WORKSHOP
14 October 2022

European SMR pre-Partnership

With the support of:

- European Nuclear Safety Regulators Group (ENSREG)
- Nucleareurope
- Sustainable Nuclear Energy Technology Platform (SNETP)
• 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
European SMR pre-Partnership – Steering Committee

General objectives

- **Identify enabling conditions and constraints** 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**: nucleareurope (chairing), SNETP, ENSREG, EC + chairs of 5 WS
- **Secretariat**: EC, nucleareurope, SNETP
- **Meetings**: Kick-off 17 March 2022; 4 meetings so far (last one 13 October)
Objectives:

• Identify future needs of the EU energy/power market (electricity, industrial and residential heat, hydrogen), market size and global competitiveness in a context of high RES deployment;

• Assess 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 sustainability criteria to highlight SMR technologies added value (SMR/AMR) compared to alternative energy options.

Responsibility: nucleareurope
Chair: Tractebel
Contributors:
• nucleareurope-SMR-task force: Tractebel, Engie, Fortum, Rolls-Royce, EDF, Orano, Vattenfall, SCK-CEN, CEA, Nuclearelectrica.
• Kick-off meeting: 14 January 2022
Main ongoing activities:

- Task 1: Literature analysis conducted to address 1) the EU market size/needs, 2) technical-economic capabilities of SMRs, 3) market potential for SMR development
  - First draft report done and commented, Complete report expected in November
- Task 2: Surveys to assess appetite from:
  - Industrial users → no answers received yet
  - National Fora → 4 answers received
  - Member States → 3 answers received
  - TSOs → in preparation.
- Task 3: Establish a list of sustainability criteria. Report that assesses SMR technologies vs. alternative energy solutions in light of this criteria
  - List of sustainability criteria completed
  - First draft report expected in November, Complete report by the end of the year
Key insights gained at this stage:

- European market needs for low-carbon energy are huge (may appear unbelievable) → there is room for everyone (nuclear and renewables)
- What will drive success for SMRs is delivery on time and on budget
- Beyond that step, market upscale is the real challenge and needs to be at least on par with nuclear deployment pace in 1970s and 1980s
- Still a lack of knowledge of SMRs from Industrial users (probably the reason for absence of answers to the survey) → nuclear industry needs to open towards the outside and demystify SMR technology
- Security of supply, energy sovereignty cited several times in the surveys as a driver toward SMRs by national for a and member states
- National policies cited several times as the main hurdle
WS2 – Licencing

• ENSREG (European Nuclear Safety Regulators Group)

• WS2 on SMR licensing
  • Objectives
  • Activities

• SMRs new designs – what are we talking about?

• What harmonisation needs to be done for SMRs?
  • A. Safety requirements
  • B. Authorisation or licensing process

• Conclusion

• Q/A
• **European Nuclear Safety Regulators Group (ENSREG)**

• Independent expert advisory group to the Commission created in 2007

• **Senior officials** from national regulatory authorities and the Commission

• Plays a key role in:
  
  ➢ The preparation of **new EU legislation**
  
  ➢ Nuclear “**Stress Tests**” in Europe and abroad and their follow-up
  
  ➢ EU “**Topical Peer Reviews**”
  
  ➢ **Preparatory steps of the European SMR pre-Partnership**
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

Responsibility: ENSREG - Chair: ASN

Contributors: 17 experts from 14 countries’ nuclear safety authorities from: AT, DE, HU, LT, FI, SE, IT, FR, RO, SK, NL, ES, CZ and PO + industry representative: ENISS

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.)

• Collaboration ongoing with WS5 on three topics: Human Factors, Severe Accidents, Passive Systems.

• Collaboration starting with WS4 on Codes & Standards.
Goal: To have an efficient preparation for license application in different EU countries

**1.** Engage early dialogue between designers - licensees and regulators on main elements of the design options

**2.** Promote cooperation of “interested” regulators to carry out a joint safety pre-assessment on a mature design

**3.** Review in advance key elements of the licensing process and “Safety Case” of the “interested” countries to avoid blocking points at a later stage
1) SMRs new designs – what are we talking about?

