ECC-SMART Project Newsletter

January 2025

Dear ECC-SMART Partners,

As we get closer to the end of the ECC-SMART project, we are delighted to present the latest issue of our external newsletter.

In this edition, we reflect on the progress made during the project. Diving into the work of each work package and the pivotal role in fostering collaboration and enhancing synergy across the technical work packages, strengthening our collective efforts.

Additionally, this issue highlights key events and activities related to the ECC-SMART project over recent months. We look forward to seeing many of you at the upcoming events as we continue to advance our shared mission.

We extend our heartfelt gratitude to the entire ECC-SMART team for their dedication, exceptional contributions, and unwavering commitment to steering the project toward a successful conclusion.

ECC-SMART Project Team

ECC-Smart Work Packages

WP1: Project management

WP2: Materials Testing in ECC-SMART

WP3: Thermal Hydraulics and Safety of the SCW-SMR

WP4: Neutron physics of SCW-SMR

WP5: Synthesis and Guidelines for Safety Standards

WP6: Dissemination and Communication

The implementation of the ECC-SMART - WP leaders' report

WP2: Materials Testing

Work package 2 has delivered critical advancements in understanding and selecting materials for small modular reactors cooled by supercritical water (SMR-SCW) applications, directly addressing challenges recognised as open issues in previous research. Throughout the project, a total of 800 specimens were tested by 10 partners.

Key Findings:

1. **Corrosion Resistance:** Long-term exposure tests up to 7,000 hours demonstrated that selected candidate materials exhibit high corrosion resistance in supercritical water at 380 °C and 500 °C. Austenitic stainless steel 310S and alloy 800H proved their excellent performance, including projected wall penetration values of less than 20 microns after 30,000 hours of operation. The positive effect of Al for newly developed AFA (austenitic alumina-forming alloy) was not so obvious in the performed tests.
2. **High-Temperature Steam Testing:** Tests in steam at 1200 °C revealed severe spallation in 310S and AFA alloys. However, consistent with findings from prior projects, these materials still exhibited superior behavior compared to zirconium-based alloys such as Zircaloy-4 and Zirlo, further validating their potential for high-temperature applications.
3. **Stress Corrosion Cracking (SCC):** Studies revealed that 310S, 800H, and AFA alloys displayed no signs of SCC at 380 °C and only minimal indications at 500 °C, making them promising candidates for SCWR environments.
4. **Neutron Irradiation:** Neutron irradiation of candidate materials with damage corresponding to 0.3 DPA did not significantly change their corrosion behavior. However, it did impact their mechanical properties, necessitating further investigation.
5. **Radiolysis and Water Chemistry:** Radiolysis studies yielded highly encouraging results, demonstrating that radiolysis could be effectively suppressed up to 500 °C using hydrogen injection (≤40 mL·kg^{-1} H_2).
6. **Electrochemical Studies:** Temperature, pressure, surface treatments, and oxygen concentration were shown to influence material performance. Findings validated through techniques like electrochemical impedance spectroscopy emphasized the importance of these variables in optimizing regiurements on materials, water chemistry and ensuring operational stability.

