Organisation for Economic Co-operation and Development

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Fifth OECD/NEA Tennessee Valley Authority (TVA) Watts Bar Unit 1 (WB1) multi-physics cycle depletion benchmark workshop (TVA-WB1-5)

3 July 2025
Department of Engineering of the University of Cambridge, Trumpington Street, CB2 1PZ, Cambridge, United Kingdom

The workshop will be held in Cambridge, UK, as part of the Benchmarks Workshops of the Working Party on Scientific Issues and Uncertainty of Reactor Systems (WPRS). The WPRS Benchmarks Workshops event with three parallel tracks combines benchmarking efforts in common areas such as neutronics, thermal-hydraulics, and multi-physics modelling and uncertainty analysis.

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Sponsorship

The fifth OECD/NEA Tennessee Valley Authority (TVA) Watts Bar 1 (WB1) multi-physics cycle depletion benchmark workshop (TVA-WB1-5) will be held on 3 July 2025 in Cambridge, UK, as part of the Benchmarks Workshops Event of the Working Party on Scientific Issues and Uncertainty of Reactor Systems (WPRS). This event with three parallel tracks combines benchmarking efforts in common areas such as neutronics, thermal-hydraulics, and multi-physics modelling and uncertainty analysis. The full schedule for the incoming WPRS Workshops, SINUS-3 school and CTF-11 Meeting and Training is given on the public meeting web page: https://www.oecd-nea.org/jcms/pl_98752/wprs-benchmarks-workshops-2025

Executive Summary

Development of high-fidelity full-core modelling capabilities for Light Water Reactors (LWRs) within the completed US Department of Energy (DOE) Consortium for Advanced Simulation of LWRs (CASL) activities resulted in the establishment of the Virtual Environment for Reactor Applications (VERA) for multi-physics applications. VERA includes a neutron transport solver MPACT, the core-thermal-hydraulic sub-channel code CTF, and the fuel performance code CTFfuel. For Verification and Validation (V&V) of VERA, CASL has developed a set of benchmark progression problems ranging from simple two-dimensional pin cells to three-dimensional multi-physics reactor-core problems. The detailed specifications were prepared by CASL with data for the Watts Bar Unit 1 (WB1) provided by TVA and Westinghouse. As part of the cooperation activities between the US DOE and the OECD/NEA, part of the TVA WB1 data and specifications are provided to serve as a basis for the development of an OECD/NEA multi-cycle depletion benchmark for multi-physics tools with corresponding specifications in a NEA format. The OECD/NEA multi-physics benchmark draft specifications are based on Cycles 1 through 3 of the TVA WB1. We would like to acknowledge TVA and Westinghouse for providing the data and DOE CASL for preparing the CASL benchmark specifications for Watts Bar Unit 1.

The OECD-NEA TVA WB1 benchmark activities are in the framework of the Expert Group on Reactor System MUlti-physics (EGMUP) WPRS/NSC at NEA and are supported by the US DOE Nuclear Energy University Program (NEUP) project award. The benchmark team, consisting of North Carolina State University (NCSU), Westinghouse, and Idaho National Laboratory (INL) with the support of the Oak Ridge National Laboratory (ORNL), is preparing a complete benchmark evaluation for review and inclusion in the IRPhEP handbook. In such an evaluation, additional work is being performed on multi-physics uncertainty and sensitivity analyses for each cycle depletion. Please note that the original models developed with the VERA suite for the CASL progression problems are used, but are adapted for this comprehensive integral benchmark evaluation, in which benchmark specifications have some differences with the definition of the CASL progression problems. The quality-assured and peer-reviewed benchmark specifications and a proposal for a multi-physics, multi-cycle depletion evaluation protocol will be provided based on the IRPhEP protocol. A quality assurance program according to the criteria specified by the DOE and IRPhEP handbook will be established, including internal review (NCSU/ORNL), a second independent peer review (INL), and a third review by the Technical Review Group at the NEA/OECD.

Specifications based on the full three-dimensional (3D) reactor-core configuration, with control rods and burnable poisons consistent with actual nuclear power-plant designs, are developed. Eight benchmark

exercises are defined based on the first three cycles of TVA WB1 data. The exercises are organized in such a way that they span:

a) Exercise 1: Start-up Zero Power Physics Tests (ZPPT) – focused on validation of a stand-alone 3-D neutronics model at Hot Zero Power (HZP) conditions;
b) Exercise 2: Hot Full Power (HFP) Beginning of Cycle (BOC) Physical Reactor with Xenon – focused on validation of a multi-physics steady-state model for HFP conditions (coupled neutronics/thermal-hydraulics/fuel model);
c) Exercise 3: Physical Reactor Cycle 1 Depletion – validation of multi-physics cycle-depletion model for WB1 Cycle 1;
d) Exercise 4: Fuel Shuffle and Decay for Cycle 2 BOC ZPPT – perform Cycle 1 shuffle and account for fuel decay, accurately predicting reactivity at HZP BOC conditions of Cycle 2;
e) e) Exercise 5: Physical Reactor Cycle 2 Depletion – validation of multi-physics cycle depletion model for WB1 Cycle 2;
f) Exercise 6: Validation of Cycle 3 Fuel Shuffle and Decay BOC ZPPT Model;
g) Exercise 7: Validation of Cycle 3 Multi-physics Depletion Model;