New SMR designs are based on technologies that have existed for many years (not for commercial use, but for research reactors (molten salts, HTRs, etc.) or in the naval sector (PWRs, lead reactors))

However, considered as innovative reactors because of:

- technological innovations
- intellectual innovations

Most regulations are goal oriented

- no means specified
- licensees can choose the most appropriate provision

An innovation must be not only attractive but has to be a proven technology

- this takes time: time for R&D, experiments, studies, qualification

CHALLENGE
Engage early dialogue on innovations between regulators and innovation’s support (licensee, vendors, start-up)
2) What harmonisation needs to be done for SMRs?

Industry calls for harmonization

There is a need to distinguish harmonisation of

- A. Safety requirements
- B. Authorisation or licensing process

A. Safety requirements

- Established in different frameworks (IAEA, WENRA) and built on the experience of what is already implemented (mainly derived from water reactors)

No need really for requirements harmonization now, nor for C&S

- It is rather how to demonstrate compliance with the requirements that needs to be worked on
2) What harmonisation needs to be done for SMRs?

Cooperation between regulators on the pre-assessment of SMRs is an opportunity

- to share regulators’ approach

- it brings robustness to the assessment: it may lead (or not) to common positions. The common positions or dissensus (and why) are made clear to the licensees and provides predictability.

It requires a **mature design**, a **similar time frame** for regulators reviews and therefore a cooperation of licensees as well.

**CHALLENGE**

Promote cooperation of interested regulators to carry out a joint pre-assessment on a mature design.
3) What harmonisation needs to be done for SMRs?

B. Authorisation or licensing process

- Cooperation carried out in some frameworks (EU, IAEA, NEA, etc.): should contribute to a certain convergence in the pre-licensing or licensing processes

At this stage, it cannot lead to international certification or reciprocal recognition of the authorisations issued by the safety authorities

**CHALLENGE**

Review in advance key elements of the licensing process and “Safety Case” of the “interested” countries to avoid blocking points at a later stage

*NB: Authorisation remains the sovereign responsibility of states*
Conclusion

Goal: To have an efficient preparation for license application in different EU countries

1. Engage early dialogue between designers - licensees and regulators on main elements of the design options

2. Promote cooperation of “interested” regulators to carry out a joint safety pre-assessment on a mature design

3. Review in advance key elements of the licensing process and “Safety Case” of the “interested” countries to avoid blocking points at a later stage
Goals:

• 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
WS4 – Supply chain adaptation

Objectives:

1. Identify specific needs for SMR manufacturing
2. Identify tier1/ tier 2 supply chains in Europe and their adequacy to the needs
3. Standardisation: how, and how far, to promote it
4. Modularity, Quality insurance & Reliability: possible synergies with other industrial sectors
5. How to maximise new tools and methods in SMR manufacturing
6. Possible use of non-nuclear, high quality components
7. Robustness of the future supply chain
WS4 – Supply chain adaptation

1. Identify specific needs for SMR manufacturing
   • Key features to support series effects
   • Factory fabrication (at which extent?)
   • Lead times
   • …..

   interaction with several vendors

2. Identify tier1/ tier 2 supply chains in Europe and their adequacy to the needs
   • EU based
   • Wide-range categorization

   survey among national industrial member fora
WS4 – Supply chain adaptation

3. Standardisation: how, and how far, to promote it
   - New codes and standards required?
   - Transnational application/ licensing aspects
   Review of IAEA works / interaction with WS 2

4. Modularity, Quality insurance & Reliability
   - How can we learn from other industrial sectors?
   - Which potential barriers in terms of quality requirements?
   Interviews with experts

5. How to maximise new tools and methods in SMR manufacturing
   - How to improve series production through advanced manufacturing?
   - How to qualify new manufacturing techniques for nuclear application?
   Interviews, review of existing literature from other sectors
6. Possible use of non-nuclear, high quality components
   • Path towards simplification and cost reduction?

   Review of JRC works on the subject

7. Robustness of the future supply chain
   • More components per installed power: capability issues?
   • Dedicated factory management issues
   • Staffing considerations for SMR design, manufacturing & operations
Objectives: building a R&D&I roadmap, in line with market needs and regulatory requirements, and promoting its realization

- 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/scientific 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

Responsibility: SNETP

Contributors: (~60 p.) JRC, EDF, CEA, IRSN, GRS, Framatome, SCK.CEN, VTT, Engie/Tractebel, UJV Rez, ENEA, Ansaldo Nucleare, NCBJ, NRG, Ecole des Mines, CIEMAT, NINE, NC2I, Becker Technologies, …
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

