



Advanced Reactor Projects in Canada: Regulatory Status and Perspectives

Advanced Reactors Technical Summit VI & Technology Trailblazers Showcase

January 30, 2019

University of California San Diego, U.S.

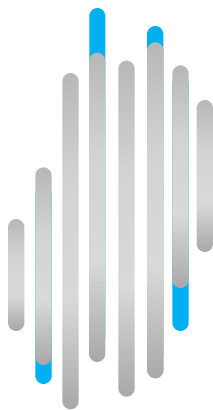
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Outline



- Canadian status
- New technologies
- Regulatory readiness
- Vendor design reviews



CANADIAN STATUS



Provincial and Territorial Activities

- Ontario Ministry of Energy sponsored the report *Feasibility of the Potential Deployment of Small Modular Reactors (SMRs) in Ontario*
- Established electrical utilities
 - are interested in becoming SMR operators in Canada
 - are providing advice to SMR vendors
 - have introduced a new CANDU Owners Group (COG) forum to discuss SMR issues
- New Brunswick: establishment of nuclear cluster to support research and development of SMRs



Canadian Nuclear Laboratories (CNL) Activities

Positioning itself to provide science and technology services

- Engaged with SMR vendors for a wide range of activities
- Stated goal to “host an SMR on a CNL site by 2026”

Request for expression of interest: CNL’s SMR strategy

- To better understand market demands for activities related to SMRs
- Vendor, utility, and provincial government interest

CNL’s invitation for SMR demonstration projects

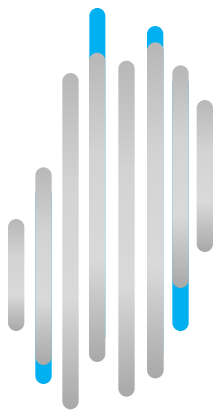
- A number of proponents responded



Federal Activities

- Government of Canada responds to House of Commons Standing Committee report agreeing to support the development of SMRs (October 2017)
- Natural Resources Canada facilitated the *Canadian SMR Roadmap*
 - report published November 2018
 - concluded that regulatory framework and waste management regime well positioned to respond to SMR paradigm
 - still a need for continuous improvements to adapt to new reactor technologies and deployment





NEW ADVANCED REACTORS



What We Know Is Coming: Newer Designs

The CNSC is reviewing various SMR designs, several of which feature

- non-traditional fuel
- operation in the fast neutron spectrum
- gas, light water, or liquid metal cooling
- longer fuel cycles
- non-traditional deployment models
- modular construction
- transportable reactors
- security by design



**NEW DESIGNS
BRING NEW
INNOVATION**

Regulatory Considerations: Fuel

Innovative types of fuels are being proposed

- Liquid fuels
- Metallic fuels
- Molten salt fuel

Non-traditional fuel cycles

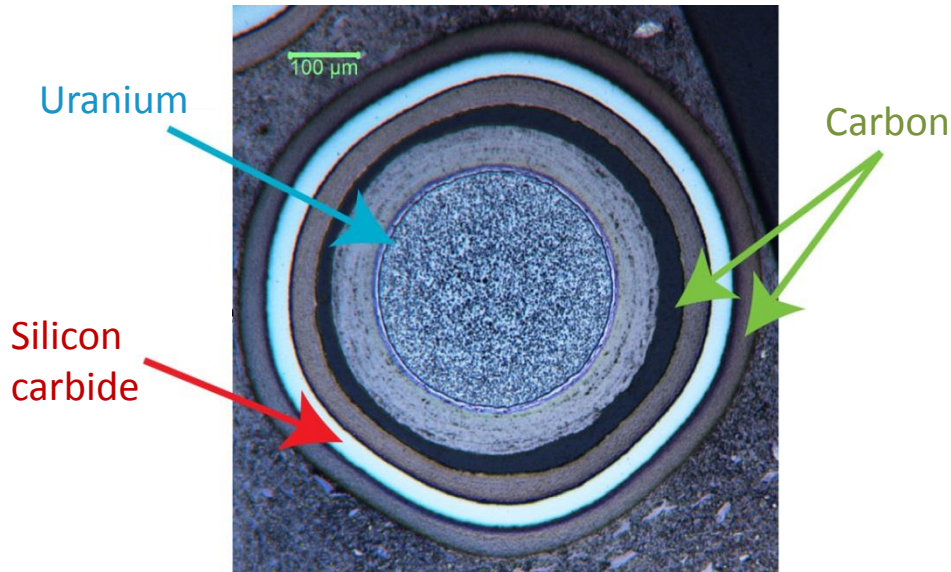
- Proposed refuelling times being extended
- Some designs have no provisions for refuelling
- Gaps in fuel qualification
 - some fuels have not been fully tested at the proposed power/radiation levels and time periods outlined in new designs
- Burner and breeder reactors

