Organisation for Economic Co-operation and Development

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Eighteenth OECD/NEA Light Water Reactor (LWR) Uncertainty Analysis in Modelling (UAM) Benchmark Workshop (LWR-UAM-18)

2 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 Eighteenth OECD/NEA Light Water Reactor (LWR) Uncertainty Analysis in Modelling (UAM) Benchmark Workshop (LWR-UAM-18) will be held on 2 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

The OECD/NEA UAM-LWR Benchmark is an international high-visibility benchmark under the auspices of WPRS for uncertainty quantification and propagation in best-estimate coupled code calculations for design, operation, and safety analysis of LWRs. The benchmark activities are coordinated by the North Carolina State University (NCSU) with the following objectives:

a) To determine major uncertainties in modelling and simulation (M&S) of LWR systems under steady-state and transient conditions, quantifying the impact of uncertainties for each type of calculation in the multi-physics analysis:
   - Neutronics (reactor physics) M&S;
   - Thermal-hydraulics M&S;
   - Fuel behavior M&S.

b) For each of these types of calculation, the major sources of uncertainty are determined, arising from:
   - Data (e.g., nuclear data, geometry, materials);
   - Numerical solutions;
   - Physical models.

c) To develop and test methods for combining the above sources of uncertainty for each type of calculation so as to yield uncertainty assessment for the coupled multi-physics analyses;

d) To develop a benchmark framework, which combines information from available integral facility and Nuclear Power Plant (NPP) experimental data with analytical and numerical benchmarking. Where available, experimental data will be used to test the individual types of calculation as well as coupled multi-physics simulations.

To summarize, in addition to LWR best-estimate calculations for design and safety analysis, the different aspects of UAM are to be further developed and validated on scientific grounds in support of its performance. There is a need for efficient and powerful analysis methods suitable

for such complex coupled multi-physics and multi-scale simulations. The proposed benchmark sequence will address this need by integrating the expertise in reactor physics, fuel performance, thermal-hydraulics and reactor system modelling as well as uncertainty and sensitivity analysis and will contribute to the development and assessment of advanced/optimized uncertainty methods for use in best-estimate reactor simulations.

Reference systems and scenarios for coupled code analysis are defined to study the uncertainty effects for all stages of the system calculations. Measured data from plant operation are available for the chosen scenarios. The proposed technical approach has established a benchmark for uncertainty analysis in best-estimate modelling and coupled multi-physics and multi-scale LWR analysis, which is composed of a series of well-defined problems with complete sets of input specifications and reference experimental data. The objective is to determine the uncertainty in LWR system calculations at all stages of a coupled reactor physics/thermal-hydraulics calculation. Uncertainty propagation is being estimated through the whole simulation process – the benchmark builds a unified framework, which can be used and followed in the future. The full chain of uncertainty propagation from basic data, engineering uncertainties, across different scales (multi-scale), and physics phenomena (multi-physics) are tested on several benchmark exercises for which experimental data are available and for which the power plant details have been released. The implemented principal idea is: a) To subdivide the complex system/scenario into several steps or exercises, each of which can contribute to the total uncertainty of the final coupled system calculation; b) To identify input, output, and assumptions for each step; c) To calculate the resulting uncertainty in each step; d) To propagate the uncertainties in an integral systems simulation for which high quality plant experimental data exists for the total assessment of the overall computer code uncertainty. The main scope covers uncertainty (and sensitivity) analysis (SA/UA) in best estimate modelling for design and operation of LWRs, including methods that are used for safety evaluations. As part of this effort, the development and assessment of different methods or techniques to account for the uncertainties in the calculations are investigated and reported to the participants.

The general frame of the OECD/NEA LWR-UAM benchmark consists of three phases with different exercises for each phase:

Phase I (Neutronics Phase) – Focused on Standalone Steady-State Multi-Scale Neutronics Calculations

- Exercise I-1: "Cell Physics" focused on the derivation of the multi-group microscopic cross-section libraries
- Exercise I-2: "Lattice Physics" focused on the derivation of the few-group macroscopic cross-section libraries
- Exercise I-3: "Core Physics" focused on the core steady-state, stand-alone neutronics calculations

Phase II (Core Phase) – Introduces M&S of the Other Physics Phenomena in the Reactor Core and Time Dependence on Different Time Scales

- Exercise II-1: "Fuel Physics": Fuel thermal properties relevant to steady-state and transient performance
- Exercise II-2: "Time-dependent Neutronics": Neutron kinetics and depletion stand-alone performance

Exercise II-3: "Bundle Thermal-Hydraulics": Thermal-hydraulic fuel bundle performance

Phase III (System Phase) – Introduces Multi-Physics Coupling in the Reactor Core and its Further Coupling with Reactor/Plant System

Exercise III-1: "Core Multi-Physics" - Coupled neutronics/thermal-hydraulics core performance (coupled steady state, coupled depletion, and coupled core transient with boundary conditions)

Exercise III-2: "System Thermal-Hydraulics" - Thermal-hydraulics system performance

Exercise III-3: "Coupled Core-System" - Coupled neutronics kinetics thermal-hydraulic core / thermal-hydraulic system performance

Exercise III-4: "Comparison of Best Estimate Plus Uncertainties (BEPU) vs. Conservative Calculations"

This benchmark project is challenging and responds to the needs of estimating confidence bounds for results from simulations and analysis in real applications. Separate Specifications are being prepared for each phase to allow participation in the full Phase or only in a subset of the Exercises. Boundary conditions and necessary input information are provided by the benchmark team. The intention is to follow the calculation scheme for coupled calculations for LWR design and safety analysis established in the nuclear power generation industry and regulation. The benchmark activities on Phase I have been completed, with the final specifications and comparative analysis report finalized and published. At the incoming workshop, participants' presentations related to Phases II and III will be included, followed by devoted discussions. The latest version of the Specifications on Phase II and Phase III will be discussed together with updates on Excel submission templates.