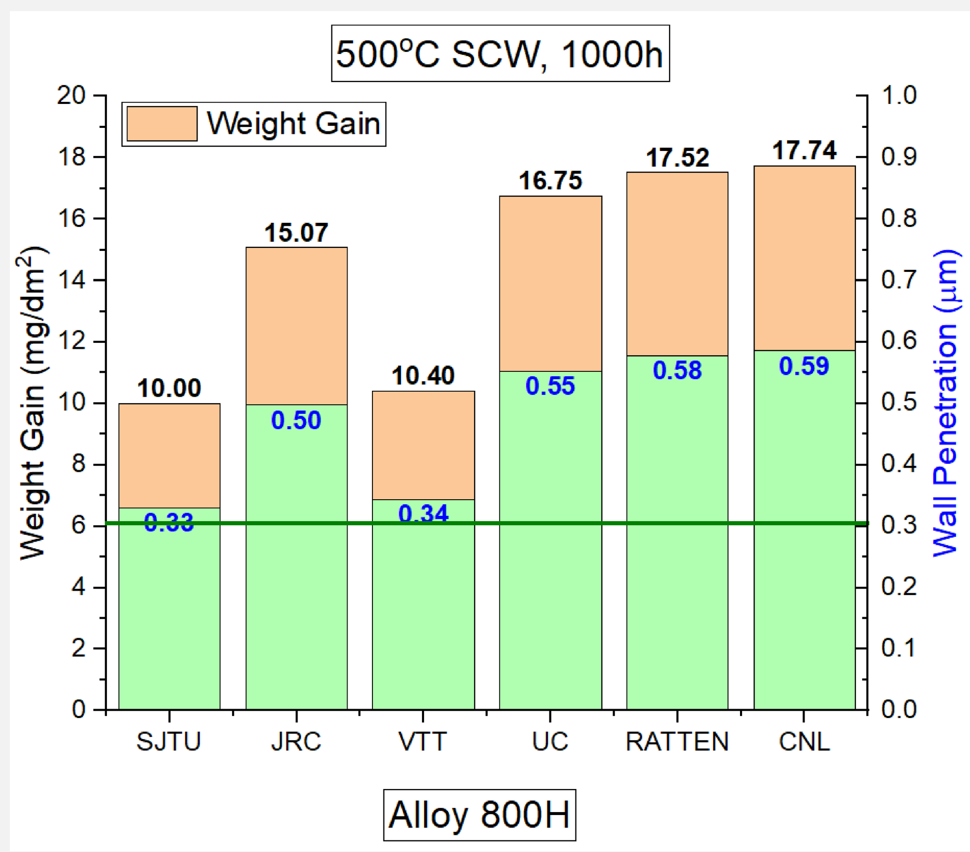

Figure 1: The weight gain, calculated wall penetration for 800H tested by parters of the project.

These studies were carried out in collaboration with the other work packages (namely WP3 and WP4), further enhancing the robustness and significance of the results. This cross-package cooperation has provided a solid foundation to support the advancement of SCW technology and its application in future nuclear systems. The outcomes of WP2 mark a significant leap forward in addressing critical gaps in SCW technology. The results have enabled decisive steps in identifying fundamental materials for the concept of SMR-SCW systems and refining reactor chemistry, both of which remain vital milestones for the future of advanced nuclear systems.

WP3: Thermal Hydraulics and Safety of the SCW-SMR

A **reference database** was created to collect data for thermal-hydraulic investigations at supercritical conditions, focusing on corrosion impact on heat transfer. KIT conducted experiments with SC Freon (R134a) to study surface finishing effects, finding that rough surfaces improve heat transfer and delay deterioration. In Canada, CNL and Carleton University used **DNS** (Direct Numerical Simulation) to analyze surface effects on turbulent forced convection, identifying a roughness height threshold. CNL also measured the roughness and **thermal conductivity of the oxide layer** on fuel cladding candidates exposed under SCW conditions to develop a corrosion model. The University of Sheffield conducted **DNS** of flow over rough surfaces, and KIT developed a DNS solver for supercritical water.

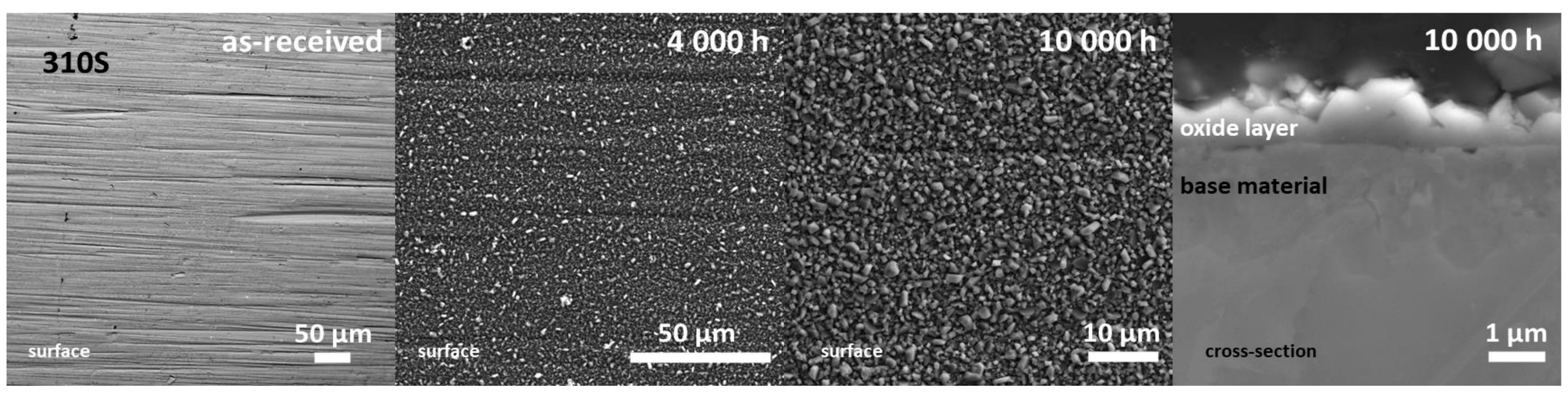

Figure 2:The evaluation of the surface of 310S during the long-term exposure in SCW at 500°C/25 MPa. Cross-cutting topic between WP2 and WP3.

