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The challenges of future nuclear power in Europe: SMR partnership

Bernard SALHA,

President SNETP

The Nuclear in the EU : Overall vision of SNETP between 2021 and 2050

2021

- 104 power reactors (=50% of carbon free generation)
- 100 billions €
- 1.1 M jobs
- 29 research reactors
- Many applications (medical, chip doping, space, industry, etc.)

Industry & Research vision 2050

- Significant share of Nuclear across 2050 EU scenarios
- Nuclear brings dispatchable carbon-free power to a system w/ large share of vRES
  Nuclear is v. flexible / versatile & provides massive carbon-free energy for H2, district / industrial heat, etc.
- New technologies & applications have emerged (SMRs, Gen IV)
- Long Term solutions for High Level Waste available (inc repositories)

=>To achieve this & keep EU leadership, the nuclear industry needs:

- A conducive investment framework
- A performing, continuous & modernized supply chain, R&D labs and competences
- **Investing in Innovation & R&D in order to support Industry & Research Vision 2050**

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- **The association (AISBL, under Belgian law) gathers more than 110 stakeholders (including SCK.CEN, BELV, ENGIE….) from industry, research centers, safety organisations, universities, non-governmental organisations, SMEs …**

Gen II = existing Light water reactor
GEN III = new LWR
GEN IV = advanced (modular reactor)

SNETP is the European Technology & Innovation platform for Nuclear Energy focused on Gen II-III and IV reactors with electric and non-electric application

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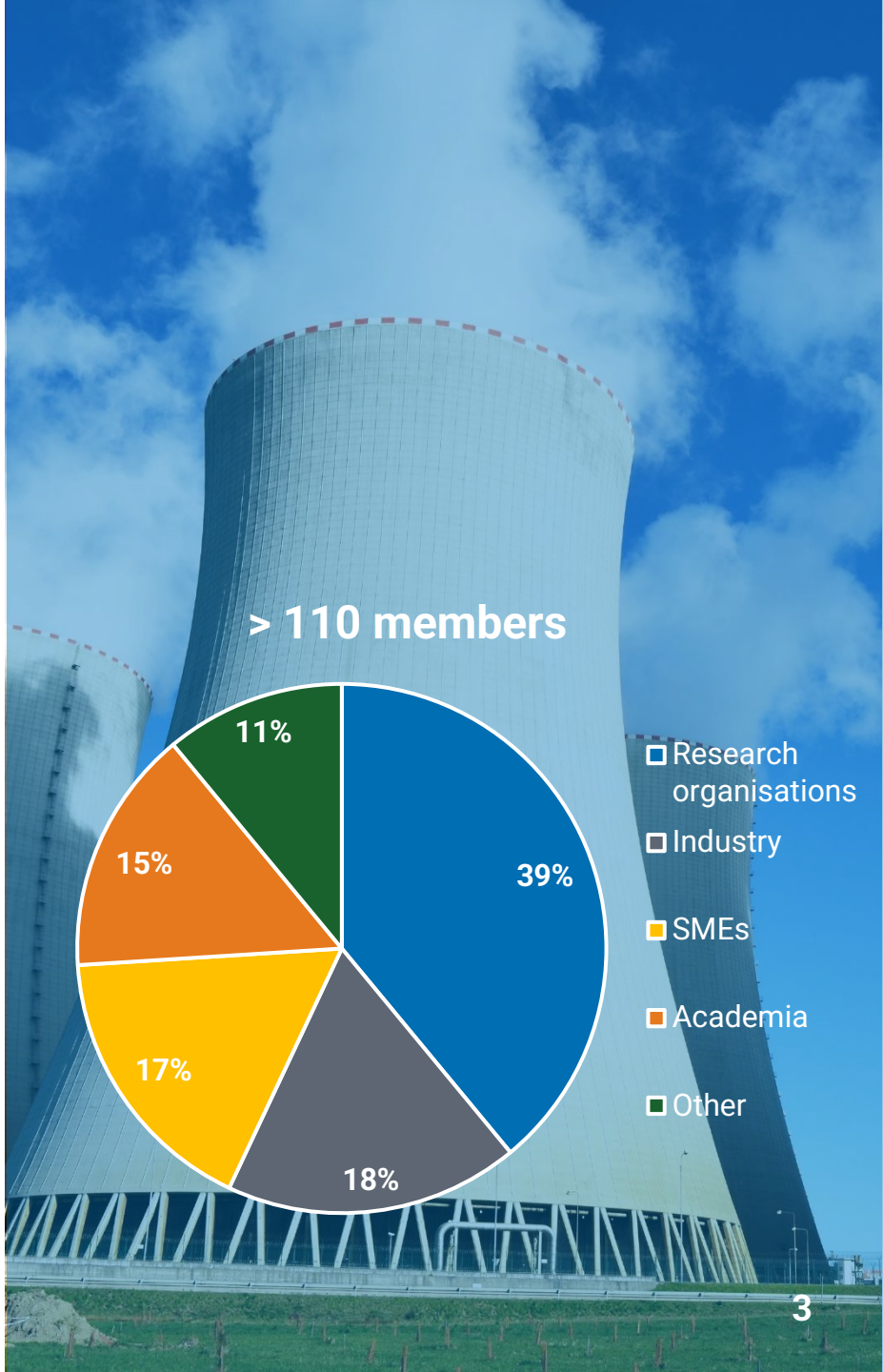


