews, Commission authorizations, and licences, for the phases of site preparation, construction, operation, decommissioning and abandonment. The CNSC’s safeguards requirements evolve through these licensing phases to ensure that Canada can meet its safeguards obligations for IAEA reporting and access.

As per the CNSC regulatory requirements, applicants submit a preliminary Design Information Questionnaire (DIQ) for a proposed facility to the CNSC at the time of their application for a licence to construct. In accordance with the subsidiary arrangements to its safeguards agreement, the CNSC then declares the new facility to the IAEA and initiates discussions on a safeguards approach and measures.

Prior to this step, during the licence to prepare site phase, applicants or licensees have a reduced set of safeguards requirements for providing the applicable information and access to the site. Applicants or licensees are required to provide information to the CNSC on general plans for the succeeding ten-year period relevant to the development of the nuclear fuel cycle (including planned nuclear fuel cycle-related research and development activities) to support Canada’s annual declaration to the IAEA pursuant to Article 2 of the Additional Protocol. Further, applicants or licensees must provide the IAEA with the necessary access to the site for complementary access and associated assistance, particularly if the proposed facility is part of an existing site. Beyond requirements, one of the CNSC’s expectations during this phase is early engagement to prepare the preliminary DIQ to ensure the submission of a correct and complete document at the time of the licence to construct application and to start the considerations and discussions on safeguards-by-design (see below).

During the licence to construct phase – prior to the introduction of nuclear material to the facility – the licensee is additionally required to provide the IAEA inspectors with design information and access to the site to perform design information verifications (DIVs) as construction progresses and to provide further declarations pursuant to the Additional Protocol including an annual update on the description of the site. During this phase, the applicant or licensee is required to make the necessary arrangements for the installation and support of IAEA safeguards equipment. And finally, the licensee is required to submit updates to the DIQ, including a completed DIQ based on preliminary construction plans as early as possible and no later than 270 days before the start of construction.

During the licence to operate phase, the licensee is required to meet all safeguards requirements from the CNSC’s regulatory framework, including those relating to nuclear material accountancy. The licensee is required to provide the IAEA with the necessary information and access to support the agreed safeguards approach and measures for the facility. Regular updates to the DIQ, operational program, and annual Additional Protocol updates provides the IAEA with information on the facility during its operating phase.

Throughout these three phases, and during the subsequent licence to decommission and abandon, CNSC staff ensure that the licensees are meeting requirements and expectations through various compliance activities including inspections. CNSC staff responsible for safeguards review the licensee’s nuclear material accountancy and safeguards-related submissions, participate in IAEA inspections, and undertake other desktop and in-field compliance activities to ensure these requirements are being met. The results of these compliance activities are reported to the Commission during relicensing hearings and annual regulatory oversight reports. This on-going process throughout the facility’s lifecycle ensures the CNSC is meeting its mandate to implement Canada’s safeguards agreements for both new and existing facilities.

## Vendor Design Reviews

One way that the CNSC is preparing for these new reactor designs and considering safeguards needs for these proposed projects is through Vendor Design Reviews (VDRs). VDRs are an optional service provided by the CNSC to vendors under the terms of a service agreement [13]. It’s an opportunity for CNSC staff to confirm that the vendor, through its design documentation, understands Canadian requirements and CNSC expectations, as applicable to novel conditions or novel technologies. It can also help identify any fundamental barriers to licensing early in the process. During this process, there are no regulatory decisions; there is no issuance of a licence; and there is no certification of the design. However, feedback from the CNSC’s technical experts can be used to resolve long lead issues that could become impediments in the licensing process [13].

VDRs are carried out in up to 3 phases, with each phase representing an increasing level of detail in the design. Safeguards are considered as part of Focus Area 15, along with Security and Robustness. These engagements with vendors encourage early consideration of safeguards into the design and its nexus with safety and security. The discussions can help CNSC staff identify potential safeguards challenges in the pre-licensing process and to start discussions with the IAEA on potential safeguards approaches and measures.

A wide variety of types and sizes of small modular and advanced reactors are either under assessment by the CNSC or have been completed. As of mid-2024, there are two on-going Phase 2 assessments: ARC Clean Energy’s ARC-100 and Westinghouse’s eVinci microreactor. To date, the CNSC has completed about a dozen vendor design reviews in various phases. The complete list, including Executive Summaries of the reviews, are available on the CNSC’s website: [Vendor design review ([Vendor design review (cnsc-ccsn.gc.ca)](https://www.cnsc-ccsn.gc.ca/eng/reactors/power-plants/pre-licensing-vendor-design-review/))](https://www.cnsc-ccsn.gc.ca/eng/reactors/power-plants/pre-licensing-vendor-design-review/).

