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JOINT EUROPEAN CANADIAN CHINESE
DEVELOPMENT OF SMALL MODULAR REACTOR TECHNOLOGY

New challenges for SCWR development

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

Outline

- Description of the SCW reactor concept
- General evolution of the SCWR programme
- ECC-SMART project
  - Consortium
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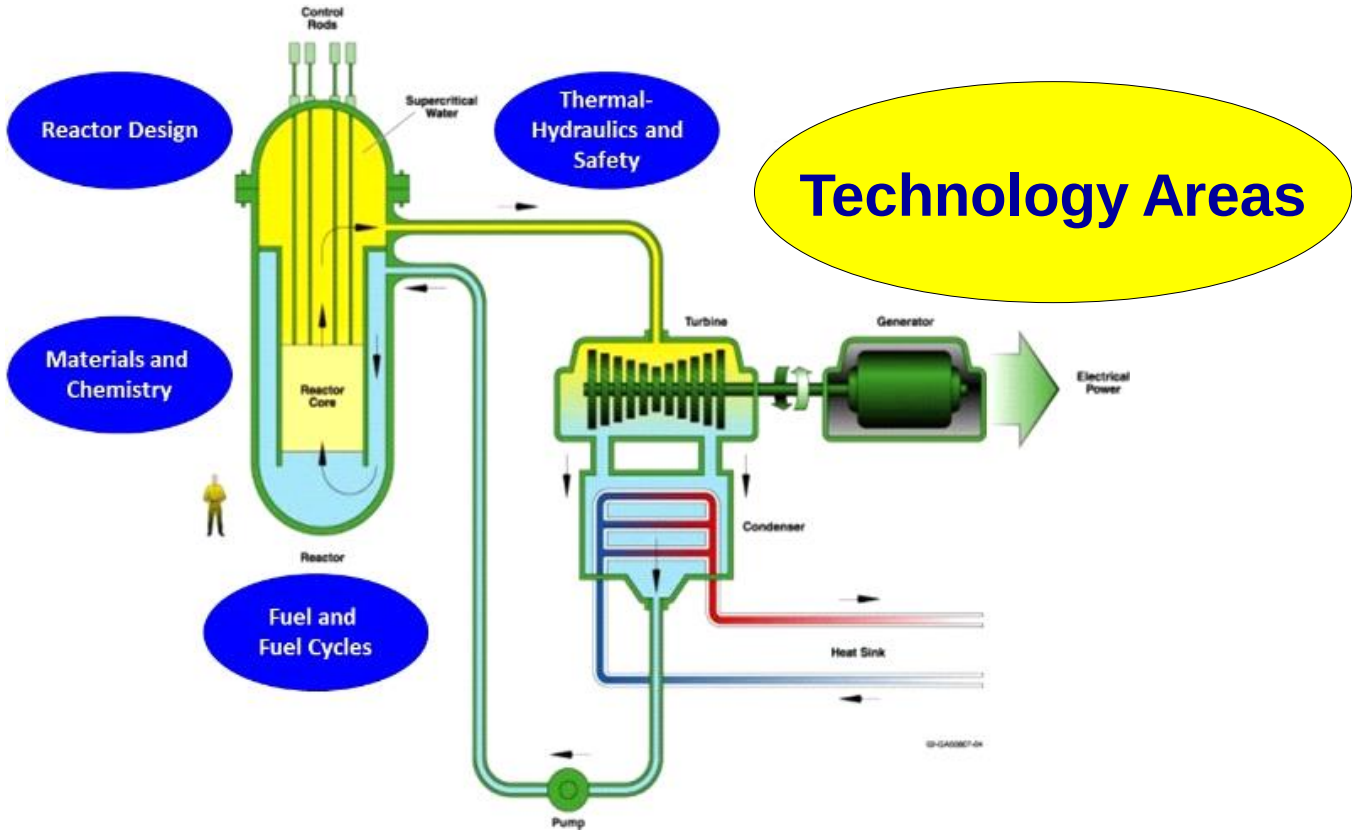
  - Goals
  - Ambition
  - Technical scope
- ISSCWR-10 event

