



April 30, 2012

**Phase 2 Executive Summary:
Pre-Project Design Review of Candu Energy
Enhanced CANDU 6 Reactor — EC6**



Executive Summary

A vendor pre-project design review of a new nuclear power plant provides an opportunity for the CNSC staff to assess a design prior to any licensing activities, and to identify potential issues that would require resolution. Phase 1 of a pre-project review determines if the design intent is compliant with CNSC requirements and expectations. Phase 2 goes into further detail to examine if there are any potential fundamental barriers to licensing. The CNSC completed a Phase 1 review of the Candu Energy Inc.¹ Enhanced CANDU-6 reactor (EC6[®]) design in March 2010, and concluded that, at an overall level, the design intent complied with the CNSC's regulatory requirements and expectations. A recently completed Phase 2 review of the EC6 design provides a further level of assurance that Candu Energy has taken regulatory requirements and expectations into account. Based on the Phase 2 review, CNSC staff concludes that there are no fundamental barriers to licensing the EC6 design in Canada. It should be noted that this is subject to the successful completion of Candu Energy's planned activities for EC6, in particular those related to severe accidents, research and development, and Candu Energy's response to the Fukushima Daiichi accident, and the related CNSC Action Plan.

1.0 Background

1.1 Introduction

The Canadian Nuclear Safety Commission (CNSC) is Canada's sole nuclear regulatory agency and operates under the *Nuclear Safety and Control Act* (NSCA). The CNSC regulates the use of nuclear energy and materials to protect the health, safety and security of Canadians and the environment, and to respect Canada's international commitments on the peaceful use of nuclear energy.

A vendor pre-project design review is a high-level assessment of a vendor's proposed reactor technology. It is an optional service provided by the CNSC when requested by a vendor. This service does not involve the issuance of a license under the NSCA and it is not part of the licensing process. The conclusions of such reviews will not bind or otherwise influence decisions made by the Commission Tribunal.

The review is solely intended to provide early feedback on the acceptability of a nuclear power plant (NPP) design based on Canadian regulatory requirements and expectations. The CNSC will

¹ On October 2, 2011, SNC-Lavalin Group Inc. acquired certain assets of AECL's commercial operations. The business operates as a wholly owned subsidiary called Candu Energy Inc.

require a much more detailed review of the design and safety case for a specific application for a license to construct a nuclear power plant at a specific site.

Candu Energy, a vendor of nuclear power plants, is designing a two-unit EC6[®] NPP, each unit with a gross electrical output of 740 megawatts. The EC6 design is largely based on the design concept and the reactor and process system designs of current CANDU plants. Despite these similarities, there are some significant differences between the EC6 design and existing CANDU technologies. At this time, the EC6 design is being developed for a generic site.

The EC6 design project has three stages: Product Definition Stage, Design Change Engineering Program (current stage), and Project Final Design.

In January 2009, Atomic Energy of Canada Ltd. (AECL) requested the CNSC to perform a Phase 1 pre-project design review of the EC6 design, and a Service Agreement was then signed between the two organizations. The Service Agreement outlines the objectives, the technical scope of the review, the schedule guideline, the organizations' deliverables, costs, working arrangements and general conditions.

In April 2011, AECL and CNSC signed a Service Agreement for a Phase 2 review. The Service Agreement was subsequently amended and signed between the CNSC and Candu Energy. to complete the Phase 2 review for EC6.

1.2 Design Review Objectives

The objectives of a pre-project design review are to:

- Assess whether a proposed reactor design is, at an overall level, compliant with the CNSC regulatory requirements;
- Assess whether the design provisions for selected review topics meet the CNSC's expectations for new nuclear power plants in Canada; and
- Identify, based on the review of the review topics, any potential fundamental barriers to licensing of a proposed reactor design in Canada.

A vendor pre-project design review provides an opportunity for the CNSC staff to assess the design prior to any licensing activities, and to identify potential issues for resolution related to the compliance of the design with regulatory requirements and expectations. Such a review will help increase regulatory certainty and ultimately contribute to public safety.

1.3 Design Review Phases

The pre-project design review process is divided into three phases:

- **Phase 1: Assessment of Compliance with Regulatory Requirements.** This phase is an overall assessment of the information submitted in support of a reactor design against the CNSC regulatory requirements and regulatory documents. Its purpose is to determine whether the design intent is compliant with CNSC requirements and meets the CNSC’s expectations for the design of new nuclear power plants in Canada.
- **Phase 2: Identification of Fundamental Barriers to Licensing.** Subsequent to Phase 1, this phase goes into further detail with a focus on identifying whether there are any potential fundamental barriers to licensing the reactor design in Canada. It should be noted that the findings from Phase 1 review do not in any way prejudice the conclusions of Phase 2 review.
- **Phase 3:** A follow up to Phase 2, this phase focuses on a more detailed review of selected topics identified by the vendor.

The Phase 2 pre-project design review for the EC6 is now complete and key findings are provided below.