## Safeguards-by-Design in Canada

Separate from, but related to, the VDR process the CNSC implements a second approach for the early safeguards consideration is the application of safeguards-by-design (SBD). SBD is the integration of safeguards considerations into the design process for new or existing facilities from initial planning through the design, construction, operation, and decommissioning phases [10]. The purpose of SBDs is to avoid the need for design modifications or retrofits to address safeguards which can be costly in terms of time and resources.

The engagement on SBD between the State and the IAEA is voluntary and begins before there is a legal requirement to declare the new facility under the safeguards agreements. The CNSC has successfully considered safeguards aspects in the design of new – or modification of existing – facilities or processes for decades [13]. The CNSC encourages vendors and applicants to consider SBD as part of proposed projects through its regulatory framework including its regulatory documents on licence application guides. The process builds awareness amongst all stakeholders around both the design and safeguards requirements.

As part of the Canadian Safeguards Support Program (CSSP), the CNSC accepted the IAEA’s Member State Support Program (MSSP) task on SBD for small modular reactors in 2019. The task aims to identify the key technical challenges for safeguards implementation involving SMRs, and the steps that can be taken to support incorporating SBD principles into the designs. Working with vendors, the CNSC presents safeguards-relevant information about the design to the IAEA for engagement on potential safeguards approaches, equipment and techniques. For each design, the task aims to develop nuclear material accountancy and control strategies; evaluate and test the technical feasibility of safeguards measures; develop safeguards approaches for the SMR; and generate a safeguards technical report (STR).

To date, the CNSC has shared with the IAEA information for three SMR designs – one high-temperature gas cooled and two molten salt reactors – and has initiated discussions with the IAEA on potential safeguards approaches for these designs as part of the overall task [14]. Both virtual and in-person meetings have been held between the vendors and the IAEA, typically involving staff from the divisions responsible for Concepts and Planning, Operations, Information Management, and Technical and Scientific Services. Initial discussions have been productive and have identified several questions that will need to be resolved on potential safeguards approaches and measures for these novel design in Canada. Further discussions are planned between the CNSC, the IAEA and the vendors.

## Challenges and Opportunities

Small modular and advanced reactors will present many challenges and opportunities to the implementation of safeguards in Canada and the CNSC’s regulatory framework:

First, as noted above, CNSC regulatory requirements and expectations for safeguards are defined in the regulatory framework, including in REGDOC-2.13.1, *Safeguards and Nuclear Material Accountancy*. While applicable to all licensing phases, REGDOC-2.13.1 focuses on the requirement for operating facilities. The CNSC’s licence application guides for new reactor facilities (REGDOC-1.1 series) provides additional guidance on the CNSC’s safeguards expectations during each licensing phase, but still relies on the fundamental requirements in REGDOC-2.13.1. As part of the routine review of its regulatory instruments, the CNSC published a discussion paper in April 2024 to outline proposed amendments to its safeguards regulatory document and invited stakeholders and interested parties to provide their thoughts and feedback [15]. Based on this feedback, the CNSC will ensure that there is increased clarity on, among other things, the expectations for each phase of the licensing process for new facilities.

Second, with the vast scope of the various designs being reviewed as part of the VDR process or proposed by vendors – and their significant departure from Canada’s safeguards experience with CANDU reactors – planning when to address novel safeguards issues has been a challenge to the CNSC. This includes when to engage with industry and the IAEA on the development of new safeguards measures and equipment, and how to identify short- versus long-term priorities. Recently, the CNSC has focused first on designs that are part of a licence to construct application and second on designs in Phase 2 of the VDR process once the vendors are ready to engage with the IAEA. However, if more designs are considered and safeguards progress on these designs require more resources (e.g., funding for equipment development), the CNSC will need to remain agile.

Third, the CNSC believes that collaboration and cooperation remain the keys for the successful development and implementation of safeguards. While there has been some engagement with industry on safeguards requirements and expectations, the CNSC can do more to be proactive with vendors and the wider nuclear sector to raise awareness of safeguards. This may include presentation at industry forums, targeted outreach, and additional resources available on the CNSC’s external website. Likewise, the CNSC continues to engage bilaterally with other safeguards regulatory authorities and multilaterally through groups such as the SMR Regulators’ Forum to support and promote the concept of SBD and to share the Canadian experience with safeguards implementation.