Supercritical water-cooled reactor

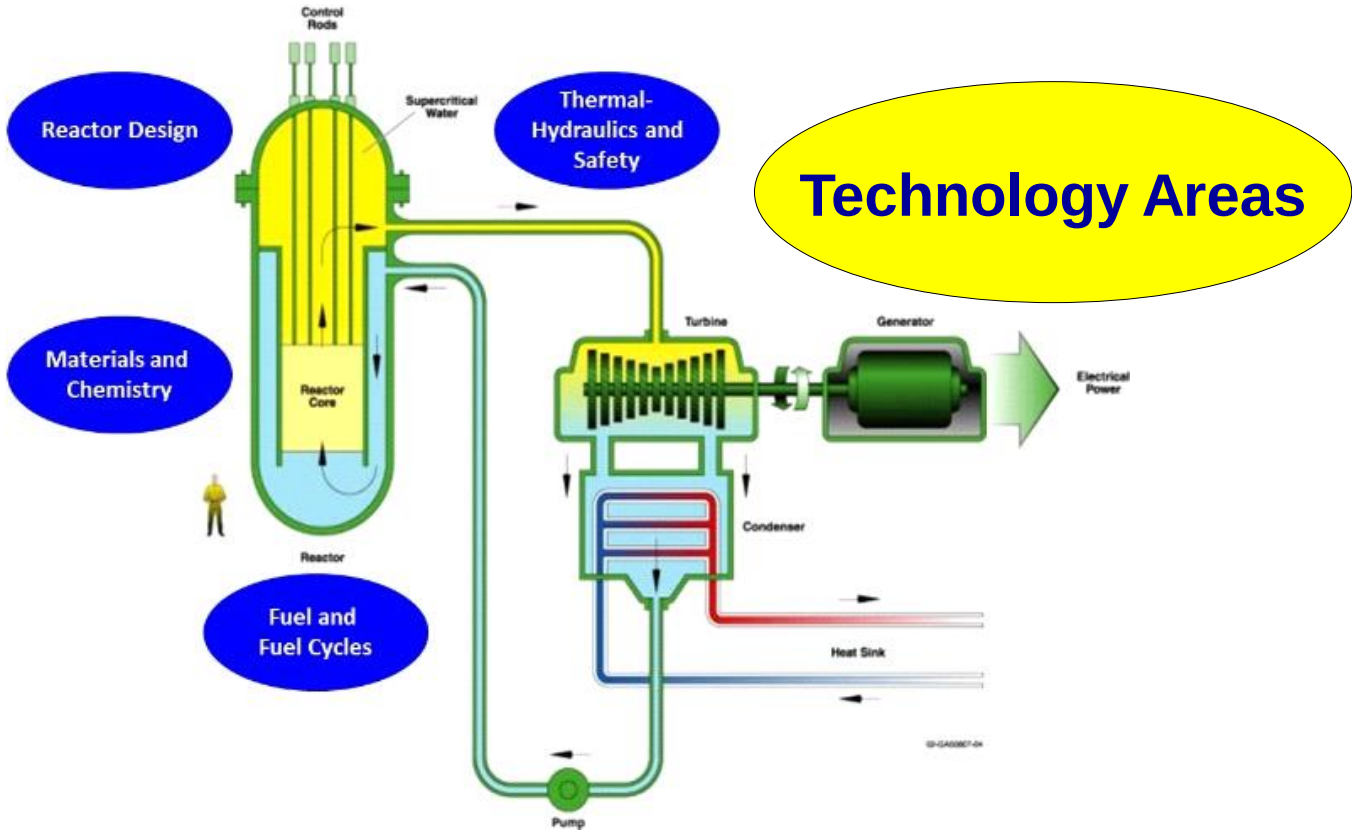
- Water-cooled reactors
- Thermal, fast or mixed spectrum
- Pressure vessel or pressure-tube configuration
- Supercritical pressures at ~25 MPa
- Core outlet temperatures from 500ºC to 625ºC
- Thermal Efficiency between 40% and 48%
- Direct Cycle
- GIF SA: Canada, China, Euratom, Japan, Russian federation
- Main areas: materials and chemistry, thermalhydraulics and safety, systém integration and assessment



Supercritical water-cooled reactor

Main technical goals:

- The development of cladding materials to withstand the high pressure and high temperature environment.
- The establishment of a chemistry-control strategy to minimize water-radiolysis effect and activation-product transport.
- The optimization of the fuel assembly geometry and configuration to enhance the power output and safety characteristics.



