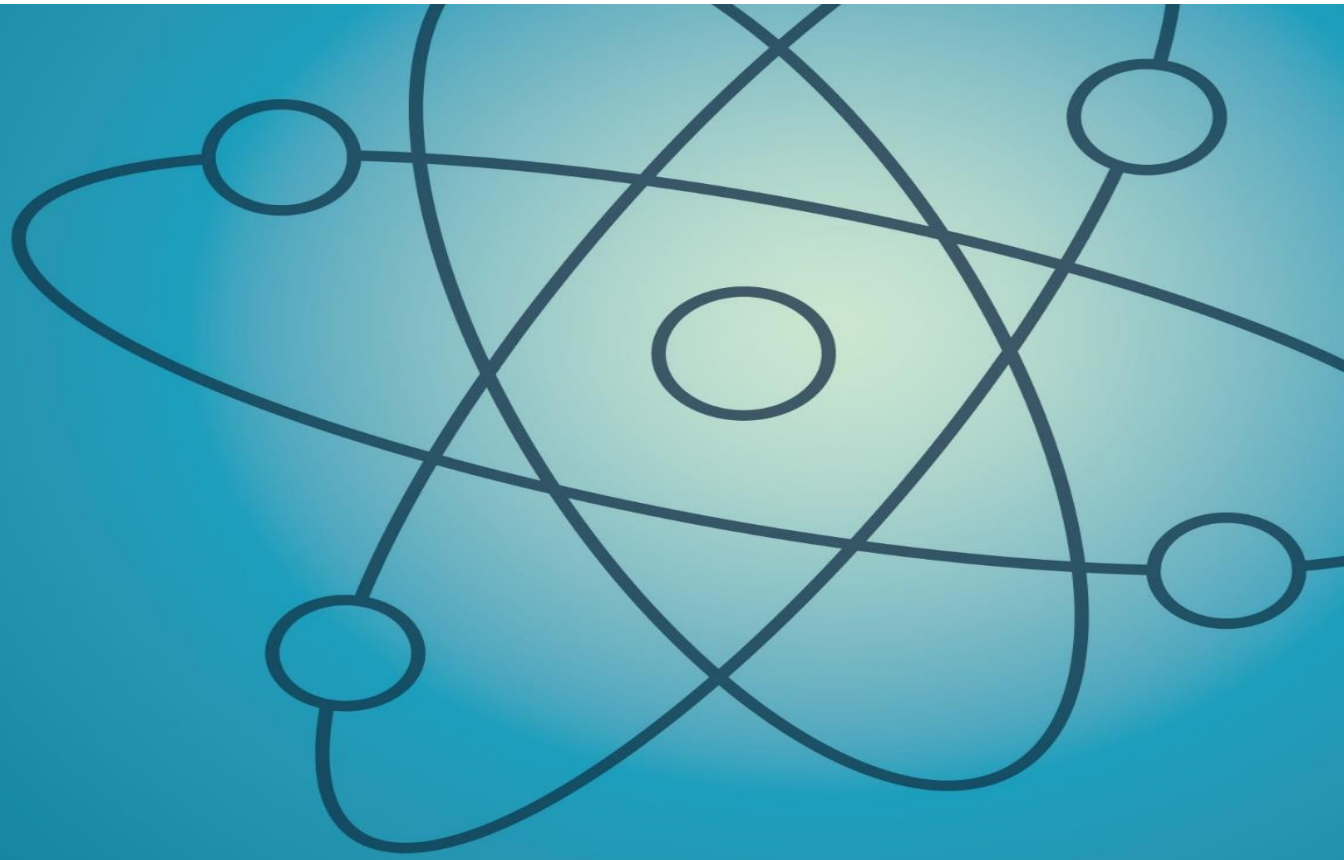
European SMR pre-Partnership

Stakeholders'Forum
26 October 2023

Introduction session



With the support of :

Nucleareurope

- act as the voice of the European nuclear industry in energy policy discussions with EU Institutions and other key stakeholders

Corporate Members:

CEZ (Czech Republic),
Fermi Energia (Estonia),
KGHM (Poland)
Nuvia (France),
PEJ (Poland),
Rolls-Royce led SMR
Urenco (Global)

- provide information and expertise on the role of nuclear energy

- membership of nucleareurope is made up of 15 national nuclear associations representing more than 3,000 companies

Nucleareurope SMR Task Force

- **A task force composed of members from key companies from all around Europe, from SMR vendors to supply chain. Activities include:**

1. Estimation of potential scenarios for SMR deployment in Europe (installed capacity & deployment schedule) – exercise done in the past for the Pathways to 2050: Role of nuclear in a low-carbon Europe - 2021 updated results report
2. Creation of a repository with easily accessible information on SMRs to the general public.
3. Analysis of possible investment frameworks for SMRs. Suitability of existing frameworks for large reactors. Private investment.
4. Creation of targeted communication on SMRs to be sent to policy makers in Brussels.

- **The nucleareurope SMR Task Force issued an SMR Position Paper in October 2022**

ENSREG European Nuclear Safety Regulators Group

nucleareurope

SNETP Sustainable Nuclear Energy Technology Platform

SNETP
Sustainable Nuclear Energy Technology Platform

SAFE, COMPETITIVE & SUSTAINABLE NUCLEAR

SNETP is a European Technology Platform recognised by the European Commission, which supports and promotes the safe, reliable and efficient operation of Generation II, III and IV civil nuclear systems.