NUGENIA Vision

- **Importance of LTO for NPP economics & the grid:**
  - as nuclear has high fixed costs and low running costs
  - as it operates within a deregulated competitive electricity market
  - as nuclear remains essential to complement variable sources → Need for flexibility
  - as it supports the security of electricity supply
- **A European-wide, industrial-driven nuclear R&D programme:**
  - is key to maintaining nuclear competitiveness & safety in the EU
  - paves the way for the emergence of spin-offs in other sectors (health, energy, clean heat, hydrogen, construction, industrial manufacturing, etc.)
- **Three R&D & innovation priorities**
  - Innovation & competitiveness (inc. EPR, SMRs, passive safety, EATF, additive M, etc.)
  - Digital transition (digital reactor, multi-physics modelling, advanced computing)
  - Safety & environment (accidents & hazards, severe accidents, D & WM)

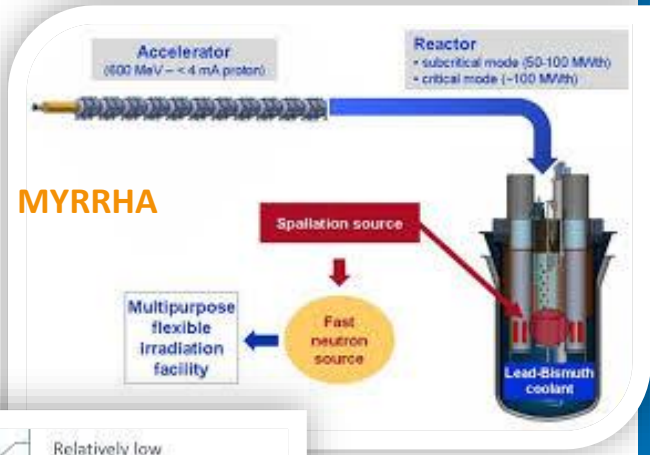
ESNII vision: Advanced (Modular) Reactors Technologies

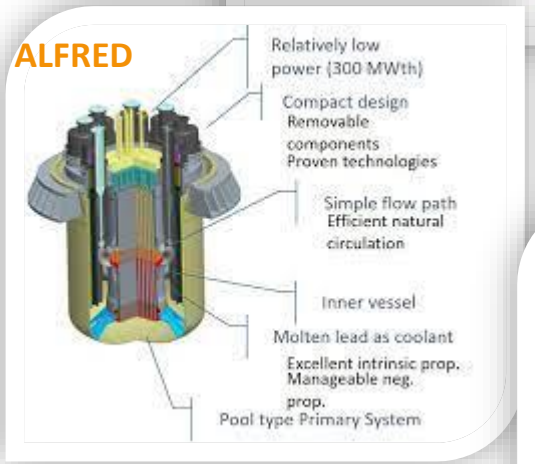
- **MYRRHA** (Multi-purpose hYbrid Research Reactor for High-tech Applications) , a **lead-bismuth Accelerator Driven System** to demonstrate transmutation of high-level waste, & to support the maturity of ESNII technologies