Evolution of the SCWR concept

- **EU:**
- High Performance Light Water Reactor (5th framework programme 8/2000 – 7/2002)
- High Performance Light Water Reactor Phase 2 (6th framework programme 9/2006 – 2/2010)
- SCWR-FQT (7th framework programme 1/2011 – 12/2014)
- **Canada:**
- National Canadian programmes
- Cooperation under GIF umbrella
- **China:**
- China SCWR TH&S R&D Project in support of GIF international activities (2020-2022), funded by the MOST.
- China SCWR M&C R&D Project in support of GIF international activities (2020-2022), funded by the MOST
- China SCWR Project (2012-2014) – China SCWR technology development Phase 1. In this project, the China Supercritical Water-Cooled Reactor design (CSR1000) was proposed.
- China-EU joint project SCWR-FQT-SCRIPT (2011–2014) – Supercritical Water Reactor - Fuel Qualification Test.
- China MOST Project (2012 - 2014) – China SCWR fundamental technology research funded by the China Ministry of Science and Technology (MOST)

ECC-SMART Project introduction

- Joint European Canadian Chinese development of Small Modular Reactor Technology
- Duration: September 2020 – August 2024

- Total budget: 8 911 950 €
- EC contribution: 3 997 237,50 €
- Total effort: 958 PM

- CORDIS: https://cordis.europa.eu/project/id/945234

- Consortium: 15 European, 1 Canadian, 3 Chinese and 1 Ukrainian partners

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Project partners

CVŘ Research Centre Řež

enen

Shanghai Jiao Tong University

European Commission

Műegyetem 1782

KIT Karlsruher Institut für Technologie

Gobierno de España · Ministerio de Ciencia e Innovación · Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

The University of Nottingham
United Kingdom · China · Malaysia

KTH Vetenskap och Konst

Jožef Stefan Institute

R4 Reactor Engineering Division

Ministerul Economiei, Energiei și Mediului de Afaceri
RATEN Regia Autonomă Tehnologii pentru Energia Nucleară

University of Chemistry and Technology Prague

Università di Pisa

IPP Centre
Intelligent Practical Profound

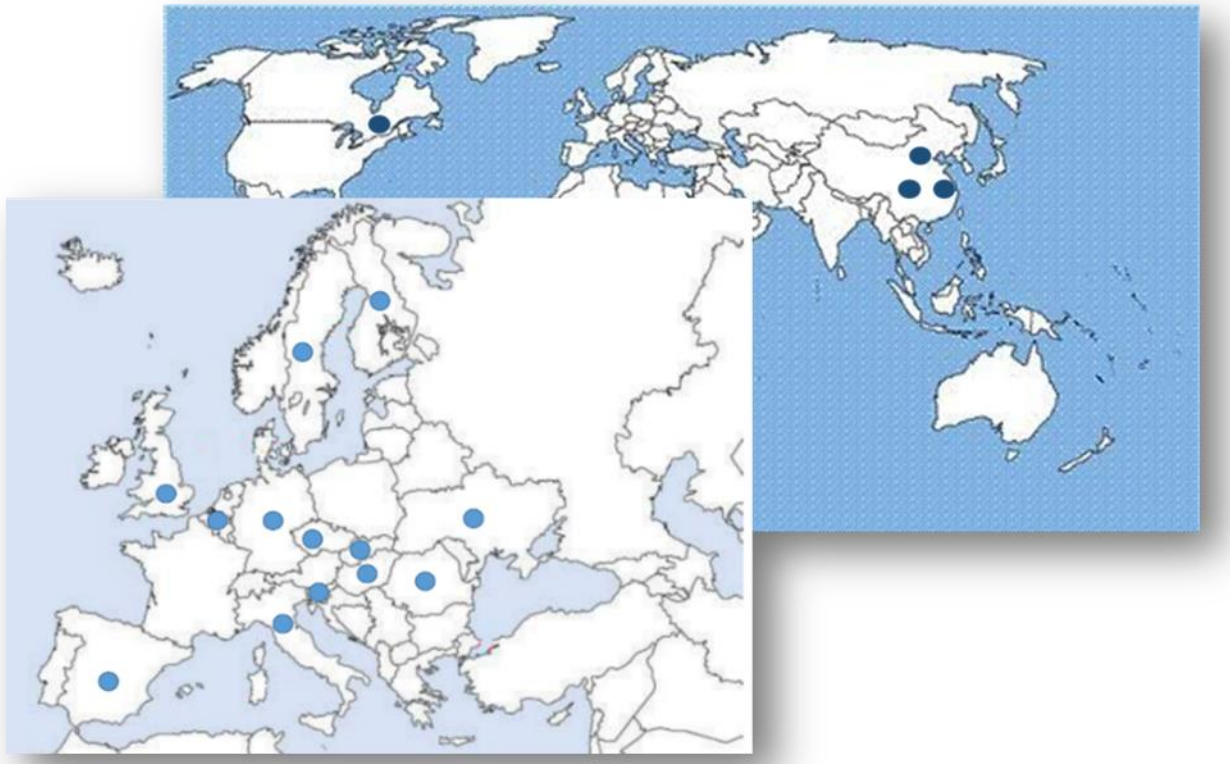
The University Of Sheffield.