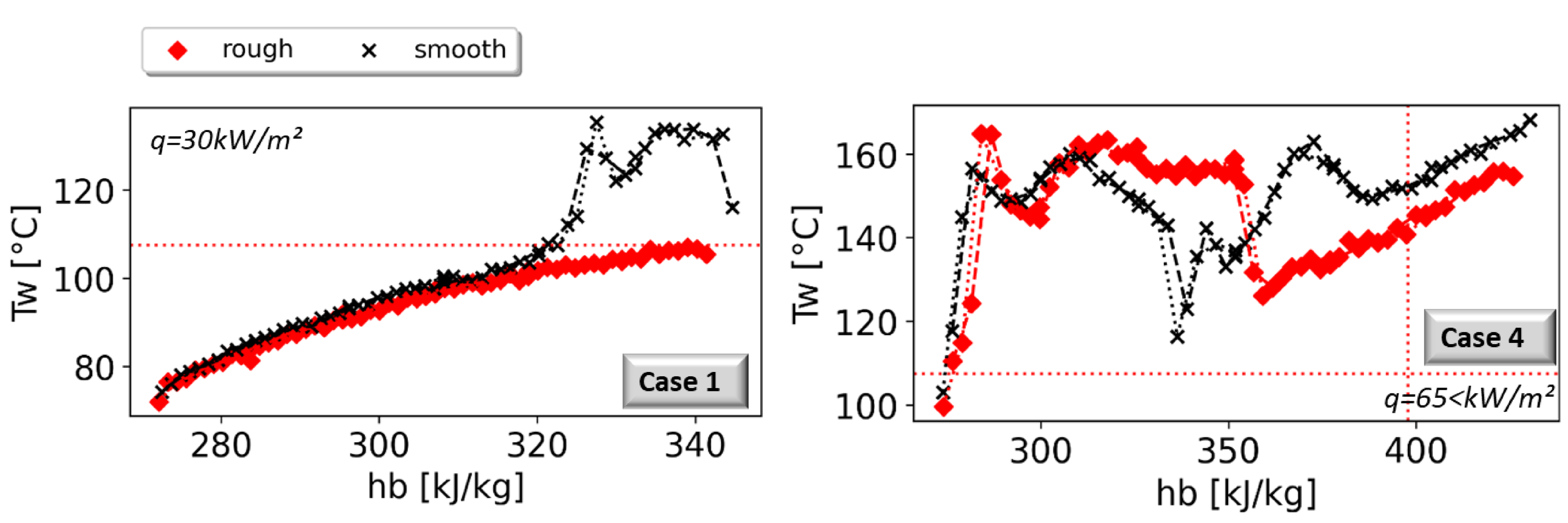

Figure 3: Newly generated experimental data for heat transfer to supercritical pressure R134a revealing the effect of the surface roughness.

For SCW-SMRs, **safety systems** were assessed under ECC-SMART and GIF PMB TH&S collaborations. UNIPI and BME analyzed safety systems using RELAP and APROS codes, concluding that minimal passive systems could ensure cooling during long-term blackouts. CNL and NPIC conducted similar analyses for Canadian and Chinese SCW-SMRs, respectively. IPP in Ukraine modelled severe accidents for ECC-SMART using an inhouse and CFD (Computational Fluid Dynamics) codes.

European participants conducted **CFD studies** on heat transfer in nuclear fuel bundles under supercritical conditions. UNIPI developed and validated a CFD model for rough surfaces, while BME and UoN performed comprehensive CFD analyses. KTH developed CFD models for supercritical heat transfer along rough corroded surfaces.

This project has received funding from the Euratom Research and training programme 2019-2020 under Grant Agreement No 945234.