**R&D Program**
- From LW-SMR (main portion) to advanced SMR

**Market needs**

**Licensing req.**

**R&D Program**
- Sub-topic
  - SMR type(s)
  - Gaps (scientific and technical challenges)
  - R&D needs

**R&D facilities?**

**Training program?**

**Cross-sectorial Synergies?**

**Roadmap**
WS5 needs will be more accurate when technologies of specific interest will be selected

<table>
<thead>
<tr>
<th>Topic</th>
<th>Leader</th>
<th>A: LW-SMR vs. B: AMR</th>
<th>Sample of key subtopics</th>
</tr>
</thead>
<tbody>
<tr>
<td>0. General</td>
<td>S. Takenouti (EDF), V. Tulkki (VTT)+ SNETP (Scientific com.)</td>
<td>Overall consistency</td>
<td>Aspects not covered by other topics?</td>
</tr>
<tr>
<td>1. Core/Fuel</td>
<td>E. Hanus (CEA) + 12 contributors</td>
<td>Different issues: A then B (HTGR; others Gen 4)</td>
<td>Adaptations to regular LWR fuel (shorter fissile length, burnable poisons, InCore instrumentation)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Irradiation of control rods / fuel with burnable poison</td>
</tr>
<tr>
<td>2. NSSS Vessel</td>
<td>O. Martin (JRC) + 7 contributors</td>
<td>Common for advanced manufacturing. A (iPWR specific) then B</td>
<td>Advanced manufacturing methods; adaptation of In-Service Inspection requirements/means; Specific components development</td>
</tr>
<tr>
<td>3. Passive systems</td>
<td>F. Mascari (ENEA) + 8 contributors</td>
<td>Common</td>
<td>Study of the coupling between reactor coolant system and (small) containment</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Reliability evaluation (methodologies robustness vs. different transient scenarios and conditions, assessment of functional failure related to the T-H phenomena and associated uncertainties)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Facilities to expand the experimental database for code validation for PCCS, SACO, etc.</td>
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**WS5 needs will be more accurate when technologies of specific interest will be selected**

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| 4. Severe Accidents    | P. Dejardin (ENGIE) + 13 contributors       | Different issues: A then B | Postulated SA scenarios, **numeric tools and methods** for deterministic and probabilistic analyses  
Specific modeling of phenomena in small containments |
| 5. Modularity          | M. Marconi (Ansaldo) + 8 contributors       | Common               | Codes, connecting solutions/qualification  
Methodologies for the modularization: full integrated Building Information Model addressing modules (tools and methods, including digital twins) |
| 6. Human Factors       | S. Couix (EDF) + 4 contributors             | Common               | Virtual or real-size surrogate MCR for 2 reactors or more (**Multi unit operation in a single control room**)  
Organization and procedures for passive systems, hybridization |
| 7. Uses beyond electricity | V. Tulkki (VTT) + 7 contributors          | Common               | **Follow-up TANDEM project, waiting for WS1** (**markets**) inputs  
Capability of hybrid systems to enhance the load follow capabilities |
Objectives: building a R&D&I roadmap, in line with market needs and regulatory requirements, and promoting its realization

- Preparation of the involvements of reactor designers/vendors is key
  - Discussions within WS5 on the possible first R&D actions for LW-SMR LW Designs / AMR technologies selection is needed to further develop the roadmap: biggest part of specific needs depend on the actual designs of interest (e.g. validation of NSSS components), and the generic needs would be more accurate when a few designs (LW-SMR) or technologies (AMR) of interest are selected (e.g. for materials)

- Interfaces with other workstreams
  - WS1 markets: to confirm R&D is consistent with the market needs
  - WS2 licensing: Have a clear view on the level of harmonization (on the licensing process, on safety objectives) among European Regulatory Bodies, in order to facilitate the design development of innovative reactors, that could in the end meet national regulatory requirements.

Be in position to propose robust SMR designs, where a unique design would fit to accommodate the variety of national regulatory expectations or interpretations.
Objectives: build a comprehensive and credible R&D&I roadmap to secure an on-time deployment of SMR in Europe

- Identification and prioritization of the relevant R&D work needed to enable SMR deployment, considering market needs and regulators expectations.