VTT

中国核动力研究设计院
Nuclear Power Institute of China
中核集团

STU FEI Slovak University of Technology in Bratislava
Faculty of Electrical Engineering and Information Technology

Canadian Nuclear Laboratories | Laboratoires Nucléaires Canadiens



Horizon 2020

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Motivation - SCW cooled SMR technology

- Based on the SCWR research worldwide
- Need for flexible power source for wide range of users – the SMR
- Passive safety
- Water-cooled design
- Reaching the GIF requirements*
- Lower capital costs
- Higher efficiency

SCW-SMR

SuperCritical Water-cooled Small Modular Reactor

*Sustainability, Economics, Safety and Reliability, Proliferation Resistance and Physical Protection

Evolution of the project

E-SMART

- EU project
- Applied in 2016
- science-based recommendations and standards for a SCW-SMR to competent bodies in the EU
- **rejected**

MACHETE

- Joint EU-Canada-China
- Applied in 2018
- Research on Materials, Corrosion and Turbulent Heat and Mass Transfer Issues in high Pressure
- **rejected**

ECC-SMART

- Joint EU-Canada-China-Ukraine
- Applied in 2019
- Joint European Canadian Chinese development of Small Modular Reactor Technology
- **Approved&supported**

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Previous cooperation + support of the project

- GIF Round Robin test nr.1: Corrosion testing I
- GIF Round Robin test nr.2: Corrosion testing II
- IAEA CRP: Understanding and Prediction of Thermal Hydraulics Phenomena Relevant to Supercritical Water Cooled Reactors

- GIF SSC/PMB
- IAEA Technical Expert Group

- **The project proposal was officialy supported by:**
- NUGENIA/SNETP (the label was awarded in 2016 to the E-SMART project)
- GIF
- EERA JPNM (CVR, KIT, CIEMAT, KTH, JRC, VTT members, STUBA, RATEN, UNIPI associated)
- Industry: DOOSAN Škoda Power, Škoda Nuclear Machinery

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ECC-SMART: Design targets

- **Objective: collect all experience from design studies in EU, Canada and China to derive a joint <u>design requirements document</u> following the design targets:**

- The electric power output of the SMR should be around 200 to 300 MW.
- The specific plant erection costs (€/kW installed electric power) should be less 20% compared with SMR concepts based on a PWR.
- The power plant shall remove the residual heat without the need of electric power at least within a time period of 3 days.
- The specific fuel cost (€/MWh electric power) shall be smaller than those of SMR concepts based on a PWR, which may be accomplished by a higher efficiency compensating higher fuel production costs.

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Project goals

- To define the design requirements for the future SCW-SMR technology
- Harmonisation and fostering of the trans-continental cooperation in the advanced nuclear technology to gain the most effective multi-national scientific and technical cooperation and gather the knowledge relevant to the SMR-SCWR development
- Harmonisation of the laboratory procedures and tools for effective research and development in the field of SMR-SCWR environment
- To keep and support the EURATOM to be active member of the multinational scientific platforms related to the SCWR/SMR-SCWR research
- Organize the events providing the interaction with regulatory bodies, vendors, operators and other end-users to spread the information of the SMR (especially the SCWR)
- Identify the key obstacles for the future SMR licencing and propose strategy for this process based on the findings on multinational level

Project goals II

- Complete the understanding of the corrosion behaviour of the most promising candidate materials at different conditions to support the qualification procedure of the future SCW-SMR constructional materials and assess the relation to the existing standards and guidelines
- Provide Reactor physics analysis of preliminary core layout
- Verification and validation and further development of the selected thermo-hydraulic system-, subchannel-, safety-, and CFD-codes and assessment of the proposed SMR-SCWR concepts by applying these codes
- Develop pre-licensing study and guidelines for the demonstration of the safety in the further development stages of the SCWR-SMR concept.