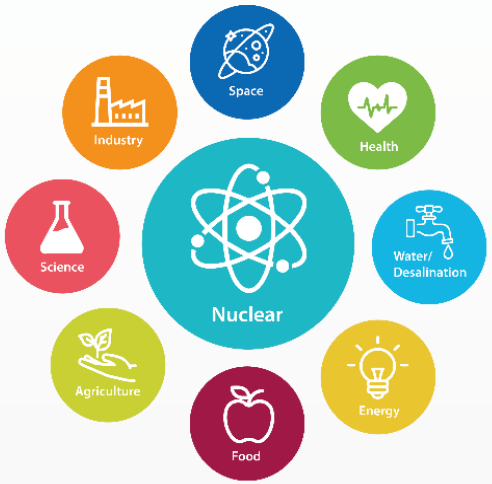
STRATEGIC VISION

1/ Nuclear Power in Europe's 2050 Energy Mix.

2/ Emphasizing Research and Innovation for Safety and Efficiency.

3/ Open to New Reactor Technologies (SMR, Gen IV).

4/ Transverse technology with strong impact on other fields (Medicine, Data, Industry, Renewables, etc.).



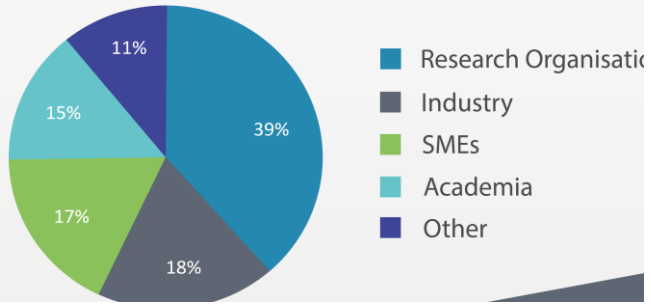
SNETP PILLARS

SNETP pillars support the EU's transition towards a **carbon neutral economy by 2050.**

SNETP MEMBERS

SNETP COMMUNITY

Approx. 120 members



Strong support schemes for SMR R&D&I development all over the world

USA

- **Inflation reduction act:**
  - Direct R&D funding in the act includes **USD 2 billion** for improvements to federal laboratories up to 2027,
  - USD **3.6 billion** to guarantee up to USD 40 billion of loans to innovative technology projects,
  - 50% grants to demonstration projects for industrial decarbonisation by 2026, and tax credits up to 2045
- **US DOE : ARDP / US DOD (MMR and space)**
  - **$180m** of initial funding from the Department of Energy, closed in 2020
  - **$3.2b** will be invested in TerraPower's Natrium and X-Energy's Xe-100 in the next years
- **Export:**
  - Foundational Infrastructure for Responsible Use of Small Modular Reactor Technology (FIRST) incl. Project Phoenix (USD 8m) and NEXT One Stop Shop

Canada

- 2023-27: CAD 29.7m support for R&D projects
- CAD 970m Canada's bank financing for Darlington SMR + commit CAD 74m in Saskatchewan

UK

- £385 millions from Advanced nuclear fund
- In addition to the GBN and SMR competition launches, the government announced a grant funding package for the nuclear sector totaling up to £157 million

Japan

- ca. EUR 400m (2024-26) for SFR and EUR 400m for HTGR

Korea

- SMR alliance (created July 2023)

China

- Construction of demonstrator (s)

Others (Russia, Argentina, …)

Figures exclude private investments

The EU needs to strengthen its leadership, sovereignty and expertise on R&D&I for SMR/AMRs

- France: LW-SMR: 50 + 500m€ (2021-2030), AMR: 500m€ (2023-2030); Belgium: EUR 25m€/y (2023-2026); Netherlands EUR 65m€ foreseen in 2024 for SMR; Sweden: Announce support of SEK99m (~EUR9m) for construction of LFR prototype;
- And Fi, Cz, Ro, HG, Bu, Pl, D, It ….: few m€/y
- Euratom: ~10m€ /y for SMRs

Take-away:

- **At this moment, R&D&I is key to succeed with SMR/AMR industrial development.**
- **The R&D&I efforts to develop new reactors are substantial (order of magnitude b€ / reactor and b€ / new fuel)**
- **Worldwide, SMR R&D&I is taking profit from strong governmental supports (in addition to private Investors).**
- **In the EU: Member states interested in nuclear (SMRs) are beginning to strengthen their cooperation.**
- **No unique country in Europe has sufficient means to develop several models of SMR/ AMR by its own.**
- **As a result strong cooperation on R&D&I as proposed by the WS5 is necessary between the EU members interested by nuclear technology.**

ENSREG European Nuclear Safety Regulators Group

nuclear europe

SNETP Sustainable Nuclear Energy Technology Platform

- **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**

Collaborations between EU and non-EU regulators are taken place for SMRs and AMRs in different formats (e.g.):

- **Within initiatives in other international organizations and associations**
- **In bi-/multilateral initiatives in the pre-licensing safety assessment of specific designs**
  - **Joint Early Review of Nuward ASN(FR)-STUK(FI)-SUJB(CEZ) on Nuward SMR, joint by SSM (SE), PAA (PL), ANVS (NL) in phase II**
  - **Bilateral collaborations between U.S. NRC and EU Nuclear Safety Regulators (e.g. RO) on Nuscale**
  - **Observation of the Generic Design Assessment by ONR (UK) of RollsRoyce**
  - **Joining of PAA (PL) with the joint US NRC and CNSC (CA) assessment of BWRX300**