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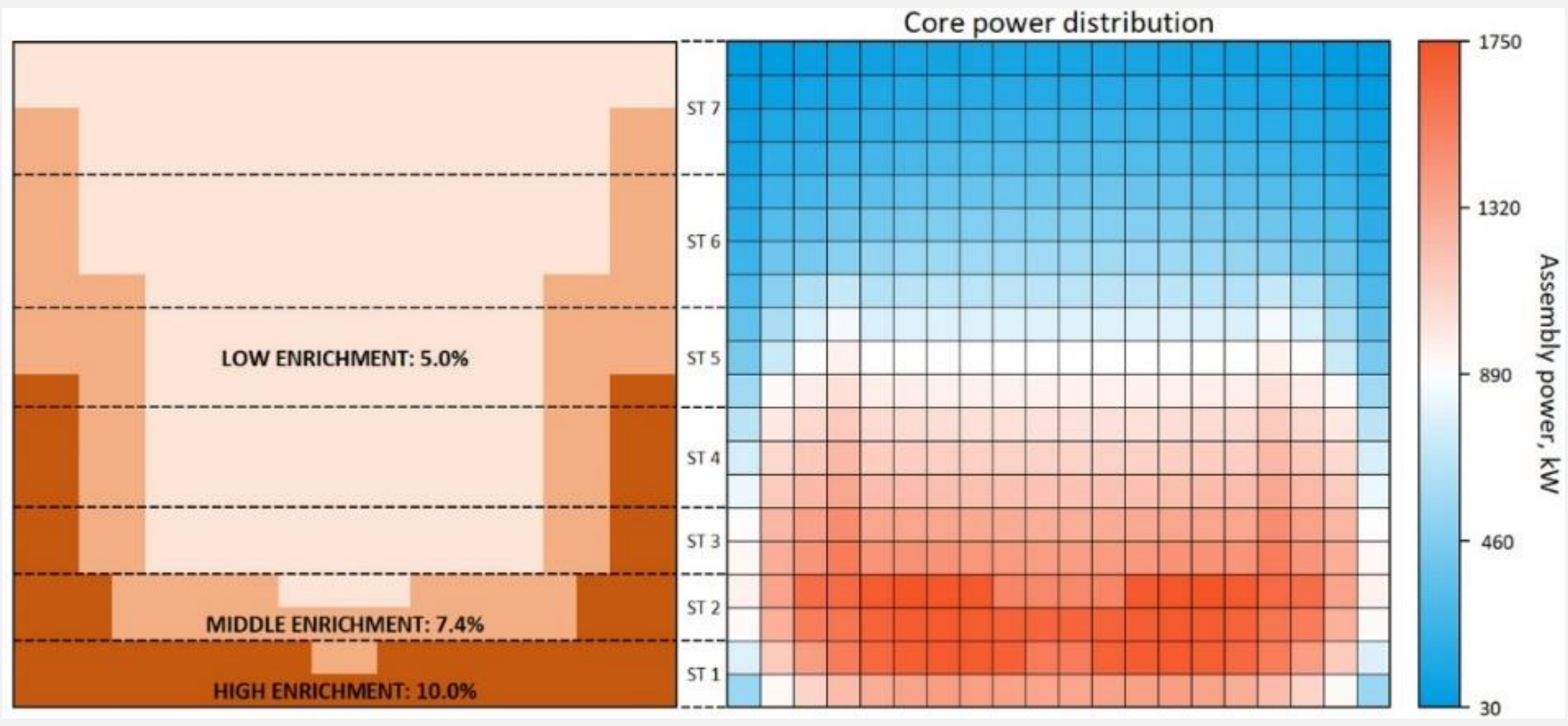

Figure 4: Optimized core layout. The enrichment map is shown on the left-hand side, while the assembly power distribution of the core is shown on the right.

WP4: Neutron physics of SCW-SMR

With the aid of a **Monte Carlo transport code**, the pre-conceptual **neutronic design** of the **Supercritical Water Cooled SMR** has been developed. After initial **criticality** and **burnup calculations**, the starting **core design** was improved using predetermined criteria, such as **burnup cycle length** and **power distribution**, while also considering **operational safety**. In order to achieve higher **reserve reactivity**, several modifications were considered, including the introduction of alternative **structural materials** and **fuel assembly wall type**, **moderation improvement** by adjustment of **moderator temperature** and **fuel assembly gap width**, and selection of a suitable **enrichment map**.

As a result of the introduced modifications, the **burnup cycle length** was increased to **26 months** and an acceptable **core power distribution** was achieved. The improved **core design** (Fig. 4) was used for further investigations, such as coupled calculations using **neutronic** and **thermal–hydraulic codes** and examinations targeting **reactivity control** during **burnup**.