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Ambition

- To define the methodologies and tools for future innovative SMR assessment to provide the legislation environment ready for the future SMR-type reactors

- The selected phenomena from the each of the key fields covered by the project (constructional materials and radiation resistance, thermal-hydraulics and neutronics/reactor physics) should illustrate the safety and licensing relevant processed affecting the smooth licensing process for future reactors.

Major assumptions

- **Intrinsically and passively safe operation**: Particular focus will be put on the conceptual design of a core with a low power density, which allows in principle core cooling based only on the laws of physics (i.e. conduction and irradiation), and in any case assessing the most significant accident scenarios.
- In conjunction with the previous point, participants of the proposed project aim to define design requirements to a system with a neutron spectrum and economy, which will **minimize the minor actinides production** and will be potentially suitable for fertile nuclides fertilization (e.g. thorium resources exploitation).
- **Decommissioning**: Particular attention will be given to neutron fluency minimization outside the reactor core, in order to reduce the amount of activated materials for the dismantling of the reactor after the operational life of the reactor. Technical solutions, which will reduce the complexity of the reactor will be carefully considered.
- **Competitiveness**: The choice of SCW instead of conventional light water as coolant allows to increase reactor efficiency and reduce the capital costs, thus adopting an innovative technology which represents the natural evolution of common LWRs.
- **Cogeneration**: The adoption of SCW technologies, given the better heat conversion exploitation, will also facilitate the implementation of cogeneration in the industrial field, e.g. for water desalination (which represent a critical problem in some areas of the world, even more than energy availability).

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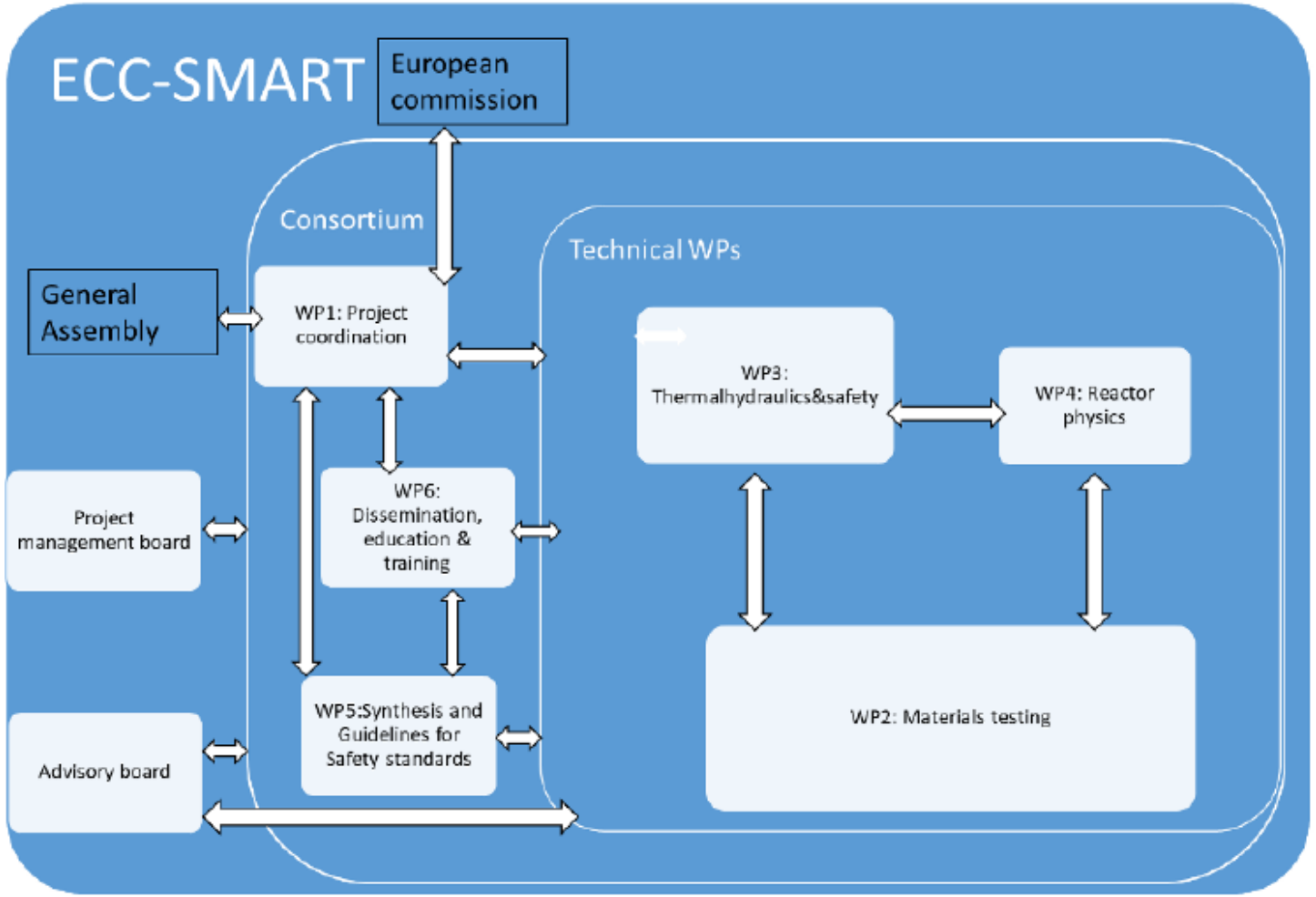
Project structure