IAEA

Western European WENRA Nuclear Regulators' Association

NEA Nuclear Energy Agency

Role in pre-Partnership:

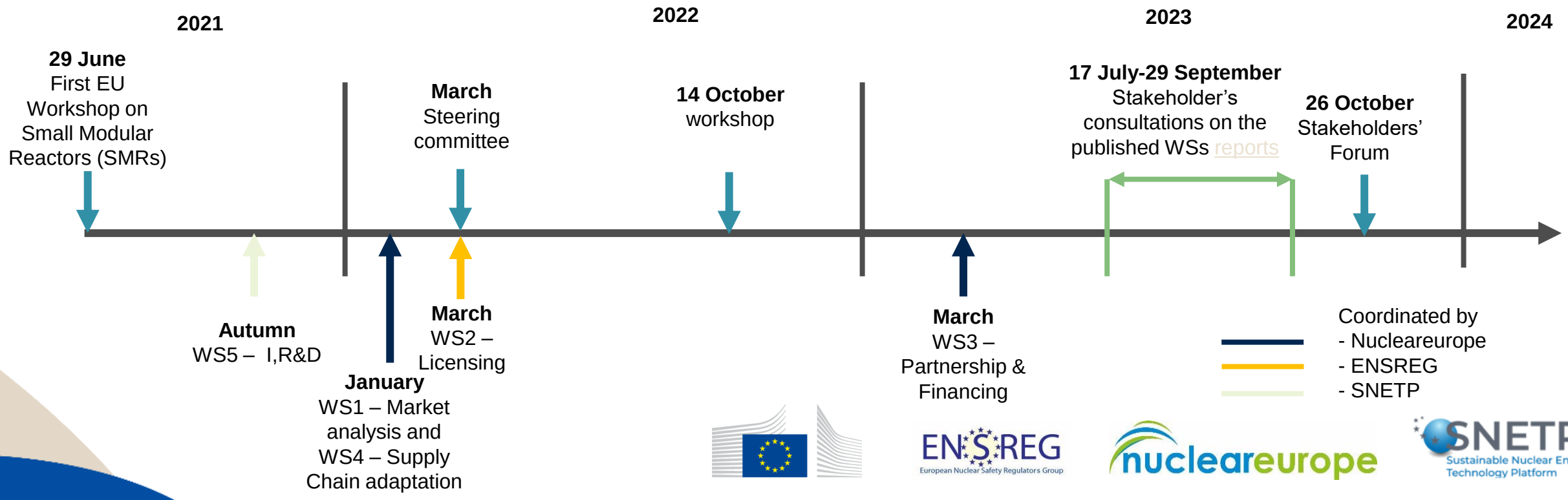
- The **nuclear safety regulators** are **neither involved in promoting or stimulating SMRs** deployment, **nor discouraging such projects**.
- Through ENSREG, the **EU nuclear safety regulators participated in this pre-Partnership** phase to review possibilities:
  - **To improve through enhanced inter-regulator collaboration the safety assessments in the pre-licensing phase**, while maintaining fully their sovereign responsibilities.
  - To ensure that **Europe remain at the top front for what concerns nuclear safety, radiation protection, emergency plan preparedness, radioactive waste management, etc.**

European SMR pre-Partnership

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.

• Timeline



General comments received during the consultation

KEY FEEDBACKS

SMRs/AMRs: pro and cons

- Need a **rapid launch of an official EU initiative**, with the support of the European Commission, to **accelerate the deployment of European SMR by the early 2030s.**
- **SMRs** can **improve the energy independence and competitiveness of Europe**, as well as the stability of the electricity system.
- Clearly highlights the **role SMRs** could play in the **EU net-zero strategy, the big market potential** for SMR in various industrial sectors that will need a strong effort in decarbonization**.**
- **SMRs as an innovative solution** for increasing the **circularity of nuclear fuels,** limiting the radiotoxicity of nuclear waste and optimizing the use of uranium.
- Given that the **civil society and independent academic experts were excluded** from the initial drafting of the reports, **the documents feature a clear nuclear industry bias.**
- **Overstrong advertisement bias for SMRs**, **fail to address concerns and problems** in any substantial way (safety, costs, implementability, environmental impacts and proliferation).
- **No need for SMRs**. Need for energy efficiency and renewable energies, decarbonization of key industries

ENSREG European Nuclear Safety Regulators Group
nuclear europe
SNETP Sustainable Nuclear Energy Technology Platform

General comments received during the consultation

KEY FEEDBACKS

Other main comments

- **Stronger focus** is needed on **closing of fuel cycle** and support of **development not only of demonstrators**
- **Non-discriminatory approach is preferable for SMRs development** and in line with free market rules. Should be more open to the different designs of SMRs because the EU **needs to decarbonize various energetic sources with various power**
- since the **nuclear waste** issue was such a **heated topic in the recent taxonomy debate**, add information for the **back end of the fuel** cycle and its R&D effort, especially for the **fuels** considered for the various **Generation IV AMR's and HTGR's**.
- **Role of TSOs** (and in particular ETSON) which can support the development of SMR and AMR?
- Considering the on-going programs of Long Term Operation and the large reactors NNB, we shall pay attention to the difficulty of **mobilization and education of human resources**
- Importance of **research and innovation for SMRs/AMRs**