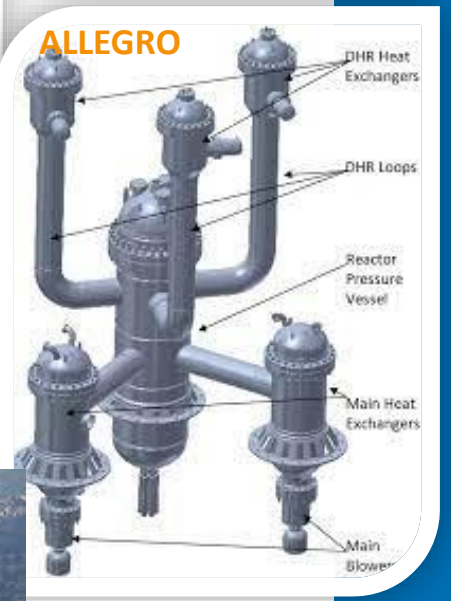
- The **Lead-cooled Fast Reactor (LFR)** and the **ALFRED** (Advanced Lead-cooled Fast Reactor European Demonstrator) project to build a European demonstrator of the LFR technology;

- The **Gas-cooled Fast Reactor (GFR)** and the **ALLEGRO** project (GFR demonstrator), an initiative with the goal to build an experimental facility to demonstrate the technological viability of the concept;

- The **Sodium-cooled Fast Reactor (SFR)** is the most internationally mature technology. Its industrial deployment in Europe necessitates still some improvements (safety, economic, …).







Demo Project at the soonest by 2035

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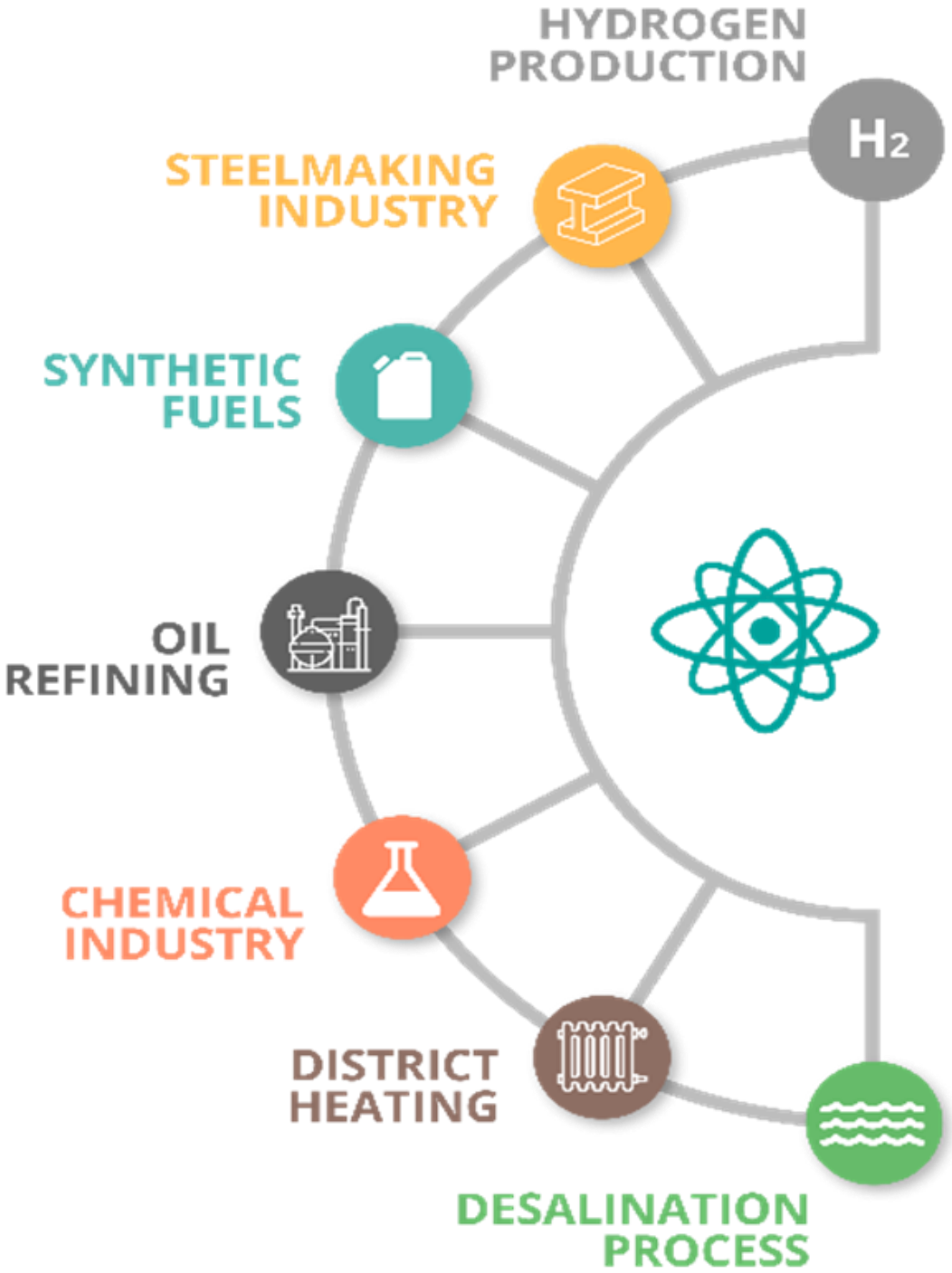
NC2I Mission