- Make it possible to pool resources for common R&D needs among SMR designs, e.g. enhancing the experimental database for accuracy of numerical simulation

- Network of R&D facilities across EU
Panel discussion
Overview of the LWR SMR designs considered in Europe – Anicet Touré, ENGIE-Tractebel

Discussion with LWR SMR designers:

- Nuward - Sandro Baldi
- Rolls-Royce SMR - Sophie Macfarlane-Smith
- GE-Hitachi - Fredrik Vitaback
What drives the industry towards SMRs

#1
Foster nuclear investments → Improve delivery

#2
Recreate **public trust** in nuclear

#3
Expand **role in zero-carbon transition**

- **Smaller & Modular**
- **Simpler & Safer**
- **Standardized & Versatile**
The first wave of SMRs will be Light Water Reactors

- BWRX-300 (GE-Hitachi)
  - Single-Module BWR
  - 300MW
  - Expected COD: 2028, Darlington, Canada; ca. 2029, Clinch River, USA

- RR SMR (Rolls-Royce)
  - Single-Module PWR
  - 470MW
  - Expected COD: ca. 2030, UK

- NuScale VOYGR (Fluor)
  - Multi-module PWR
  - 6x 77MW
  - Expected COD: 2029, Idaho Falls, USA

- Nuward (EDF)
  - Multi-module PWR
  - 2x 170MW
  - Expected COD: ca. 2034, France

Key characteristics of LW-SMR:

- +70 years industry and operating experience
- Existing supply chain
- Mature regulatory landscape
- 1 design approval granted by US NRC
- 10+ companies actively developing a LW-SMR design
- 10+ deployments announced in Europe and North America < 2035
The market need is there!

**Electricity**
- 1600 TWh/y
  - EU Low carbon electricity production to be deployed by 2040
- 80GW
  - European Nuclear capacity to be replaced by 2050 (end of life)

**Hydrogen**
- >20 Mt H₂/y
  - REPowerEU Market Estimate for 2030
- 1000 TWh/y
  - Equivalent additional clean electricity demand
- >125 GW
  - Equivalent nuclear capacity

**Industrial heat**
- ~1250 TWhₜₜ/y
  - Iron – Steel, Non-metallic minerals and chemicals heat demand in EU26
- > 45% market
  - Heat < 400°C

**District heat**
- ~500 TWhₜₜ/y
  - Current district heat demand in EU26
- > 2/3 fossil-fueled
  - Assets to be retired and replaced in the coming two decades
This appetite is materializing

**Ontario Power Generation** – Darlington, CANADA
- Electricity – 4 units
- First delivery expected 2028

**Global First Power** – Chalk River, CANADA
- Electricity
- First delivery expected 2027

**PacifiCorp** – Kemmerer, USA
- Electricity – 350MW
- Delivery expected < 2033

**TVA** – Clinch River, USA
- Electricity
- Delivery expected < 2030

**Dow** – U.S. Gulf Coast sites, USA
- Process heat and Power
- Delivery expected ~ 2030

**Rolls Royce** – UNITED KINGDOM
- Electricity
- Delivery ~2030

**ULC + Constellation** – NETHERLANDS
- Electricity and cogen fleet
- First delivery early 2030s

**CEZ** – Temelin, CZECH REPUBLIC
- Electricity
- Delivery expected ~2034

**Vattenfall** – Ringhals, SWEDEN
- Electricity – 2 units
- Delivery considered for ~2030

**Fermi Energia** – ESTONIA
- Electricity – 300 to 1200 MW
- Delivery by 2032 - 2035

**ORLEN Synthos** – POLAND
- Electricity and Co-gen – 10+ units
- Delivery by 2035

**KGHM** – POLAND
- Electricity – 450 MWe
- Expected delivery from 2029

**Nuclerelectrica** – Doicesti, ROMANIA
- Electricity – 450MWe
- Delivery ~2030

**Vattenfall** – Ringhals, SWEDEN
- Electricity – 2 units
- Delivery considered for ~2030

**EDF NUWARD** – FRANCE
- Electricity
- Construction start by 2030

**Dow** – U.S. Gulf Coast sites, USA
- Process heat and Power
- Delivery expected ~ 2030

**Rolls Royce** – UNITED KINGDOM
- Electricity
- Delivery ~2030

**CEZ** – Temelin, CZECH REPUBLIC
- Electricity
- Delivery expected ~2034
Overview of AMR designs considered in Europe – Sylvain Takenouti, EDF

Discussion with AMRs designers:

- NAAREA - Jean-Luc Alexandre
- Newcleo - Michele Battistin
- U-Battery Limited - Peter Bradley
A few definitions