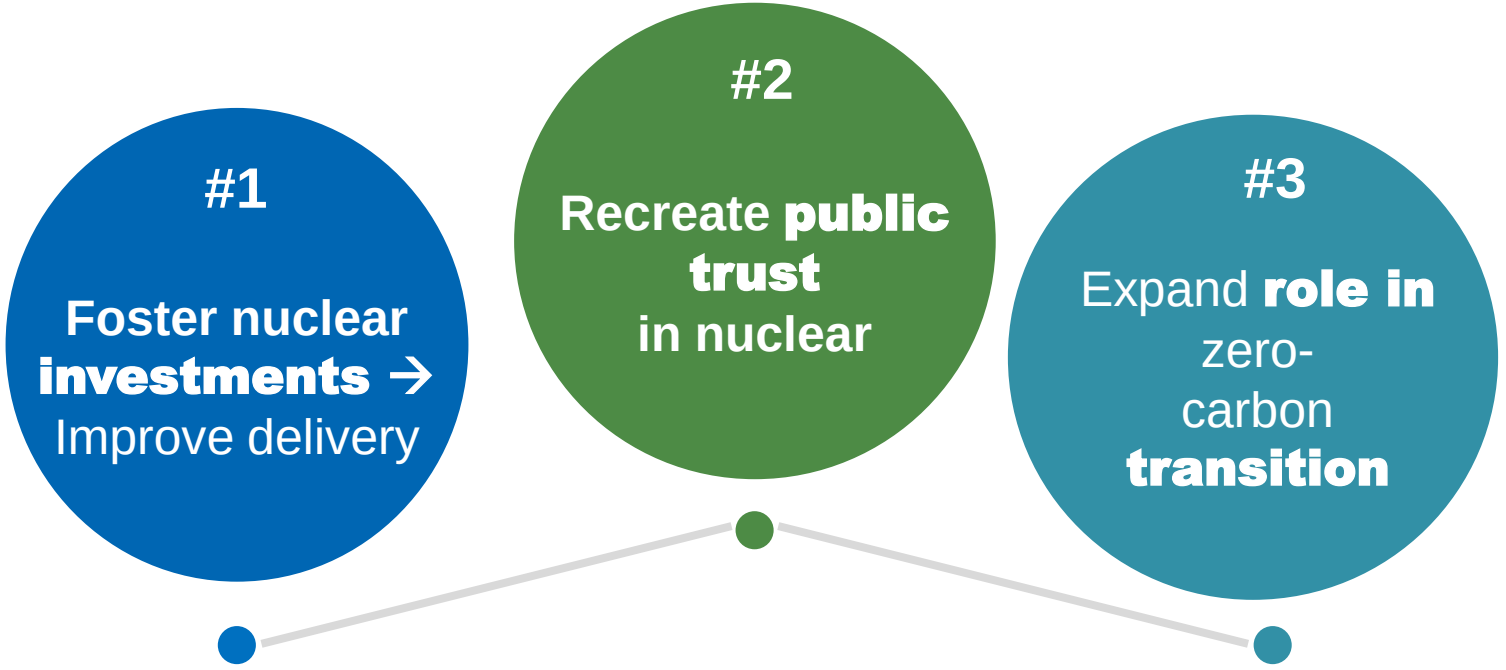
General comments received during the consultation

KEY FEEDBACKS

- **Mentioned with more depth**: **fuel cycle issues** - both front end and back end; **nuclear security, safeguards;** new nuclear site development.
- **Missing** an important input: the **human factor**. Human resource is becoming difficult to be available both quantitatively but also qualitatively thus jeopardizing the success of the initiative.
- **Need to includes findings on financing**, including specific policies and providing overall clarity for the **public and,** most notably, the **private sector**
- Support the **development of a comprehensive strategy for the deployment of SMRs** in the EU, considering the entire value chain, licensing, etc.

WS1 – Market analysis

What drives the industry towards SMRs



WS1 – Market analysis

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 H_2/y
REPowerEU Market Estimate for 2030

1000 TWh/y
Equivalent additional clean electricity demand

>125 GW
Equivalent nuclear capacity

Industrial heat

~1250 TWh_{th}/y
Iron – Steel, Non-metallic minerals and chemicals heat demand in EU26