WP2 – Materials testing

Main goals:

- to identify the licensing-related issues and knowledge gaps by gain more in-depth knowledge into the corrosion behaviour of candidate materials for the Small Modular Reactor cooled by Supercritical Water under non-irradiated and irradiated conditions.
- To perform electrochemical measurements in-situ to understand how changes in the physicochemical properties can affect the corrosion mechanismsin SCW
- To perfrom new tests focused on the radiolysis processes in supercritical water

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WP 3 - Thermal Hydraulics and Safety of the SCW-SMR

- Main goals:
  - To provide a database using experimental and numerical data
  - Improvement, implementation and validation of engineering CFD models for turbulent heat and mass transfer
  - Development and validation of heat transfer correlations and models for applications in system codes
  - Safety and design analysis of the SCW-SMR concept
  - Derivation of European-Canadian-Chinese (ECC) design requirements for a ECC SCW-SMR design concept; This design requirement document shall serve as a basis for a future conceptual design project.

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WP4 - Neutron physics of SCW-SMR

- WP4 aims at studying the design- and safety-related neutronic parameters and reactor physics behavior of SCW-SMR in order to support the pre-conceptual design

- Main goals:

1. Selection of proper neutron/reactor physics code for modelling the complex behaviour of SCW-SMR
2. Calculation of safety related neutron physics parameters
3. Reactor physics analysis of preliminary core layouts

WP 5 - Synthesis and Guidelines for Safety Standards

- Main goals:
  - Develop generic and specific safety criteria and requirements for the SCW-SMR concept;
  - Synthesize the main safety related findings and conclusions of the WPs 2-4;
  - Develop a pre-licensing study demonstrating the feasibility of the design to be licensed;
  - Develop guidelines for the demonstration of the safety in the further development stages of the SCW-SMR concept.

WP 6 - Dissemination and communication

- Main goals:
- Inform the nuclear community and the public about the Project.
- Provide proper communication and dissemination (documents and deliverables)
- Publication of Project results
- Organization of Events:
  - Project findings and advancements
  - Interaction with regulatory bodies, vendors, operators and end users to spread info of the SMR
- Organization of Training courses + setup exchange program (PhD, postdocs/young scientists)
- Communication channel with stakeholders and authorities

ISSCWR-10

The 10th International Symposium on Supercritical Water-Cooled Reactors

15th – 19th March, 2021

Prague, Czech Republic

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CVŘ Centrum výzkumu Řež

HORIZON 2020

Skupina ÚJV TECHNOLOGIE | INOVACE | LIDÉ

www.isscwr2021.com

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Thank you for your attention!

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