- **SMR**: reactors that produce electricity of up to 300 MWe per module (according to IAEA)

- **AMR** (Advanced Modular Reactors) definition is not standardized
  - SMRs whose designs include innovations which are often comparable to Generation 4 reactors (typically cooled by molten salt, sodium, lead, gas, supercritical water, and not by light water)
    - Gen4 particular embarks sustainability features (limiting raw materials, impact of long-life waste, …)
  - **MMR** (Micro Modular Reactors) : reactors that produce electricity or heat of 1 up to 20 MWe per module

- **Whereas LW-SMR**, relying on a mature technology, are expected to be deployed in the 2030s, **AMRs / Gen IV designs need to be matured by 2035 for long term prospect**
The AMR ecosystem is teeming in the recent years

- ca. 90 designs of SMRs identified in the 2022 IAEA SMR booklet
- Whereas the SMR ecosystem seem now to stabilized, AMR including MMR is still teeming
In Europe, a wide and growing variety of players for AMR designs (institutional, industrial, start-ups, etc.)

- Sodium-cooled Fast Reactors
  - ANAIS, ATRIUM (CEA, France)
  - Newcleo (IT, UK, FR)
  - LeadCold SEALER (SW)
  - ALFRED / FALCON (RO, IT)...
  - ADS: MYRRHA (BE), Transmutex (CH),...

- Lead-cooled Fast Reactors
  - NAAREA, (FR), Thorizon (NL), Seaborg (DK), EnergyWell (CZ), Moltex (UK), Copenhagen Atomics (DK), ISAC project (FR), ...

- Gas-cooled Reactors
  - HTGR: U-Battery (UK), Jimmy (FR), EUTHER, GEMINI initiative (PL)...
  - GFR: ALLEGRO (PL, CZ, ...)

- Other Gen IV

- Molten Salt Reactor

- Low Temp PWR
  - LDR (VTT, Finland)
  - LUTHER (LUT, Finland)

- PWR

- BWR
Overview of the supply chain in Europe – Roberto Adinolfi, Ansaldo Nucleare

The Nuclear Supply Chain in Europe: How to adapt?

Discussion with stakeholders of the supply chain:
- ŠKODA JS - Miloš Mostecký
- Empresarios Agrupados - María Teresa Domínguez
- Walter Tosto - Massimiliano Tacconelli
SMR Business Models: Vendor opinions

• The key feature for SMR competitiveness is «production by series»

• How is this going to affect the future Supply Chain?

  ➢ Which products for SMRs?
  ➢ How many? (i.e. capacity issues)
  ➢ Which changes in the relationship?

• Answers should start from Vendor opinion on the best way to make SMR succesful in the future EU market (i.e. their «business model»)
Which products for SMRs?

• STANDARDIZATION

Not only the reactor/plant design shall be standardised, but also component design/procurement/fabrication/factory testing

✓ Component standardization will bring savings both in costs and in time, which in turn would make fleet deployment achievable and attractive

✓ Standardization shouldn’t bring to pre-selection of single suppliers: need for more capacity and fair competition towards price reduction

✓ More stringent specifications/ requirements to be expected from Vendors
Which products for SMRs?

• FACTORY MANUFACTURING

  *Improved control of quality and schedule to reduce construction cost*

  ✓ focus of the future licensees and the regulatory bodies from the site to the manufacturing facilities

  ✓ Extensive, upgraded factory testing

• LICENSING HARMONIZATION

  *Deployment of the same model in several EU countries without redesigning*

  ✓ adaptability to different Codes and Standards
Capacity issues

• Smaller unit size can lead to larger number of components for the same amount of power to install (This can be counterbalanced by simpler designs)

• SMR vendors interested to localize production to favour series deployment in various Countries

• Interest for use of high quality, non nuclear manufacturers
Which changes in the vendor/supplier relationship

- Vendors need to achieve NOAK cost reduction to make SMR attractive in the future nuclear market

- Supply chain contributes to the largest part of potential NOAK cost reduction

- By making available their NOAK cost savings to Vendors, Suppliers can gain a larger, serial market

- A win-win startegy can be envisaged for SMRs
Overview of the energy intensive users in Europe – Peter Claes, FEBELIEC-IFIEC

Discussion with intensives users:

- KGHM - Maciej Wójcik
- CEMBUREAU - Emmanuel Brutin
- Mytilineos (member of Eurometaux) - Nick Bitsios
Thank you!

***

Q&A