Contribute to clean and competitive energy beyond electricity by facilitating deployment of nuclear cogeneration plants



The work is focused on HTR in close synergy with other technologies

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SNETP strategy based on:

- **Nuclear Energy is one key element of electricity generation by 2050 according to EU long term scenarios (15% of the mix)**
- **Nuclear research and innovation is key to keep on strengthening safety, performance, dismantling, waste management**
- **The door shall be kept widely open for research and innovation on new reactors (such as SMR, Gen IV) which could provide enhanced safety, performance and waste management**
- **Nuclear is a transverse technology with strong impact on other fields such as medicine, but also data management, industrial software development, balanced energy mix with variable RES**

Digitalisation	Advanced manufacturing	Hydrogen

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The approach: *From Long Term Operation (now) , to new Commercial Light Water Reactors (2030 and beyond) followed by Commercial Advanced Modular Reactors (beyond 2050)*

- **Together with Renewables, Nuclear reactors are a key asset to reach Net Zero by 2050**
  - **Long Term Operation of existing Nuclear Power plant has to be strengthened in a safe and industrial way**
  - New Gen III reactors are to be built: the technology has to be commercial no later than 2030 in order to play a significant role in the Net Zero Objective
  - **➔ Light Water Reactor (LWR), both big plants and Small Modular Reactors (SMR) is today the unique solution to reach this objective**

- **Nuclear has to be sustainable on the long run ie beyond 2050**
  - Long Life wastes have to be reduced;
  - Uranium fuel has to be recycled
  - **➔ Advanced Modular Reactor , big and small plants (AMR), is the unique solution to reach this objective**
  - **➔ First demonstration projects could be available at the soonest by 2035 ; commercial projects beyond 2050**

- **Continuity in policy is necessary between those two calendars steps:**
  - Nuclear industry is a long leading time industry (20 years from Lab to Industry)
  - Research development for LWR is beneficial to AMR
  - Huge synergies exist for Industrial supply chain and human competences between LWR and AMR