Long-term fuel storage

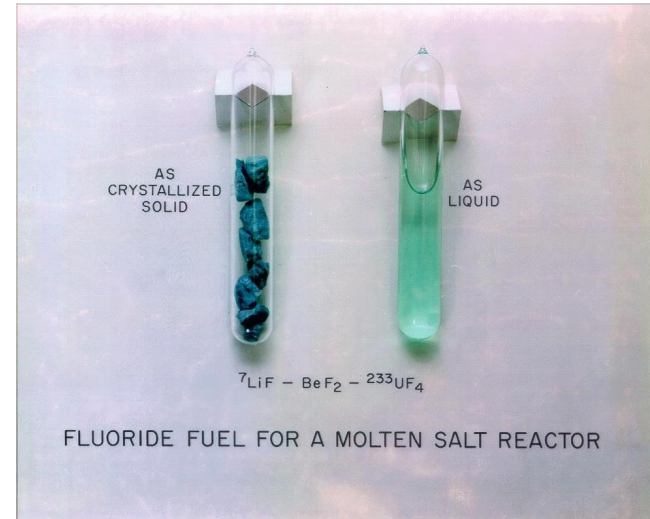
- New fuels could challenge the designs of long-term fuel storage facilities

Advanced Designs

Non-Traditional Fuel



TRISO fuel for a high-temperature gas reactor



Fluoride-based salt with suspended uranium fuel for a molten salt reactor

Regulatory Considerations:

Reactor Design, Operation, Control and Shutdown

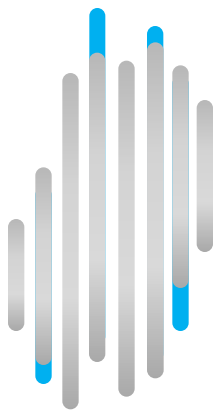
- Strong negative coefficients of reactivity with temperature
- Reducing the likelihood of the occurrence or progression of accident scenarios
 - e.g., better fission product retention in fuel
 - designs with fewer accident paths
- Inherent safety features
- Self-regulation of power
- Passive shutdown for design-basis accidents
- Fission product retention in fuel matrix
- Automatic passive heat removal in all modes of operation



Regulatory Considerations:

Digital Instrumentation and Control

- New generation of control systems
 - more control being given to automated systems
- Operating models may be different:
 - remote monitoring
 - reduced staffing
 - glass control rooms
 - multi-site monitoring
- Aging management and continuous improvements
 - component lifetimes



REGULATORY READINESS



Impact of Technology on Regulatory Framework



Early prototype reactors
(NPD, Douglas Point)



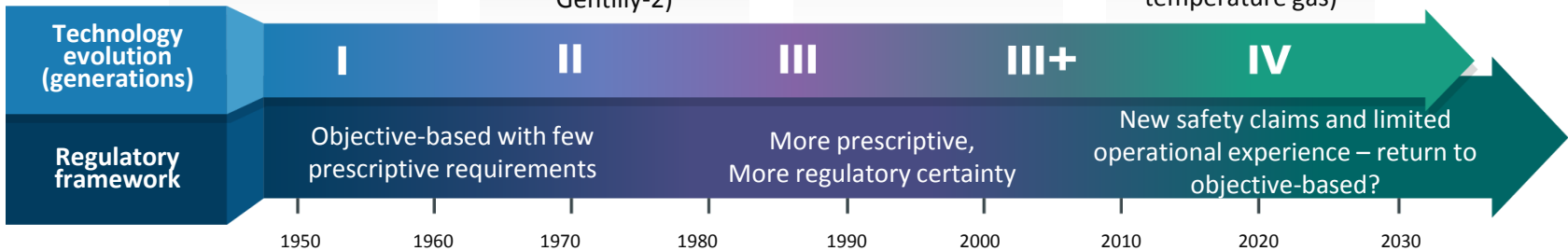
Commercial power reactors
(Pickering, Darlington, Bruce, Point Lepreau, Gentilly-2)