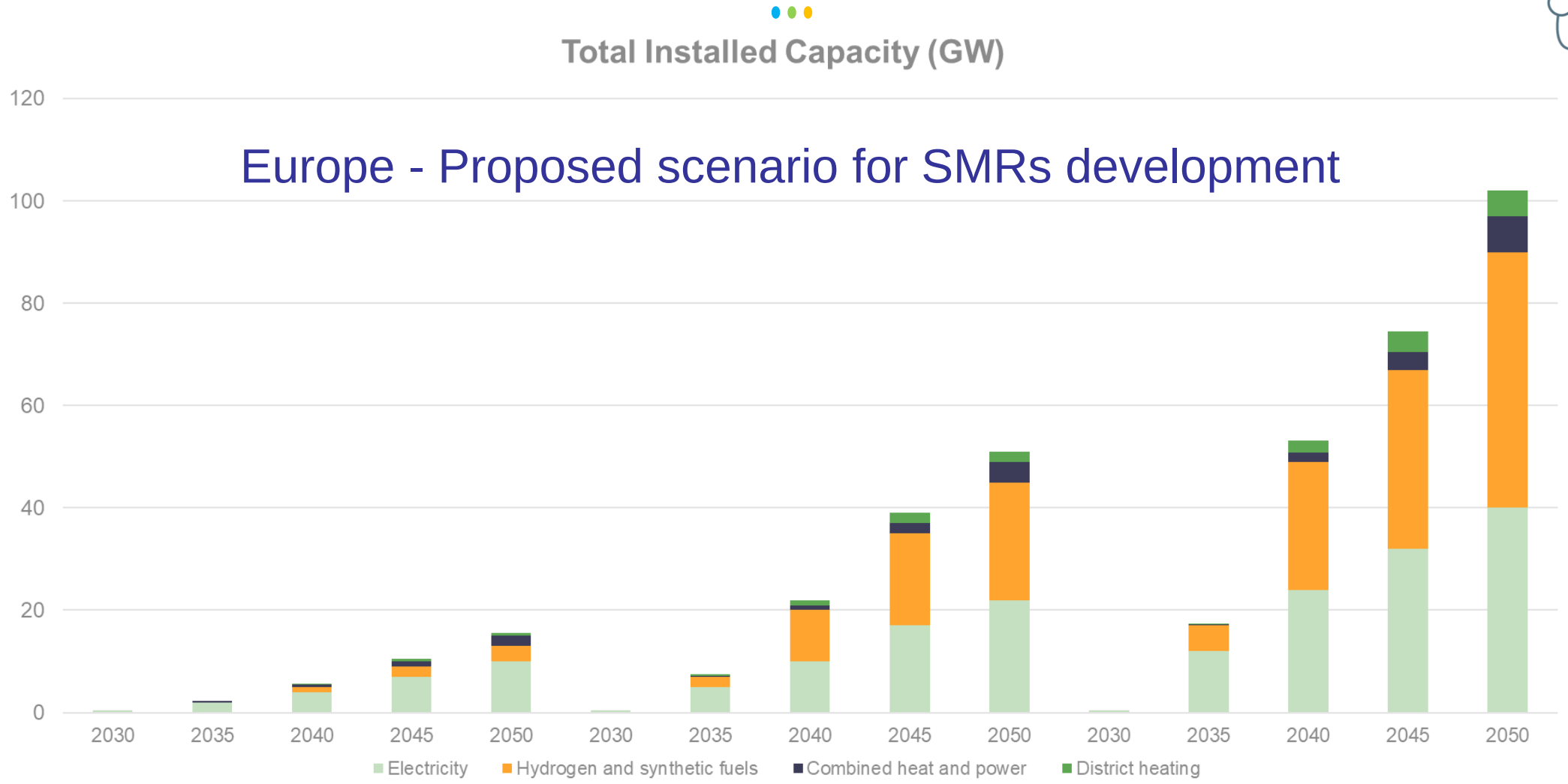
> 45% market
Heat < 400°C

District heat

~500 TWh_{th}/y
Current district heat demand in EU26

> 2/3 fossil- fueled
Assets to be retired and replaced in the coming two decades

WS1 – Market analysis



WS1 – Market analysis

KEY FEEDBACKS

- **E-fuels, electrolysers capacity as well as (competitive and sustainable) water desalination** should be considered when potential of SMRs is assessed as part of an integrated energy system
- Additional opportunities can be identified for the **SMRs operating in cogeneration mode with potential in producing heat** for district heating or heat for industrial processes beside the electricity
- **Forecasts of SMRs deployment can still be considered conservative**, taking into account the overall international context but some more explanations has to be given on the assumptions on heat and hydrogen production from the WS1 report
- Smaller local **footprint of SMRs** is matching a higher variety of sites, giving more possibilities to decarbonize other sectors such as industry and heating
- Related to the footprint of SMRs but also other matters like security and safeguards, a new topic on **public acceptance** should be detailed and analysed in the next steps
- The **management SMRs' produced radioactive waste** topic that should be detailed and analysed in the next steps

ENSREG European Nuclear Safety Regulators Group
nuclearеurope
SNETP Sustainable Nuclear Energy Technology Platform

WS2 – Licensing – what is key for licensing SMRs in Europe?

Licensing process / safety requirements

Licensing process

Quite similar in Europe

Authorisation remains the sovereign responsibility of states

Cannot lead to international certification or reciprocal recognition of the authorisations issued by the safety authorities

Safety requirements

Established in different frameworks (IAEA, WENRA)

Built on the experience of what is already implemented

Rather how to demonstrate compliance with the requirements that needs to be worked on

Further cooperation

WS2 – Licensing – what is key for licensing SMRs in Europe?