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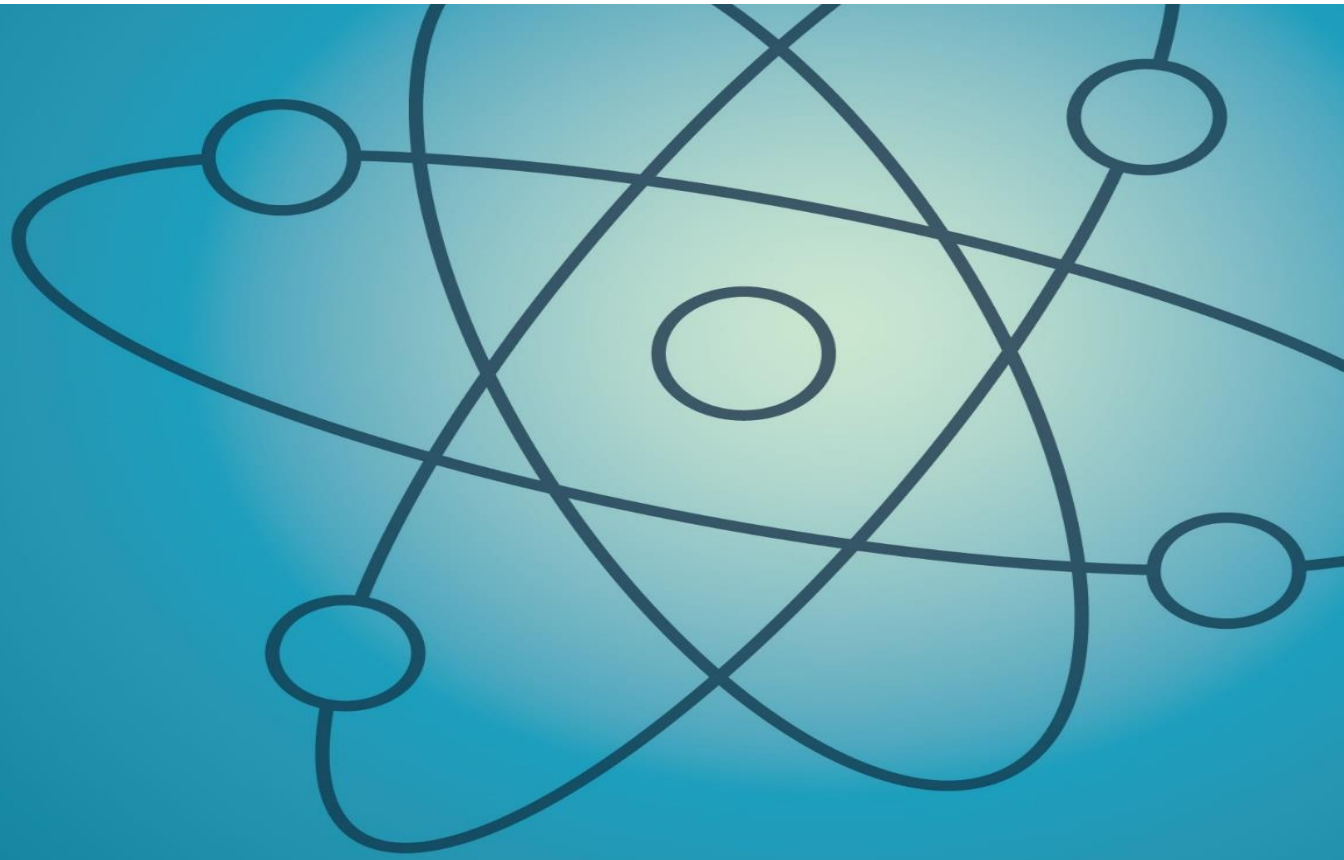
European SMR pre-Partnership

Steering Committee (SC) and specific Work-Streams (WSs)



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EU SMR-partnership to start 2023

- **Scope:**
  - **Establishing in the EU a domestic/European SMR programme as defined in the EC's "Vision for a decarbonised energy sector including European Small Modular Reactors",**
  - **creating necessary enabling conditions for the first EU SMRs to start operation in 2030.**
  - **co-ordinate MS & industry strategies towards an integrated and Robust supply chain in Europe.**
- **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-SMR, as a mature technology to be deployed in 2030.**
    - **Advanced SMR (AMR-GENIV) design has to be matured by 2035 for long term prospect (sustainability) of fission technology.**
  - **Develop an international marketing strategy of the European SMR value chain**

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First EU Workshop on Small Modular Reactors (SMRs) - 29 June 2021

- Organised by the European Commission's DG ENER in response to the call of the European nuclear industry;
- 110 participants from 22 Member States;
- A "vision paper" of industry stakeholders widely endorsed by the participants;
- Including a proposal for a 'European SMRs Partnership'.
  - collaboration scheme involving industrial stakeholders, research & technological organisations, interested customers (i.e. utilities and even Member States), as well as European policy-makers and regulators

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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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European SMR pre-Partnership – Steering Committee

Expected activities:

- Review and validate the work program (main deliverables, schedule) for each WS;
- Ensure smooth coordination across WSs, set milestones and ensure proper conclusions / outcomes;
- Analyse potential constraints to overcome for the next phase (Partnership) and propose solutions (including policy recommendations at European / national level if needed);
- Review enabling conditions for SMRs development in Europe and propose approaches to activate them or further develop them if necessary;
- Prepare the conditions for the next phase (Partnership implementation phase) which shall cover all relevant aspects (legal, resources, ….) and the ground for the Partnership phase with proper benchmarking of other coalition initiatives at EU level (batteries, hydrogen, etc.);
- Interact / report on progress made with the Stakeholder forum on a regular basis;
- Coordinate relationships with international partners (such as UK, USA, CAN, JP, etc.) and international organisations (such as IAEA, OECD-NEA, etc.) in order to avoid overlap and duplication of efforts.