The projected Exercise 8 (Ex-core transport calculations for reactor pressure vessel neutron fluence evaluation) is now part of a different OECD benchmark activity.
Non-proprietary geometry information, reactor operating conditions, core fuel and poison loading patterns, Reactor Control Cluster Assembly (RCCA) bank positions, and instrumentation locations are provided in the draft specifications. Measured and operational data for the specified exercises are also provided. Information for performing uncertainty quantification and propagation in steady-state and cycle depletion calculations is provided.
Benchmark specifications have been updated by the benchmark team and will be discussed at the incoming workshop along with the remaining missing information and needed clarifications. Current benchmark specifications are 2.3.5. Output templates for the seven benchmark exercises have been developed and posted on the benchmark website and can be downloaded.

Scope and Technical Content of the Meeting

The topics to be addressed at the workshop include:

- Review and discussion of the updated specifications, including templates for submitting participants' results
- Presenting updated benchmark support data
- Presenting updated experimental and measured data
- Discussing missing information, including uncertainty parameter information and needed clarifications
- Presenting and discussing the benchmark team's support and related studies
- Participants' presentations on their modelling and results for the two benchmark phases
- Presentations on other related activities in PWR multi-physics cycle depletion validation and ex-core transport calculations for pressure vessel neutron fluence calculations
- Defining a work plan and schedule for TVA WB1 activities

Participation in the Meeting

Participation to the meeting is not restricted. Benchmark participation is restricted to individuals from OECD/NEA member-country institutions who agree to the benchmark Non-Disclosure Agreement (NDA). Participants are asked to sign and send the corresponding NDA form to wprs@oecd-nea.org. The TVA WB1 benchmark conditions-to-release form can be found at

https://www.oecd-nea.org/upload/docs/application/pdf/2024-10/tva-wb1_conditions_for_release_2024_2024-10-04_15-31-59_949.pdf

Organization and Program Committee of the Meeting

An Organization and Program Committee has been nominated to make the necessary arrangements for the TVA-WB1-5 meeting and to draw up the final program, etc.

The members of the Program Committee are:

- **Pascal Rouxelin** – Co-Chair and Co-Cordinator
  North Carolina State University, USA
- **Scott Palmtag –** Co-Chair
  North Carolina State University, USA

NEA Technical Secretariat: **Oliver Buss**
OECD/Nuclear Energy Agency, France

Proposed Program of the Meeting

The proposed program was drawn up by the Program Committee and is enclosed as Annex 1.

Language of the Benchmark Workshop

The official language of the workshop is English.

Proceedings of the Meeting

The program committee and the session Chairs will prepare a summary report on the main results of the meeting. Presentations will be available free of charge to the benchmark participants to download from participants' restricted area of the benchmark website after the workshop.

Contacts and Registrations

Link to the registration page for the WPRS-related workshops and meetings and the overall program:
https://www.oecd-nea.org/jcms/pl_98752/wprs-benchmarks-workshops-2025

Workshop Location

The meeting place/venue for the meetings/workshops during the week of 30 June to 4 July 2025 is the Department of Engineering of the University of Cambridge:

Trumpington Street, CB2 1PZ, Cambridge, United Kingdom.

Annex 1:

Fifth OECD/NEA Tennessee Valley Authority (TVA) Watts Bar Unit 1 (WB1) multi-physics cycle depletion benchmark workshop (TVA-WB1-5)

Host Organization
Department of Engineering of the University of Cambridge, in collaboration with the Cambridge Nuclear Energy Centre, University of Cambridge, United Kingdom

3 July 2025

PROPOSED PROGRAM

WB01. Introduction and opening remarks.

WB02. Review and discussion of the updated specifications, including templates for submitting participants' results.

WB03. Presenting and discussing updated benchmark support data.

WB04. Presenting and discussing updated experimental and measured data.

WB05. Discussing missing information, including uncertainty parameter information and needed clarifications.

WB06. Participants' presentations on their modelling and results for the two benchmark phases.

WB07. Presentations on other related activities in PWR multi-physics cycle depletion validation and ex-core transport calculations for pressure vessel neutron fluence calculations.

WB08. Defining a work plan and schedule for TVA WB1 activities