KEY ELEMENTS

- **Definition of commonly shared Safety Objectives for SMRs** between the EU “interested” nuclear safety regulators
- Agreement on the **definition** of what is the **sufficient level of maturity for an SMR** design to engage a joint safety pre-assessment
- Promotion of joint pre-assessment by several regulators and definition of the **possible conditions for another regulator to join at a later stage**
- **Identification** in an early phase of **potential blocking points**
- Common understanding of the **challenges related to AMRs key safety features** (through **collaboration** between **Regulatory Bodies and EU research fro example**)

WS2 – Licensing - Conclusion

: 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 and its dissemination with other regulators confronted with that design at a later stage.**
3	**Identify in an early phase potential blocking points in the safety requirements or licensing processes and arrangements for convergence**

WS2 – Licensing

KEY FEEDBACKS

- **Benefits of a "hand-on" approach between regulators working on the same design** - Supports the concept of **"Joint Early Reviews" vs Risk of adding an additional "EU authorization process"** to the already lengthy regulatory process in the nuclear industry
- **Security and non-proliferation aspects** not covered
- **Document focuses on PWR SMRs** and does not deal enough with the generic work required to redefine the **prevailing accident scenarios to be considered for AMRs**
- Need to properly assess the **"reliability" of passive safety**
- Need to include more references to the **human factors and organizational factors (unique control room for different modules)**
- **Citizens should have a say** in the introduction of **new technologies** such as **SMRs/AMRs**
- **Contribution from TSOs** to develop computation capacity and carry-out expertise
- **HTGR reactor using TRISO fuel:** More research needed regarding the **regulatory challenges**

WS3 – Partnership & Financing

HOW TO STRUCTURE THE EUROPEAN SMR INITIATIVE?

HOW TO ENSURE MAXIMUM EFFICIENCY?

HOW TO OPTIMIZE STAKEHOLDERS' INVOLVEMENT?

WS3 - Partnership & Financing –Industrial Alliances

- Industrial Alliances constitute flexible, adaptable structures that can be tailor-made to suit the needs of involved stakeholders. **IA can be used as an umbrella to oversee diverse structures within the initiative such as Horizon Europe public-private partnerships**, Joint Undertakings, IPCEI,…
- **IA require strong political engagement to be a success**. This engagement needs to be maintained over time to keep the alliance working.
- They do not preclude the creation of an IPCEI and are not funded by EU institutions but are aimed to encourage and facilitate investments in strategic project.

