



June 2013

Phase 3 Executive Summary
**Pre-Project Design Review of
Candu Energy Inc. Enhanced
CANDU 6 Design**



Executive Summary

A vendor pre-project design review of a new nuclear power plant provides an opportunity for 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. In Phase 3, the vendor chooses to follow up on specific aspects of the Phase 2 review findings. The objective of Phase 3 is for CNSC staff to follow up on the implementation of some of the vendor's planned activities for selected review topics, and to assess the progress that the vendor is making towards the completion of these activities. Such a review will increase the efficiency of the CNSC's assessment of a construction licence application and will contribute to the vendor's regulatory certainty.

The CNSC completed a Phase 1 review of the Candu Energy Inc. Enhanced CANDU 6 reactor (EC6^{®1}) design in March 2010, and concluded that, at an overall level, the design intent complied with the CNSC's regulatory requirements and expectations. In April 2012, the CNSC completed a Phase 2 review of the EC6[®] design. The Phase 2 review provided a further level of assurance that Candu Energy has taken regulatory requirements and expectations into account. Based on the Phase 2 review, CNSC staff determined that there were no fundamental barriers to licensing the EC6[®] design in Canada.

A recently completed Phase 3 review of the EC6[®] design provided a higher level of assurance that Candu Energy has taken regulatory requirements and expectations into account and further confirmed 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 commitments with respect to each review topic.

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

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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 design based on Canadian regulatory requirements and expectations. The CNSC will 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 (Candu), a vendor of nuclear power plants, is designing a two-unit EC6[®] nuclear power plant, where each unit has a gross electrical output of 740 megawatts. The EC6[®] design is largely based on the design concept and reactor and process system designs of currently operating 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 June 2012, Candu and CNSC signed a Service Agreement for a Phase 3 review. The Service Agreement outlines the objectives, the technical scope of the review, the schedule guideline, the organizations' deliverables, costs, working arrangements and general conditions.

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
- 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 CNSC staff to assess the design prior to any licensing activities, and to identify for resolution any 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 prejudge 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 3 pre-project design review for the EC6[®] is now complete and key findings are provided in the pages that follow.

1.4 Definition of Fundamental Barriers to Licensing

CNSC staff consider *fundamental barriers to licensing* a new reactor design as shortcomings 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 barriers are considered fundamental when there is no clear and adequate path to resolution of a significant safety issues. The barriers 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 consider 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 *RD-337: Design of New Nuclear Power Plants* 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
- a design for which operational compliance introduces unacceptable operational complexity

2.0 Phase 3 Review

2.1 Phase 3 Review Process and Selected Review Topics

Based on the results of the EC6[®] Phase 2 pre-project review, Candu selected the following topics for the Phase 3 review:

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| • Classification of Structures, Systems and Components | • Safety Analysis |
| • Fuel Design and Qualification | • Radiation Protection |
| • Control System and Facilities | • Robustness, Safeguards, and Security |
| • Emergency Core Cooling and Emergency Heat Removal Systems | • Vendor's Research and Development Program |
| • Containment and Safety Important Civil Structure | • Addressing Fukushima Lessons Learned in EC6 [®] Design |
| • BDBA and Severe Accident Prevention and Mitigation | • Extreme Severe Accidents |

These topics are, in general terms, related to

- a new methodology
- a new application of a methodology
- Research and Development related to new design/analysis
- lessons learned from Fukushima Dai-ichi accident or topics characterized by a significant licensing risk.

As mutually agreed, the topic of Extreme Severe Accidents was not included in the Phase 3 Report. A high level summary of the findings for this special topic will be provided to Candu separately.

In addition to the technical follow-up on the selected findings from the Phase 2 review, the Phase 3 review was expanded at Candu's request to obtain a regulatory feedback from CNSC on the applicable interpretations of the specific RD-337 requirements.