## Conclusion

The CNSC will continue to work with the IAEA and the nuclear industry to ensure that safeguards are efficiently and effectively applied in Canada for current and future facilities. The designs under consideration and others being proposed may depart from the established safeguards measures applied to existing CANDU facilities, which may then require the development of new safeguards approaches, measures and techniques. Early engagement and cooperation are some of the keys to overcoming these challenges. The CNSC will continue to promote the application of safeguards-by-design internationally and share its experience and lessons learned during this process.

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References

1. CASTERON, J., KENT, M., “Safeguards in Canada: Some Reflections on the Past, Present, and Future”, Paper No. 262, paper presented at 48th Annual Meeting of the Institute of Nuclear Materials Management (INMM 2007), Tucson, Arizona, 2007.
2. Three-Power Declaration on Atomic Energy. *Nature* 156**,**615 (1945), <https://www.nature.com/articles/156615a0>
3. Canadian Nuclear Safety Commission, Our Mission (2024), <https://www.cnsc-ccsn.gc.ca/eng/about-us/our-mission/>
4. SARAVANABAVAN, S., McLAUGHLIN, M., “An Idealized Approach to Supporting IAEA Complementary Accesses - The Canadian Experience”, paper presented at the INMM & ESARDA Joint Annual Meeting, Vienna, Austria (2023).
5. Canada Energy Regulator, Provincial and Territorial Energy Profiles – Canada (2024), <https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/provincial-territorial-energy-profiles-canada.html>
6. Canadian Nuclear Safety Commission, New reactor facility projects (2024), <https://www.cnsc-ccsn.gc.ca/eng/reactors/power-plants/new-reactor-facilities/>
7. Ontario Power Generation, Nuclear Projects: Small Modular Reactors (2024), <https://www.opg.com/projects-services/projects/nuclear/smr/>
8. Government of Ontario, Province Starts Pre-Development Work for New Nuclear Generation to Power Ontario’s Growth (2024), <https://news.ontario.ca/en/release/1003240/province-starts-pre-development-work-for-new-nuclear-generation-to-power-ontarios-growth>
9. SaskPower, Planning for Nuclear Power (2024), <https://engage.saskpower.com/planning-for-nuclear-power>
10. WHITLOCK, J., “Safeguards by Design: Nuclear Industry’s Role in the Efficient Implementation of International Safeguards,” INMM & ESARDA Joint 2023 Annual Meeting, Vienna, Austria (2023).
11. McLAUGHLIN, M. “45 Years of Advancing Safeguards through the Canadian Safeguards Support Program,” paper presented at the Symposium on International Safeguards: Reflecting on the Past and Anticipating the Future, Vienna, Austria, 2022.
12. Canadian Nuclear Safety Commission, Safety and Control Areas (2024), <https://www.cnsc-ccsn.gc.ca/eng/resources/news-room/feature-articles/safety-and-control-areas/>
13. Canadian Nuclear Safety Commission, Vendor Design Reviews (2024), <https://www.cnsc-ccsn.gc.ca/eng/reactors/power-plants/pre-licensing-vendor-design-review/>
14. GAO, H., NGUYEN, H. “Canada’s Experience in Safeguards-by-Design,” paper presented at the Symposium on International Safeguards: Reflecting on the Past and Anticipating the Future, Vienna, Austria, 2022.
15. Canadian Nuclear Safety Commission, Discussion Paper DIS-24-03, Proposal to amend REGDOC-2.13.1, Safeguards and Nuclear Material Accountancy (2024), <https://letstalknuclearsafety.ca/discussion-paper-dis-24-03-proposal-amend-regdoc-2131-safeguards-and-nuclear-material-accountancy-0>

BIBLIOGRAPHY

CANADIAN NUCLEAR SAFETY COMMISSION, “REGDOC-2.13.1, Safeguards and Nuclear Material Accountancy,” <https://www.cnsc-ccsn.gc.ca/eng/acts-and-regulations/regulatory-documents/published/html/regdoc2-13-1/>

Small Modular Reactor Regulators’ Forum, “Safety, Security and Safeguards from a Regulatory Perspective: An Integrated Approach,” Working Group on Design and Safety Analysis Phase 3 Report, <https://www.iaea.org/sites/default/files/24/02/smr_rf_phase_3_report_-_safety_security_and_safeguards_from_a_regulatory_perspective_an_integrated_approach.pdf>