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Technology Platform

Topic 1 “reactor core and fuel”
SMR / Work Stream 5 on I, R&D

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CONTEXT: Work stream 5 / topic 1 versus European SMR pre-partnership

European SMR pre-Partnership

With the support of : ENSREG FORATOM SNETP

- WS1: Market analysis
- WS2: Licensing / harmonization
- WS3: Financing & partnership
- WS4: Supply chain adaptation
- **WS5: Innovation, Research & Development**

European SMR pre-Partnership – Steering Committee

General objectives

- **Identify enabling conditions and constraints, including financial ones,** towards safe design, construction and operation of SMRs in Europe in the next decade and beyond in compliance with the EU legislative framework in general and to the Euratom legislative framework in particular.

Specific objectives

- Develop the necessary industrial supply chain in Europe
- Encourage the implementation of common (harmonized) licensing process across the EU
- Establish a strategic research agenda :
  - LWR, as a mature technology to be deployed in 2030.
  - Advanced SMR (Gen IV) design have to be matured by 2035 for long term prospect

- **Composition:** FORATOM (chairing), SNETP, ENSREG, EC + chairs of 5 WS
- **Secretariat:** EC, FORATOM, SNETP
- **Meetings:** Kick-off 17 March 2022

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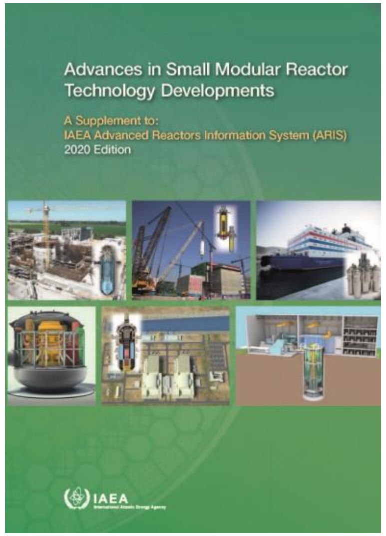
WS-5 / T-1 reactor core and fuel: output & presentation

- Ongoing work to describe topic 1 as a part of the **Strategic Research agenda on SMRs**
- Today's presentation focused on 2 sections: NEED & GAPS

- **NEED** to meet Green Deal targets in order to achieve net zero carbon emissions
  - SMRs are good candidates to replace fossil fuel fired power plants (few 100sMWe)
  - SMRs have the ability to electrify small capacity grids
  - SMRs can produce electricity, heat or a mix or deliver energy to a hydrogen production unit
  - SMRs provide flexibility to cope with Renewable Energies deployment
  - SMRs offer better financial affordability
  - SMRs present intrinsic safety features favoring public acceptance

- **GAPS** were structured depending on time-to-market of the different reactors technologies
  - LW-SMRs
  - HTGRs
  - Then AMRs



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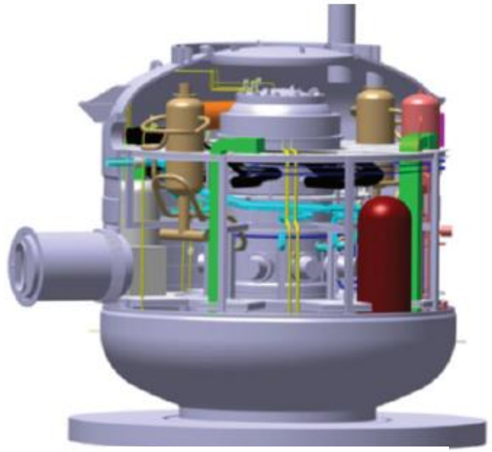
Reactor core and fuel: gaps for LW-SMRs (electricity + cogeneration)

- SMRs have smaller cores / higher neutron leakage (impact on BU, cycle length)
  - Fuel assembly with improved moderation (16x16 lattice…) or higher enrichment (>5%)
  - Reflector with new design, new material at periphery
- Design with non-soluble boron (safety & economics) → concern with local power peak factor
  - Study & qualify burnable poisons (Gd, Er, number & %)
  - Long term insertion of control rods (absorbers evolution, surrounding rods)
- Adaptability of SMRs to new fuels like Accident Tolerant Fuels & High Assay Low Enriched Uranium
- SMRs are shorter in height (impact on thermal hydraulics)
  - Critical heat flux under abnormal operation
- Possible fuels limits under cogeneration mode (different demands)
- Monitoring TH/n conditions through in core instrumentation (integrated architecture)
- Implementation of innovative multi physics and multiscale modeling and simulation to reduce design conservatisms and cost



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Reactor core and fuel: gaps for LW-SMRs (heat generation) gaps for HTGRs

- **LW-SMRs dedicated to heat production** (like district heating) will operate at low pressure (less than 15 bars) and temperature (less than 170°C)
  - Fuel (pellet and cladding) qualification at small p/T
  - Reactivity feedbacks for core driving
  - Core sensitivity to specific transients
  - Validation of thermal hydraulics models at low pressure (higher range of void fraction)

- **Modular HTGRs** offer the ability to release the decay heat by intrinsic properties of the core & reactor. Two main gaps identified:
  - European fuel manufacturing process: kernels, coating, compacts/pebbles
  - Development of NDE techniques for quality control of TRISO fuel
  - *Check the validation of core analysis tools*
  - *Development and qualification of a fuel performance code*

Reactor core and fuel: gaps for AMRs gaps Na / Pb FRs & gaps for MSRs

- **For AMRs (gen IV types):** very wide scope / necessary to focus on specific technologies (input from steering committee) then identify specific I, R&D actions regarding « small & modular » reactors

- **For sodium and lead fast reactors.** Focus on actions linked with the small size
  - Fuel qualification at higher enrichment (Pu>30%)
  - Fuel qualification at lower power ratings
  - Passive shutdown systems (design, materials, reliability)
  - For actinide burners : fuel qualification with minor actinides

- **For MSRs (molten salt reactors) :** fast spectrum chloride MSR is the most attractive technology for sustainability
  - Data acquisition on the fuel molten salt properties (thermophysical and thermochemical)
  - Fission products behavior in the salt
  - Fuel salt post-irradiation properties measurements
  - Qualification of the core neutronics and coupling with the thermal hydraulic
  - Simulation of the fuel salt composition during operation
  - Development and qualification of the fuel reprocessing
  - Nuclear data acquisition on the Cl isotopes for fast spectrum

WS-5 / T-1 reactor core and fuel: CONCLUSION

- **The group has focused on the identification of I, R&D gaps that would need to be investigated, in order to support SMRs deployment in Europe**

- **This presentation shares the current status for**
  - LW-SMRs (electricity + cogeneration)
  - LW-SMRs (heat applications)
  - HTGRs
  - AMRS, MSRs
- **Some topics were discussed in the NUGENIA TA6 meeting held in June 1, 2022**
- **This work will be consolidated in the coming months**

- **For additional information and comments, please contact : eric.hanus@cea.fr; geraud.prulhiere@cea.fr;**

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