WS3 – Partnership & Financing

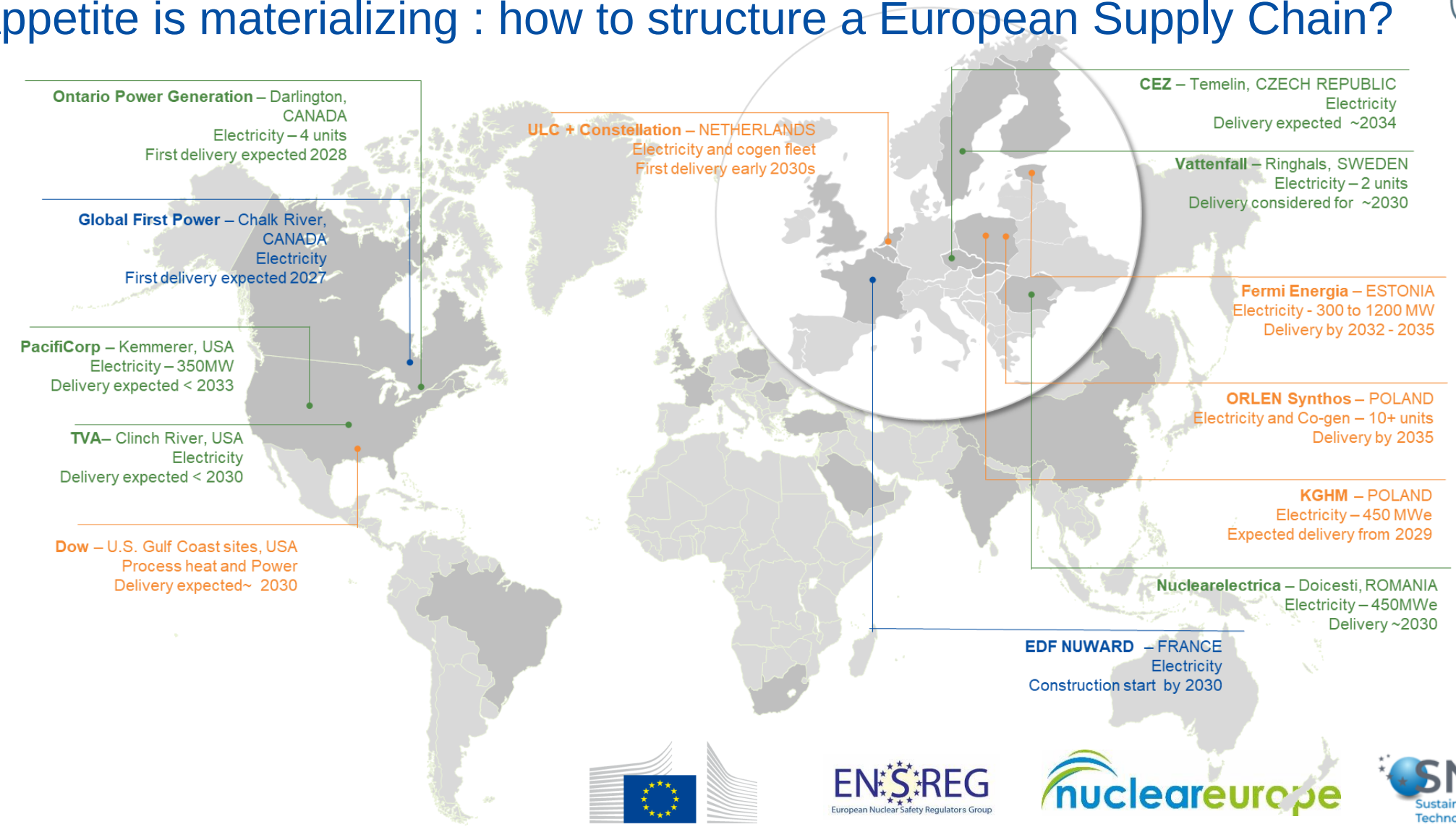
KEY FEEDBACKS

- **Financing options available for each phase should be delineated**, institutions and entities that would take part in financing should be described, and associated risks inherent to each financing approach would be highlighted.
- **The document does not address the specific aspects of SMRs/AMRs** and should focus on supply chains and the construction of SMRs, including related infrastructure.
- **The document could benefit from additional work regarding the business models of SMRs and AMRs and the split along the value chain between different actors, most importantly between the vendor, the "external" supply chain, and the operator.** An assessment of where most of the value is created between the design and the supply chain would be useful.
- The report rightly identifies the industrial alliance as the best format for a European SMR Partnership.

ENSREG European Nuclear Safety Regulators Group
nuclearеurope
SNETP Sustainable Nuclear Energy Technology Platform

WS4 – Supply Chain adaptation

This appetite is materializing : how to structure a European Supply Chain?



WS4 – Supply Chain adaptation

EU Supply Chain **capability**

Main topics

- 60% EU suppliers familiar with more than one technology (30% more than 2)
- Most of them with internal engineering capabilities
- Largely familiar with main C&S (e.g. ASME and RCC for mech. components)
- >50% ready to reconcile their products
- Digitalization underway for the majority => confidence to be able to increase their productivity

Info collected from 121 suppliers, from various EU countries:

A, BE, BG, CZ, DE, ES, FR, FI, U, HR, IT, SE, NL & CH

WS4 – Supply Chain adaptation

EU Supply Chain **capacity**

Main topics

- >60% respondents confident to increment their capability
- Main bottleneck appears to be Human Resources availability and training
- Expectation for more harmonized practices to verify quality requirements
- Other bottlenecks associated to raw materials availability, as well as high tech components (typically manufactured by Vendors or nominated subsuppliers)
- Front end fuel cycle could require significant upscaling and investments when large fleets of AMR, or LW-SMR relying on HALEU, would be deployed

WS4 – Supply Chain adaptation

Conclusion

An effective European Supply Chain to support SMR successful deployment

1	Early interaction between Vendors and Supplier to make the best use of existing capacities throughout Europe and to plan HR needs for fleet deployment
2	Establish a "win-win " relationship between Vendors and Suppliers to make "savings by series" available to final Customer
3	Promote harmonization of C&S and quality verification requirements among various EU countries