1.4 Definition of Fundamental Barriers to Licensing

CNSC staff considers a fundamental barrier to licensing a new reactor design as a shortcoming in the design or the design process that, if not corrected, could have the potential for significant risk to the public or to workers. The barrier is considered fundamental when there is no clear and adequate path to resolution of a significant safety issue. The barrier would also be considered to be fundamental if there were significant uncertainties associated with the proposed plan or if the timeline was such that it could be unresolved at the time of an application for a license to construct.

Given this definition, CNSC staff considers the following as barriers to licensing a nuclear power plant design in Canada:

- Non-compliance with Canadian legal requirements;
- Unjustified non-conformance with Canadian regulatory expectations including those in the regulatory document “Design of New Nuclear Power Plants” (RD-337) or other applicable regulatory documents and national standards for design and analysis;
- Unjustified non-compliance with design and safety analysis Quality Assurance (QA) standards and procedures;
- A design that does not address known issues of safety significance, i.e., the design has not taken into account resolution of safety concerns from past regulatory reviews;
- A design that does not meet the ALARA (As Low As Reasonably Achievable) principle for radiation protection;

- Unproven engineering practices for new or innovative design features; and
- A design for which operational compliance introduces unacceptable operational complexity.

2.0 Phase 2 Review

2.1 Phase 2 Review Process and Selected Review Topics

To facilitate the Phase 2 review, Candu Energy submitted documentation in support of the EC6 design including documents demonstrating how the NPP design meets the regulatory requirements and expectations of the CNSC. The principal document is the interim Preliminary Safety Analysis Report for a generic site. The supporting documents include the Safety Design Guides, Design Guides, Design Manuals, Design Analysis, and other design documents. Additional information was submitted as requested by CNSC staff in support of the review.

In performing the Phase 2 review, the CNSC staff aimed to identify: items requiring further information; items requiring further follow-up; issues for which there was clear non-conformance with regulatory expectations; or issues that could lead to potential fundamental barriers.

The CNSC staff selected 19 review topics to assess the EC6 design, as listed below. The topics were reviewed to confirm that fundamental safety functions — such as reactor control, reactor shutdown, reactor core cooling, and confinement of radioactive material — are provided by the design. The design also needed to meet CNSC’s regulatory requirements and expectations for new nuclear power plants.

Review topics:

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| • Defense in depth, safety goals and objectives, dose acceptance criteria | • Safety analysis |
| • Classification of Systems Structures and Components | • Pressure boundary |
| • Reactor core nuclear design | • Fire protection |
| • Fuel design and qualification | • Radiation protection |
| • Control system and facilities | • Out-of-core criticality |
| • Means of reactor shutdown | • Robustness, safeguards, and security |
| • Emergency core cooling and emergency heat removal systems | • Vendor’s research and development program |
| • Containment and safety important civil structures | • Management system of design process and QA in design and safety analysis |
| • BDBA and severe accident prevention and mitigation | • Human factors |
| | • Incorporation of decommissioning into design considerations |

Another topic was added to the standard set of review topics - the implications for the design as a result of lessons learned from the nuclear accident at Fukushima Daiichi on March 11, 2011. It is expected by the CNSC that reactor vendors identify lessons learned from this event on an ongoing basis and modify their designs as needed.

CNSC staff paid particular attention to: (i) the knowledge of the new or innovative design features and the extent to which outstanding safety issues and generic action items for the existing CANDU technology have been resolved for the EC6 design, including provision for the associated research and development program, and (ii) design provisions for severe accident prevention and mitigation. CNSC staff expects a research and development program to support any new or different features as compared to existing CANDU technology so that their adequate safety is demonstrated.

The review results were ranked using the following scheme:

- *Potential Fundamental Barriers to Licensing* (defined in Section 1.4);
- *Key Findings*, defined as:
 - exceptions from CNSC regulatory expectations contained in regulatory documents such as RD-337, RD-310; and
 - lack of supporting information on conformance with CNSC design expectations or cases when regulatory requirements/expectations are met with small margins (e.g. detailed analysis is required and cannot be performed during the pre-project review).
- *Technical Clarification*, defined as:
 - lack of information due to supporting documents that have not been submitted;
 - concerns about completeness/sufficiency/quality of submitted documents; and
 - concerns about a particular minor technical aspect of the design.

In addition, CNSC staff conducted an audit of the design process that Candu Energy is using for the EC6 design. This was done to verify that the design process is being implemented correctly and in accordance with Candu Energy's policies and procedures.

2.2 Phase 2 Design Review Criteria

To assess the review topics, CNSC staff primarily used the same set of criteria as in the Phase 1 review. These criteria are stated in regulatory document "Design of New Nuclear Power Plants" (RD-337) — a document providing technology-neutral design expectations. A limited number of review topics were also assessed against some specific Canadian regulatory documents and standards such as the *Radiation Protection Regulations*, the regulatory document *Safety Analysis*

for Nuclear Power Plants (RD-310), and the Canadian national standard Design Quality Assurance for Nuclear Power Plants (CSA N286.2).