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WS1 – Market analysis

Objectives:

- Identify future needs of the EU energy/power market (electricity, industrial and residential heat, hydrogen), SMR capabilities for these needs in a context of high RES deployment, market size, and global competitiveness;
- SMRs as technology to replace coal and gas plants, help decarbonize assets/processes such as hydrogen production, district heating, industrial heat processes, and provide load balancing capabilities to Transmission System Operators (TSOs)
- Establish a list of sustainablility criteria on a shortlist of SMR technologies (SMR/AMR).

Main ongoing activities:

- Task 1 : Literature analysis done ; the draft of the report has started with inputs expected on 1) the EU market size/needs, 2) technical-economic capabilities of SMRs, 3) market potential for SMR development
- Task 2 : Three surveys are being consolidated : 1st survey for industrial users will be launched by the end of April ; 2nd survey for Member States must be coordinated with WS 4 (questions are being gathered) : 3rd survey for TSOs is in preparation.
- Task 3 : Validate the list of sustainability criteria to be considered, and add a question regarding the relevance/importance of these criteria in the SMR users survey(s)

Responsability: FORATOM

Chair: Tractebel

Contributors:

- Foratom-SMR-task force: Tractebel, Engie, Fortum, Rolls-Royce, EDF, Orano, Vattenfall,, SCK-CEN, CEA.
- Kick-off meeting: 14 January 2022

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WS2 – Licencing

Objective:

- Identify the elements for establishing a European pre-licensing process based on commonly accepted safety assessments from different ENSREG members interested in the licensing of the same SMR design

Main ongoing activities:

- Establish a clear state of play of activities in other fora (IAEA, SMR Regulatory Forum, NEA Committees, WENRA, ENISS, CORDEL, etc.) in relation to SMR licensing
- Develop a common understanding on NPPs licensing processes in different EU countries interested in SMR licensing (main milestones, etc.)
- Review ongoing or starting H2020 research projects in the field of SMR safety and licensing

Responsibility: ENSREG

Chair: ASN

Contributors:

- 16 experts from 13 countries' nuclear safety authorities from: DE, HU, LT, FI, SE, IT, FR, RO, SK, NL, ES, CZ and PO + industry representative: ENISS

- Kick off meeting: 3 March 2022

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WS3 – Financing

Objectives:

- To clarify specifics of SMRs financing (e.g. conditions for a Private Public Partnership at EU level) and
- To define the needs for a conducive investment environment / framework for SMRs in Europe.

Responsibility: FORATOM

To be launched in the second half of 2022

WS4 – Supply chain adaptation

Objectives:

- Identify the key features of an SMR supply Chain (vs. current practice)
- Analyze the existing gaps and the main hurdles to overcome
- Identify which ones are largely technology-independent and define roadmaps to address them
- Identify recommendations to systematically address technology-dependent hurdles from various partnerships

Main ongoing activities:

- Early interaction with SMR Vendors to check which are the issues related to the Supply chain - Development of a questionnaire sent to a selected list involved in various SMR programmes in European countries (including UK).
- Standardisation, possible use of non-nuclear, high quality components - review of existing work in the field

Responsability: FORATOM

Chair : Ansaldo Nucleare

Contributors:

- Ansaldo Nucleare, Fortum, Orano, Engie, Empresarios Agrupados, Rolls-Royce, Nuclearelectrica, GIFEN, EDF, Framatome, Assystem, SNETP
- Kick-off meeting: 18 January 2022