ENSREG European Nuclear Safety Regulators Group

nuclearеurope

SNETP Sustainable Nuclear Energy Technology Platform

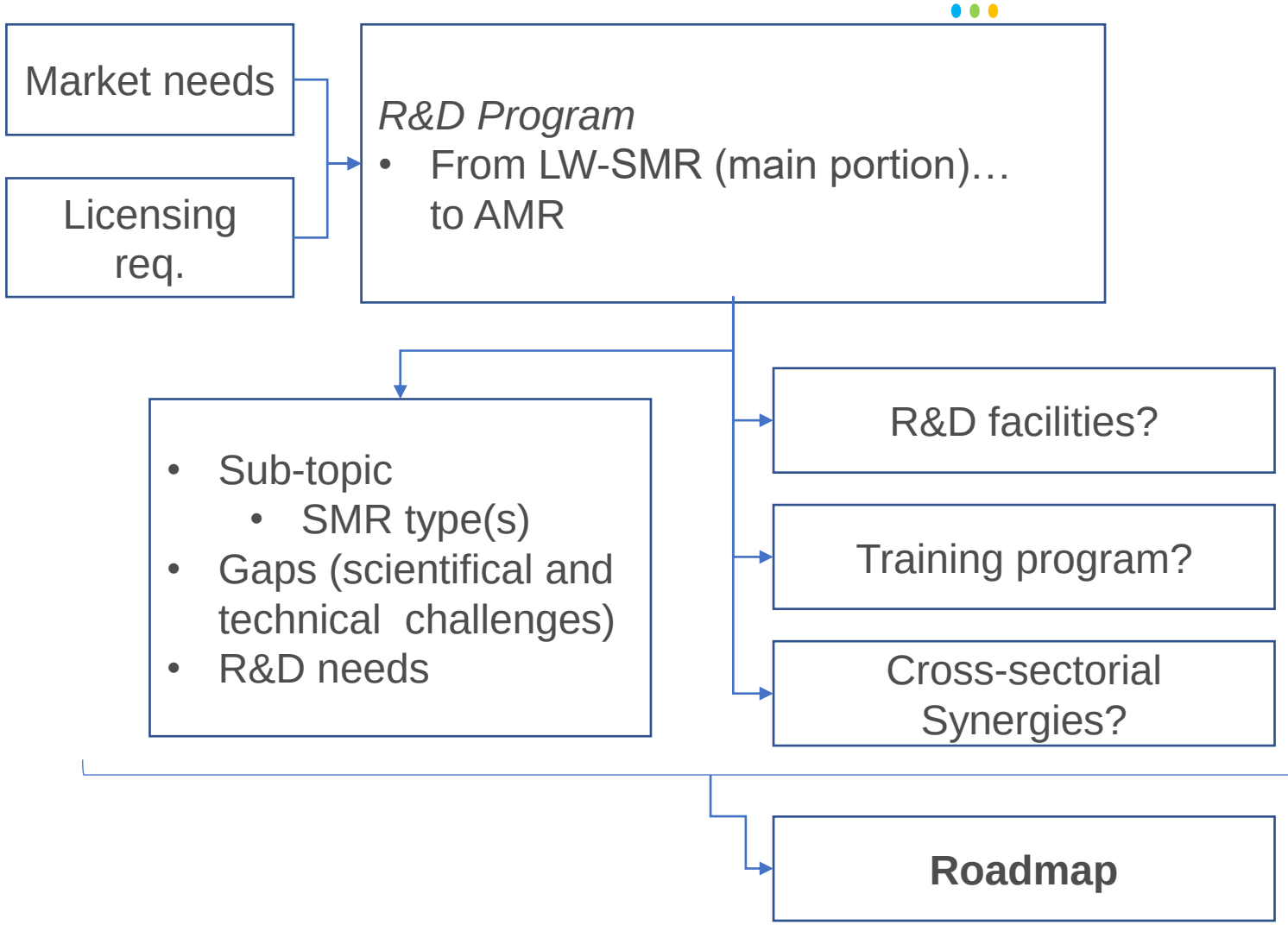
WS4 – Supply Chain adaptation

KEY FEEDBACKS

- Business visibility and entry-barriers simplification for the Supply Chain are key to enable investment.
- The issue of transportation and distribution of materials and equipment should have been more developed, notably regarding fuels for AMRs both from end and back end.
- Suppliers will need a similar surveillance and control as the one done for large-scale nuclear reactor construction.
- Industrial grade items will play a key role to scale up the capacity of the supply chain.
- Although the technologies are mature, fuel supply (HALEU) faces the chicken-and-egg problem, the financial and strategic support provided by the DoE to American industry should be replicated in Europe.
- Differences in C&S between regions and their smooth acceptance by regulators, are recognized as critical issues that should be address always taking into account conception and fabrication coherence with what is already established in each country.
- It should be emphasized that project owners should work on creating the supply chain for their projects from day one, and work together with supplier to optimize fleet deployment.
- Human resources: it could be important to request a planned and structured preparatory program for skills and competences.
- The report should establish a common route for development of innovative techniques like additive manufacturing, digital twins, etc.)

ENSREG European Nuclear Safety Regulators Group
nuclearneurope
SNETP Sustainable Nuclear Energy Technology Platform

WS5 - 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

WS5 main comments from the consultation (1/2)

- **Training and R&D human capacity building**
  - Agreed. EU SMR Pre-partnership insists (see summary report) on the need to build growing human capacities including R&D, and academics, and including cross-cutting skills, through **skills centres or network of skill centres**.
- **Material Testing Reactors (MTR) vs. prototype reactors**
  - Agreed that MTRs remain a key asset for R&D on fuel and structure materials. However, given the deployment time schedule objectives, it is deemed **promising to leverage potential prototype reactors** when available to run such experiments.
- **AMR roadmap completeness and level of detail**
  - Pre-partnership considered that **industrial support** is a necessary precondition for the promotion of AMR technologies (HTGR / SFR / LFR / MSR*). AMR roadmaps for these technologies currently rely on **SNETP Strategic Research and Innovation Agenda** and will be **further detailed in a next step**.

*HTGR : High Temperature Gas-cooled Reactors, SFR: Sodium Fast Reactors, LFR: Lead Fast Reactors, MSR: Molten Salt Reactors

WS5 main comments from the consultation (2/2)

- **Multi-uses of SMR (not only for AMR but also for LW-SMR)**
  - Already mentioned in the report. All markets including **hard-to-abate sectors** are key targets (see WS1 report). However, **electricity generation** with LW-SMR is seen as the first objective to demonstrate the soundness of SMR deployment.
- **Hazards not sufficiently mentioned**
  - Addressing external hazards is **not seen as a SMR specificity**. **Internal hazards** may however be **SMR specific** and should be addressed by the different technologies/designs.
- **Codes and Standards not sufficiently mentioned**
  - Subject addressed by WS4. The need for **R&D to provide data** for new codes and standards is considered being already addressed in the report.
- **R&D for fuel plates for LW-SMR technologies**
  - Agreed. Although rods are usually considered in the LW-SMR designs, this need will be added in the fuel section of the report.

WS5 key take aways

WS5 objectives: build a comprehensive and credible R&D&I roadmap to secure an on-time deployment of SMR in Europe.

- **A strategic research program : defining the vision, tool to monitor the progress of key actions**
  - Identification and prioritization of the relevant R&D work needed to enable SMR deployment, considering **market needs** and **regulators expectations**.
- **Roadmap structured in 2 different timelines:**
  - **LW-SMRs** with a shorter-term timeline for industrial deployment
  - **AMRs** including new uses: H_2, heat, fuel and waste management
- **R&D human resources and infrastructures**
  - 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