2.3 Other Phase 2 Design Review Considerations

CNSC Phase 2 review of the EC6 reactor was a pre-project assessment of a design which is currently in progress and for which certain details have yet to be finalised and confirmed. The issues raised by CNSC staff in the EC6 Phase 1 review have been closed by addressing them in Phase 2 review process.

The EC6 is based upon the proven CANDU 6 design and incorporates features common to many CANDU designs that have been operating successfully both in Canada and abroad. The reference design of the EC6 is the Qinshan CANDU 6 NPP, designed in the late 1990s by AECL.

Even though EC6 is an evolutionary design, CNSC staff considers it to be a new nuclear power plant and as such, modern requirements and expectation are applicable. These include CNSC regulatory documents for design and analysis of new NPPs (for example, RD-337, RD-310 and S-294), and modern codes and standards (for example, the most recent versions of CSA standards).

Candu Energy has introduced many changes to the current Qinshan CANDU 6 design so that the EC6 design can satisfy modern expectations for the design and analysis of new NPPs.

In its Phase 2 review, CNSC staff paid particular attention to each of the review topics where:

- RD-337, RD-310 and S-294 set expectations higher than or departing from past practice. Examples include the adoption of safety goals, application of the single failure criterion for the safety systems and safety support systems, the principles of inherent and passive safety features to minimize sensitivity to events, the complementary design features, the reactor control system designed to respond to anticipated operational occurrences, the containment designed to address severe accidents, and equipment performance during beyond design basis accidents;
- The design changes, new design features and provisions are introduced into the EC6 design to meet the most recent design expectations. The review focus was to confirm that there is a link to the proposed EC6 research and development program and plans for testing and analysis to prove the adequacy of such new features and provisions; and
- Outstanding safety issues and generic action items for the existing CANDU technology are implicated.

2.4 Phase 2 Design Review Results

CNSC staff acknowledges that, throughout the Phase 2 review, Candu Energy staff was open and transparent in sharing available information, and that it responded diligently to every CNSC request for clarification and additional information.

The *Key Findings* resulting from the Phase 2 review can be summarized as follows:

- Improvement is needed in the assessment of the small and large release frequencies in view of the Fukushima Daiichi accident;
- A more rigorous safety classification and process for the design of Systems Structures and Components (table in Section 2.1) should be developed;
- Application of the RD-337 single failure criterion regulatory requirement to certain aspects of the safety systems design as well as to the deterministic safety analyses requires further justification;
- Some design aspects of the severe accident prevention and mitigation are at an early stage and need to be completed;
- More information supporting the conformance of the EC6 design with the CNSC's design expectations related to design basis and beyond design basis threats is needed;
- The research and development program should be improved in the area of addressing the outstanding safety issues and generic action items for the existing CANDU technology together with the information on the program implementation status and schedule; and
- Selected quality assurance issues related to the design process require improvements.

It should be noted that Candu Energy is at an intermediate stage (Design Change Engineering Program: DCEP) of implementing changes to the reference Qinshan NPP for the EC6 design. Some key design and analysis documentation specific to the EC6 design was made available to CNSC staff. The interim Preliminary Safety Analysis Report (iPSAR), which summarizes the EC6 safety design features and some bounding/limiting safety analyses, was made available to CNSC staff. Other supporting assessments, analyses and documentation specific to EC6 are still being developed and were not available to CNSC staff during this Phase 2 review.

2.5 Phase 2 Design Review Conclusions

In summary, based on the review of the 19 review topics, CNSC staff concludes that there are no fundamental barriers to licensing the EC6 design in Canada. It should be noted that this conclusion is subject to the successful disposition by Candu Energy of the review findings (in section 2.4) as well as completion of Candu Energy's planned activities for the EC6, in particular those related to research and development. CNSC staff is of the opinion that these findings can be resolved during a Construction License Application design review.

This overall conclusion was based on the following:

- CNSC staff's review of the 19 review topics did not identify any fundamental barriers to licensing the EC6 design in Canada, subject to timely completion of research and development program and the resolution of the *Key Findings* and *Technical Clarifications* in the review topics. CNSC staff has provided detailed comments in each of the 19 review areas and these comments are related to work that CNSC staff would expect to be completed before an application for a construction license is made by the CNSC's Commission Tribunal. Although these comments do not constitute any potential fundamental barriers, CNSC staff considers that they need to be addressed to confirm actual implementation of CNSC expectations;
- CNSC staff expects the resolution of the *Key Findings* and *Technical Clarifications* in the review topics during Construction License Application design reviews. In particular:
 - The minor and therefore not listed here review results categorized under *Technical Clarification* will be eliminated once detailed design is completed;
 - The review results categorized under *Key Findings* are expected to be resolved through completion of detailed design given that the path forward towards their resolution has been established during the Phase 2 review;
 - With respect to Fukushima-Daiichi accident lessons learned and severe accident prevention and mitigation further discussions between CNSC and Candu Energy are planned for Phase 3 and Construction License Application EC6 design reviews.