To facilitate the Phase 3 review, Candu submitted documentation in support of the EC6[®] design demonstrating how the nuclear power plant design for each review topic meets the regulatory requirements and expectations of the CNSC. In addition, Candu provided additional information requested by CNSC staff on an as-needed basis and held several familiarization sessions on the details of the EC6[®] design. As a result, many technical meetings were held so that Candu could respond to CNSC staff questions and comments as well as pursue specific technical aspects for the individual topical areas.

As in the Phase 2 review, during Phase 3, 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
- (ii) design provisions for severe accident prevention and mitigation. CNSC staff expect 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 same scheme used in the Phase 2 review:

- *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
 - 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
 - concerns about a particular minor technical aspect of the design

2.2 Phase 3 Design Review Criteria

The review was centered on the compliance assessment against criteria of the applicable regulatory requirements. To ensure the consistency of the assessment, CNSC staff primarily used the same set

of criteria as in Phase 1 and Phase 2 reviews. These criteria are stated in *RD-337: Design of New Nuclear Power Plants*, which provides 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* or the regulatory document *RD-310: Safety Analysis for Nuclear Power Plants*.

2.3 Other Phase 3 Design Review Considerations

The CNSC's Phase 3 review of the EC6[®] reactor design was a pre-project assessment of a design that is currently in progress and for which certain details have yet to be finalized. The issues raised by CNSC staff in the EC6[®] Phase 1 review have been closed by addressing them in Phase 2 review process. Similarly, the new issues raised in Phase 2 review have been addressed in Phase 3 review.

The EC6[®] design 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 nuclear power plant, designed in the late 1990s by AECL.

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

During the Phase 3 review, CNSC staff paid particular attention to:

- The incorporation of 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 and implemented in the EC6[®] design, including provision for the associated research and development program.
- Design provisions for severe accident prevention and mitigation (CNSC staff expect a research and development program to support any new design features and departures from the existing CANDU technology, so that their adequate safety is demonstrated).

2.4 Phase 3 Design Review Results

CNSC staff acknowledge that, throughout the Phase 3 review, Candu staff was open and transparent in sharing available information, and that it responded diligently to every CNSC request for clarification and additional information.

CNSC staff completed the Phase 3 review of the 11 topics requested by Candu (as per mutual agreement, extreme severe accident considerations are being addressed separately). In this review, CNSC staff assessed whether Candu is making satisfactory progress toward the completion of activities related to the design readiness for a licence to construct. A number of Candu's activities aim to resolve questions that arose in the Phase 2 review.

The *Key Findings* resulting from the Phase 3 review are:

- Although progress has been made with respect to the classification of structures, systems and components, further discussions will be needed during the Construction License Application review.
- To support justification as to why Emergency Core Cooling System heavy water check valves could be exempt from the Single Failure Criteria, in the design of the Emergency Core Cooling System, a consequence analysis should be considered for the limiting channels to show that there is no cliff-edge effect (or no unacceptable risk) resulting from a design basis initiating event.
- Higher (than proposed by Candu) containment leakage-rate test pressure over the service lifetime should be considered.
- CNSC staff expects a more in-depth submission from Candu in support of the EC6[®] radiation protection design with respect to RD-337 requirements at the Construction License Application review.

CNSC staff found that the design provisions applicable for generic design already included, or under development, for the EC6[®] take into account the lessons learned from the Fukushima Dai-ichi accident.

2.5 Phase 3 Design Review Conclusions

In summary, the in-depth review of the 11 topics led CNSC staff to the conclusion 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 of the review findings in section 2.4 as well as the completion of Candu'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 Licence Application review.

This overall conclusion is based on the following:

- Candu has provided sufficient design and analysis information for the purpose of this review.
- Candu is progressing satisfactorily towards completion of a number of activities to resolve issues arising from CNSC's Phase 2 review as per scope of Phase 3 review.
- Candu incorporated in the EC6[®] design Fukushima nuclear accident lessons learned.

- The future progress is subject to the successful completion of the remaining planned activities. The specific items of each of the eleven topics covered in Phase 3 are likely to be satisfactorily addressed within a reasonable timeframe.

CNSC will follow up on the commitments made by Candu during the Construction License Application phase.