Based on the findings of coupled **neutronic** and **thermal-hydraulic calculations**, the cores were further developed in accordance with suggestions put forth by **WP3**, including the incorporation of **inlet orifices**. The results of these examinations are to be **published soon**.

A **comprehensive investigation** was conducted into the potential applications of **burnable absorbers** in **in-assembly power profiling**, encompassing an extensive exploration of the available types of **burnable absorbers** and the possible methods for their **utilization**. In addition, the proposed **fuel assembly model** incorporates a **heterogeneous pin enrichment map** for more accurate results. A **paper** containing these findings is in preparation, and further calculations are underway, applying the aforementioned results in **full-core burnup examinations**.

WP5: Synthesis and Guidelines for Safety Standards

The **pre-licensing study** has been developed. It relates the safety criteria and requirements for the SCW-SMR concept with the safety-related behavior and features of the SCW-SMR to the available level of detail at the current conceptual design stage.

The development of the guidelines for the safety demonstration of the future reactor is now complementing the pre-licensing study. These guidelines will:

- **Outline Safety Requirements and Criteria:**

Define the safety requirements, criteria, and methods suitable for demonstrating the safety of the SCW-SMR.

- **Ensure Compatibility with Regulatory Levels:**

The safety demonstration guidelines will be aligned with levels 1a and 1b of the applicable rules, as depicted in the corresponding table.

Levels of rules	Description
1a	**Level 1a: Legislation & safety regulations** • Country legislation (examples of Canada, China, Czech Republic, Finland and United Kingdom) • WENRA, Safety of new NPP designs • WENRA, Applicability of the Safety Objectives to SMRs
1b	**Level 1b: IAEA (International Atomic Energy Agency) Safety Standards** • IAEA SF-1, Fundamental Safety Principles • IAEA SSR-2/1 Rev. 1 Safety of Nuclear Power Plants: Design
2	**Level 2: Nuclear process oriented documents** • Quality assurance • Design and operation
3	**Level 3: Nuclear component oriented documents** • Pressure boundary codes and standards • Codes and standards for electrical equipment • Operations and maintenance codes
4	**Level 4: Conventional codes and standards** • Usually applied to the structures, systems and components of conventional facilities • Conventional pressure vessel codes and standards

WP6: Dissemination and Communication

Work Package 6 has played a pivotal role in advancing dissemination and communication activities, ensuring impactful outreach and knowledge sharing for the ECC-SMART project.

Training Materials

Under *Deliverable 6.5*, ENEN developed comprehensive training materials, including a booklet and presentations, summarizing the outcomes of the *Workshop on Post-Irradiation Examination (PIE)*. This workshop took place from August 26 to 30, 2024, at the **CVR** in the Czech Republic. It addressed the objectives of **Task 6.3** and **Task 6.4** within Work Package 6 of the ECC-SMART project.

Project Newsletter

A dedicated project newsletter featuring insights from the *Post-Irradiation Examination (PIE) Workshop* was created and shared with the broader community in **September 2024**.

Project Representation at Key Events

Throughout 2024, the ECC-SMART project was highlighted as part of ENEN's portfolio at prominent international events:

•**68th IAEA General Conference**
(September 2024) *ENEN hosted a side-event*: *"The Network Effect: Enhancing the European Nuclear Competency through Collaboration"*
•**IAEA International Conference on Nuclear Knowledge Management and Human Resources Development**
(July 2024) ENEN presented a poster showcasing all its projects.
•**IAEA International Conference on Small Modular Reactors (SMRs)** (October 2024)
•**ENEN Members' Meeting** (December 2024)
•**Comprehensive Two-Week Blended Course on Nuclear Safeguards** in Geel/Mol, Belgium (November 2024).
•**1st and 2nd NURECAB Workshops** on EU-UA Nuclear Research and Education Capacity Building:

- *"UA and EU Nuclear Education Trends and Nuclear Industry Prospects"* (October 2024)
- *"Nuclear Research and Innovation: UA Integration to European Nuclear Research Area"* (December 2024).

PROJECT CONSORTIUM - 20 partners: 15 from Europe, 3 from China, 1 from Canada and 1 from Ukraine

FIND OUT MORE!

CORDIS EU research results

JOINT EUROPEAN CANADIAN CHINESE DEVELOPMENT OF SMALL MODULAR REACTOR TECHNOLOGY

This project has received funding from the Euratom Research and training programme 2019-2020 under Grant Agreement No 945234.