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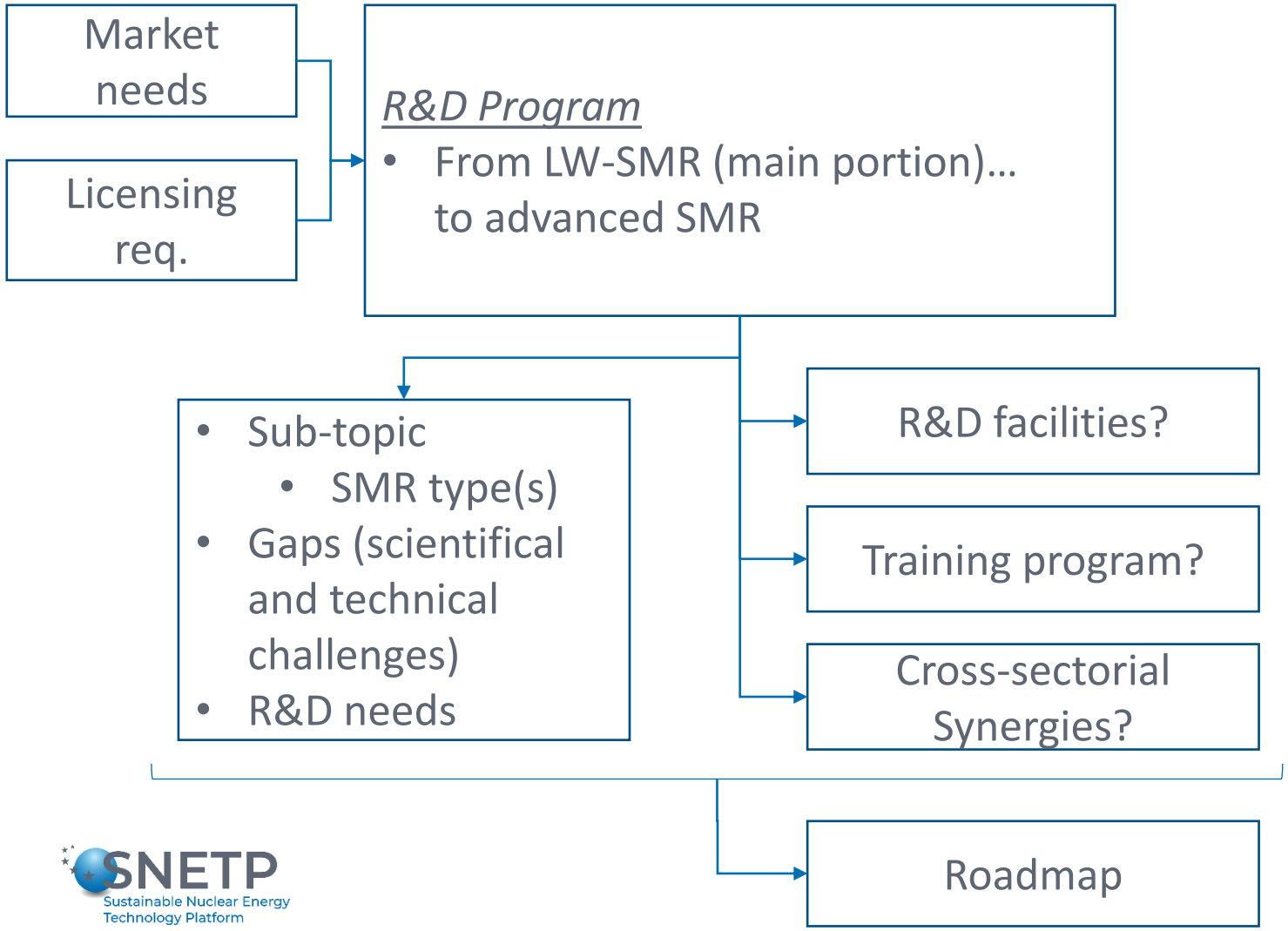
What R&D&I roadmap for a European SMR development?

- **Objectives of the Workstream 5**
  - Define R&D&I program consistent with market needs and licensing requirements for SMRs development,
    - Share a common view on the roadmap to clear technical/scientifical hurdles and necessary R&D to demonstrate the safety and performance of SMR features.
      Paving the way to LW-SMR deployment to achieve timely the Net Zero by 2050 objective, by demonstrating the maturity and competitiveness of SMR with a first commercial operation in the 2030s.
    - …and from LW-SMRs to advanced SMR (AMR / Gen IV) in the longer term, for nuclear sustainability (raw materials – uranium, limiting the impact of long-life waste)
  - identify the needed facilities to execute this program
  - set up a coherent training and education program
- WS5 is composed of ~60 contributors from various EU players:
  - JRC, EDF, CEA, IRSN, Framatome, SCK.CEN, VTT, Engie/Tractebel, UJV Rez, ENEA, ANSALDO Nucleare, NCBJ, NRG, Ecole des Mines, CIEMAT, NINE, NC2I….