Advanced water + evolutionary designs
(EC-6, ACR 1000)



Revolutionary designs
(molten salt, liquid metal, high temperature gas)



Regulatory Readiness

Stay flexible to technological developments

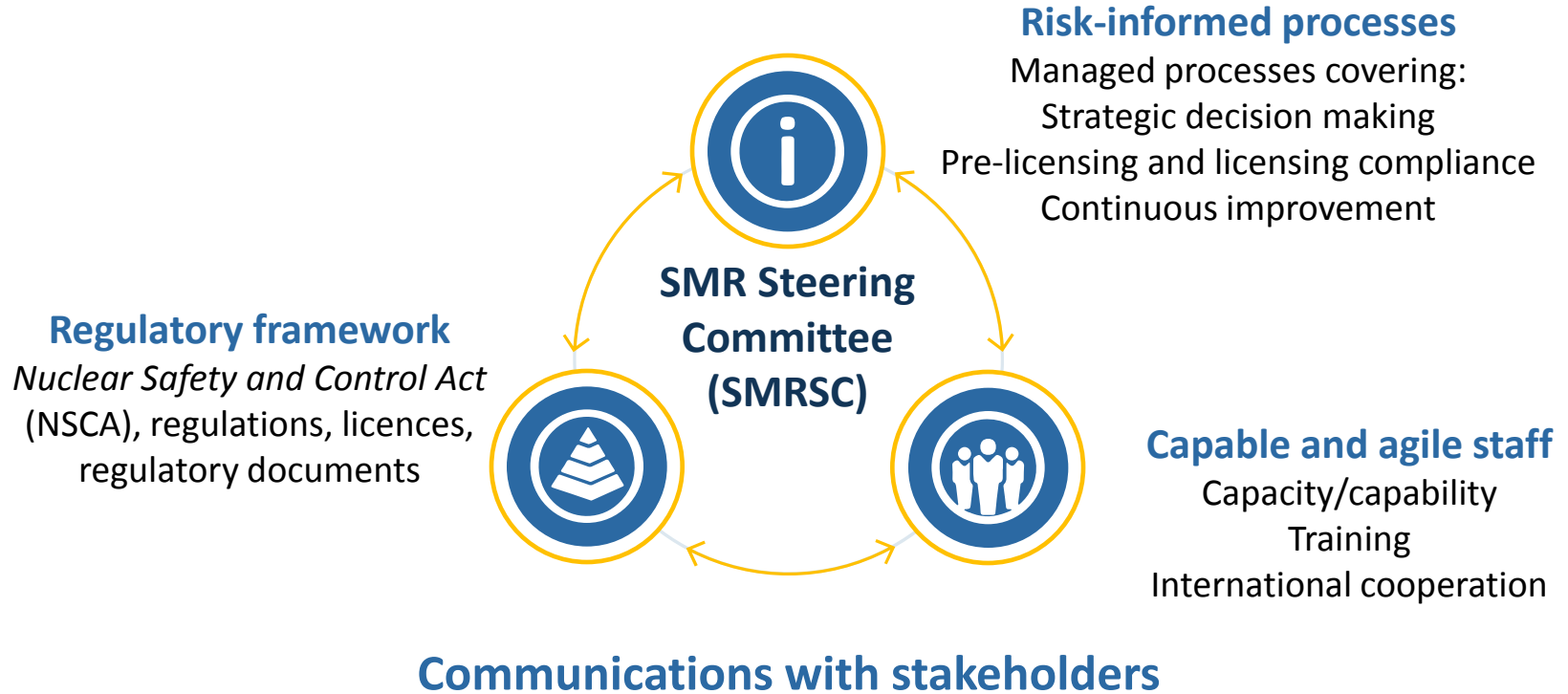
- Allow testing and development with appropriate safety margins