The OECD Kalinin-3 Coolant Transient benchmark and OECD/NRC Oskarshamn-2 BWR Stability benchmark have been merged in the Phase III of LWR-UAM benchmark through their uncertainty analysis exercises (phases) along with the OECD/NRC TMI-1 PWR Main Steam Line Break (MSLB), OECD/NRC PB-2 BWR Turbine Trip (TT), and OECD TVA WB1 Multi-Physics Cycle Depletion benchmarks.

The information about the LWR-UAM benchmark is provided at:

https://www.oecd-nea.org/jcms/pl_32175/benchmark-for-uncertainty-analysis-in-best-estimate-modelling-for-design-operation-and-safety-analysis-of-light-water-reactors-lwr-uam

Scope and Technical Content of the Meeting

The topics to be addressed at the workshop include:

- Review and discussion of the current version of specifications and support data for Phase II including templates for submitting participants' results,
- Review and discussion of the latest specifications and support data for Exercise III-1, Exercise III-2, Exercise III-3 and Exercise III-4 of Phase III including templates for submitting participants' results,
- Participants' presentations on their modelling and results for all Phases,
- Presentations on other related activities in uncertainty and sensitivity analysis of LWRs,

- Discussions on the development of appropriate verification, validation, and uncertainty quantification (VVUQ) guidelines and protocols for multi-physics steady-state, depletion, and transient applications.
- Benchmark participants' presentation on their models and results;
- Discussion of education activities associated with LWR-UAM: discussion of lessons learned and outcomes of the Third International School on Simulation of Nuclear Reactor Systems (SINUS-3),
- Defining a work plan and schedule for the LWR-UAM benchmark activities.

The LWR-UAM benchmark activities are also related to other meetings to be held within the same week and at the same premises:

- 30 June 2025: OECD/NEA EGMUP Task Force on Artificial Intelligence and Machine Learning Benchmark meeting- presentations and discussion on work plan and activities of Task Force, including uncertainty quantification and propagation.

- 3 July 2025: The OECD/NEA Task Force on Fuel Temperature Assumptions in Depletion Analyses session will include presentations and discussion on work plan and activities of the Task Force on Effective Doppler Feedback Temperature approximations in multi-physics M&S and associated uncertainties.

The proposed meeting program is attached as Annex 1.

Organization of the Meeting

The meeting is organized around the discussion of the LWR-UAM benchmark specifications, preliminary results, participants' concerns, and benchmark-related activities. The participants are requested to present their expertise and experience in benchmark-related modeling, verification and validation, uncertainty quantification/propagation and applications.

Participation in the Meeting

Meeting participation 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.

Benchmark LWR-UAM conditions to release form can be found at:

https://www.oecd-nea.org/upload/docs/application/pdf/2024-10/uam-lwr_conditions_for_release_2024.pdf

Organization and Program Committee of the Meeting

An Organization and Program Committee has been nominated to make the necessary arrangements for the LWR-UAM-18 benchmark workshop and to draw up the final program, etc.

The members of the Program Committee are:

Gregory Delipei – Co-Chair

North Carolina State University, USA

Agustin Abarca – Co-Chair
North Carolina State University, USA

Maria Avramova - Coordinator
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 for presentation to the EGPRS, WPRS, and NSC. 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:

OECD/NEA Light Water Reactor (LWR) Uncertainty Analysis in Modelling (UAM) Benchmark (LWR-UAM) – Eighteenth Workshop (LWR-UAM-18)

Host Organization

Hosted by Cambridge Nuclear Energy Centre, University of Cambridge,

Cambridge, United Kingdom

July 2, 2025

PROPOSED PROGRAM

U01. Introduction and opening remarks.

U02. Overview and status of benchmark activities.

U03. Overview of the current version of Specifications for Phase II, templates for submitting participants' results, support data, and studies.

U04. Participants' presentations on their modelling and results for Phase II.

U05. Presentations of related activities and reference analyses to Exercises of Phase II.

U06. Overview of the latest version of Specifications for Phase III, templates for submitting participants' results, support data, and studies.

U07. Participants' presentations on their modelling and results for Phase III.

U08. Presentations of related activities and reference analyses to Exercises of Phase III.

U09. Discussion on the development of appropriate verification, validation, and uncertainty quantification guidelines and protocols for multi-physics steady, depletion, and transient applications.

U10. Discussion of education activities associated with LWR-UAM and SINUS-3 lessons learned and outcomes.

U11. Action items and schedule of benchmark activities - next workshop and plans.

U12. Conclusions and closing remarks.