R&D&I proposed roadmap is structured according to 7 technical topics



- General
1. Core/fuel
2. NSSS Integrated vessel and its internals
3. Passive systems
4. Severe Accidents
5. Modularity
6. Human Factors and autonomy
7. Uses beyond electricity

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Topic 1: Core / Fuel

- Leader: Eric Hanus (CEA) + 12 contributors
- A: LW-SMR vs. B: AMR
  - Different topics: A then B
- Sample of key R&D&I topics
  - Critical Heat Flux of shorter Fuel Assemblies, burnable poisons, InCore instrumentation, vibration and mechanical behavior of the fuel assemblies / Control rods
  - Specific AMR fuel qualification

Topic 2: NSSS vessel and internals

- Leader: Oliver Martin (JRC) + 7 contributors
- A: LW-SMR vs. B: AMR
  - Common portion + A (iPWR specific) then B
- Sample of key R&D&I topics
  - Specific components development for compact designs
  - Thermal-Hydraulics in integral reactors
  - Advanced incl. additive manufacturing
  - Adaptation of In-Service Inspection requirements/means
  - Materials, especially for advanced SMR

Topic 3: Passive systems

- Leader: Fulvio Mascari (ENEA) + 8 contributors
- A: LW-SMR vs. B: AMR
  - Common
- Sample of key R&D&I topics
  - Lack of available experimental test campaigns: large scale facilities at low flow regime, experiments to validate CFD, high-resolution data
  - Deterministic analysis codes qualification
  - Passive systems reliability

Topic 4: Severe accidents

- Leader: Philippe Dejardin (ENGIE/Tractebel) + 13 contributors
- A: LW-SMR vs. B: AMR
  - Different topics: A then B
- Sample of key R&D&I topics
  - Tools and methods to demonstrate
    - RPV integrity
    - Containment integrity
    - and Emergency Planning Zones
  - SA Scenarios for advanced SMRs

Topic 5: Modularity

- Leader: Massimo Marconi (Ansaldo) + 8 contributors
- A: LW-SMR vs. B: AMR
  - Common
- Sample of key R&D&I topics
  - Adaptation of engineering methodologies
  - Construction techniques and technologies to shorten construction duration
  - Modules assembly and connections to the structure

Topic 6: Human factors

- Leader: Stanislas Couix (EDF) + 4 contributors
- A: LW-SMR vs. B: AMR
  - Common
- Sample of key R&D&I topics
  - Multi unit operation in a single main control room
  - Impact of the passive safety system on tasks and activities of staff

Topic 7: Uses beyond electricity

- Leader: Ville Tulkki (VTT) + 7 contributors
- A: LW-SMR vs. B: AMR
  - Common
- Sample of key R&D&I topics
  - Technical coupling technologies between nuclear plant and heat use facility
  - Safety & licensing issues due to the colocation of nuclear + other plant
  - Operability / Maneuverability performance of hybrid systems

WS5 way forward

- Clarify the interfaces and expectations from other workstreams, especially WS2 on licensing: e.g., streamlined EU Regulatory Bodies position on topics of interests such as passive system qualification, severe accidents scenarios, or operator crew organization; specific SMR safety objectives?
- Issue a first revision of the R&D program document in the short term, before complementing it with insights from designers/licensees forerunners of the EU SMR partnership, and EU R&D facilities
- Be in position to provide a consolidated R&D&I roadmap at the effective launch of the Partnership addressing R&D gaps beneficial to all EU SMR partners

Take-away

- EU-citizens and industry need access to energy 24/7 in a **safe , resilient and affordable way**;
- Electricity demand is set to **increase from 3000TWh to 4808TWh by 2050** due to increased electrification;
- Nuclear provides **both flexible and dispatchable electricity**, **generating large quantities** of low-carbon energy **24/7** without the need for other backup sources of energy nor large-scale storage;
- SNETP as **the unique technological platform** for fission R&D&I to dialogue with the EC services and member states;
- **Big reactors and SMR development and deployment** in Europe is an opportunity for a **better mitigation of climate change, affordable energy prices, security of supply and Net-Zero emission by 2050**;
- **Together with big LWRs existing design, LWR- SMR are mature** to be deployed starting 2030 as a key asset to succeed with Net Zero by 2050;
- **AMR design to be matured by 2035 to ensure the sustainability** of fission technology by 2050 and beyond;
- The multiple challenges necessitate:
  - **high and continuous involvement of EU-Member states** together with EC services and industry (such as SMR partnership)
  - State of the art **experimental facilities** and demonstration
  - **Highly skilled competences** and **affordable supply chain in a continuous process**

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