Be responsive to evolving expectations and trends

- Continuous effort to maintain and modernize regulatory framework

**THE LICENSEE IS
RESPONSIBLE FOR
SUPPORTING SAFETY
CLAIMS
WITH SUITABLE
EVIDENCE**

Elements of Regulatory Readiness Strategy



Availability of Pre-Licensing Processes

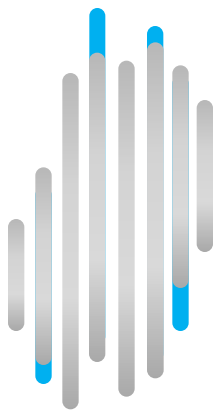
Pre-licensing vendor design review (VDR) process

- Assessment of a nuclear power plant design based on a vendor's reactor technology
- Objective is to verify the acceptability of a nuclear power plant design with respect to Canadian nuclear regulatory requirements, codes and standards (it is not a certification process)

Determining the licensing strategy for novel applications

- Process to inform applicants of expectations regarding information to be submitted in support of the licensing process



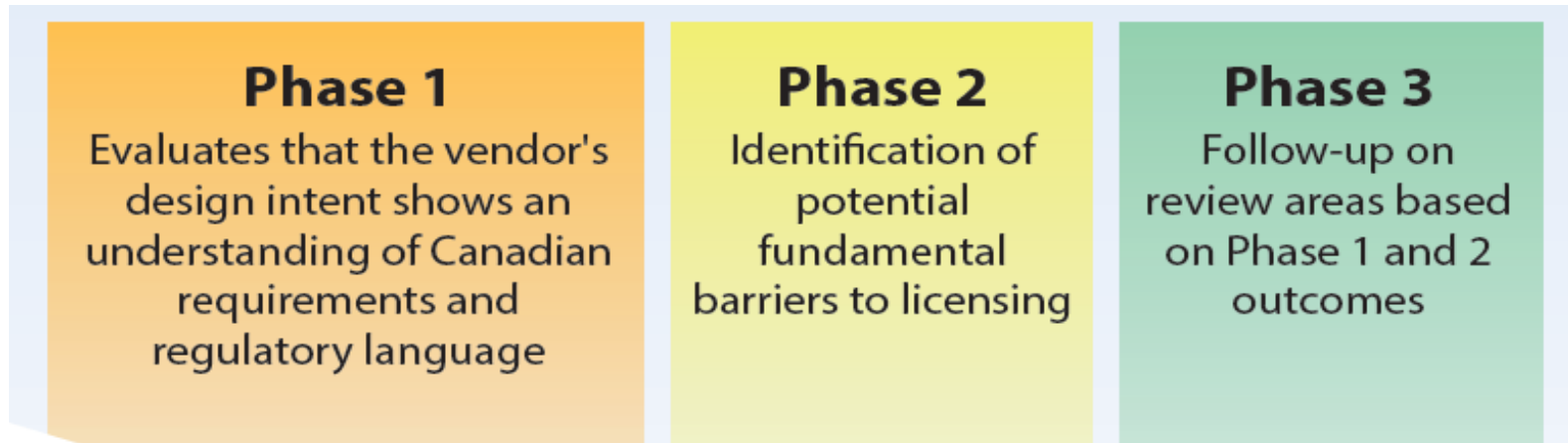


VENDOR DESIGN REVIEWS



Vendor Design Review Phases

VDRs are conducted in three phases of increasing review depth, and evaluate 19 cross-cutting design and safety analysis areas, as follows:



Vendor Design Reviews

| VDR no. | Country of origin | Company | Reactor type / output per unit | VDR status |
|---------|---------------------|--|---|--|
| 1 | Canada / U.S. | Terrestrial Energy | Molten salt integral / 200 MWe | Phase 1 completed, Phase 2 in progress |
| 2 | U.S. /Korea / China | UltraSafe Nuclear / Global First Power | High-temperature gas prismatic block / 5 MWe | Phase 1 in progress completion date winter 2019 Phase 2 service agreement established |
| 3 | Sweden/Canada | LeadCold | Molten lead pool fast spectrum / 3–10 MWe | Phase 1 on hold at vendor request |
| 4 | U.S. | Advanced Reactor Concepts | Sodium pool fast spectrum /100 MWe | Phase 1 in progress |
| 5 | U.K. | U-Battery | High temperature gas prismatic block / 4 MWe | Phase 1 service agreement under development |
| 6 | U.K. | Moltex Energy | Molten salt fast spectrum / ~300 MWe | Phase 1 in progress |
| 7 | Canada/U.S. | StarCore Nuclear | High-temperature gas prismatic block / 10 MWe | Phase 1 and 2 service agreement under development |
| 8 | U.S. | SMR, LLC. (A Holtec International Company) | Pressurized water / 160 MWe | Phase 1 in progress |
| 9 | U.S. | NuScale Power | Integral pressurized water / 50 MWe | Phase 2* service agreement established |
| 10 | U.S. | Westinghouse Electric Co. | eVinci micro reactor / < 25 MWe | Phase 2* service agreement under development |

* Phase 1 objectives will be addressed within the Phase 2 scope of work

Vendor Design Review Benefits

| Vendor | Potential applicant | CNSC |
|---|--|--|
| <ul style="list-style-type: none">• Gains a better understanding of the regulatory requirements and process• Understands which aspects of their proposal may trigger additional regulatory scrutiny and can consider whether scaling their proposal is desirable• Provides the vendor with information that can be used when holding discussions with a potential applicant | <ul style="list-style-type: none">• Helps ensure an efficient and effective licensing process• Identify and address regulatory issues early enough so that delays in licensing and facility construction can be minimized | <ul style="list-style-type: none">• Leads to higher-quality licence applications• Aids CNSC staff with readiness for licence applications |

International Collaboration on SMRs

The CNSC and Government of Canada are cooperating and sharing information with a number of countries on SMR technologies

- Working closely with the International Atomic Energy Agency and the Nuclear Energy Agency on sharing best practices in the regulation of SMRs
- Working bilaterally with a number of countries (e.g., United States, United Kingdom)
- Leveraging the experience of others – CNSC technical review can be informed by other regulators' assessments



Challenges of New Advanced Reactors

- Transparency and dissemination of scientific information
- Stakeholders' acceptance of these new technologies
 - as a viable part of carbon-free energy mix
 - of inherent safety aspects of the design
- Technologies not yet proven
 - most designs still at the conceptual stage
 - limited global operating experience
 - utilities will need further confirmatory evidence before buying in

What Can Industry Do?

- Support the design and safety analysis with adequate research and development activities
 - well structured and appropriately quality-assured
 - contribute to international benchmarking through international safety standards
- Participate in harmonization of engineering safety standards
 - defence in depth and safety analysis
 - risk-informed approaches
 - international analytical code to code benchmarks
- Improve the supply chain capability in both design and deployment

Conclusion

Current regulatory framework in Canada

- Is suitable for licensing projects using advanced technologies as it provides flexibility to adapt to new types of reactors, and is backed by solid management system processes and a capable workforce
- Is ready to address disruptive technologies
- Provides flexibility for licensees to propose alternative means of meeting legal requirements, where appropriate

Thank you!



APPENDIX



Vendor Design Reviews

Vendor Design Review Topic Areas

- 1 General plant description, defence in depth, safety goals and objectives, dose acceptance criteria
- 2 Classification of structures, systems and components
- 3 Reactor core nuclear design
- 4 Fuel design and qualification
- 5 Control system and facilities
- 6 Means of reactor shutdown
- 7 Emergency core cooling and emergency heat removal systems
- 8 Containment/confinement and safety-important civil structures
- 9 Beyond-design-basis accidents and severe accidents
- 10 Safety analysis (probabilistic safety analysis, deterministic safety analysis, hazards)
- 11 Pressure boundary design
- 12 Fire protection
- 13 Radiation protection
- 14 Out-of-core criticality
- 15 Robustness, safeguards and security
- 16 Vendor research and development program
- 17 Management system of design process and quality assurance in design and safety analysis
- 18 Human factors
- 19 Incorporation of decommissioning in design considerations

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