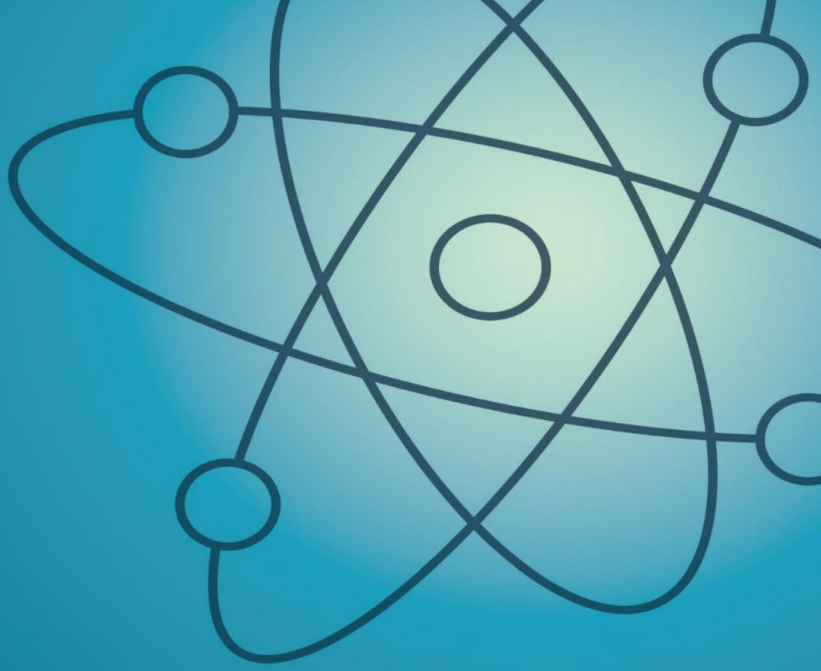

European SMR pre-Partnership

Executive summary and way forward

ENSREG European Nuclear Safety Regulators Group

nuclareurope

SNETP Sustainable Nuclear Energy Technology Platform

Contents

Summary

On 29 June 2021, in response to the call of the European nuclear industry and the R&D&I community, the European Commission organized the first EU Workshop on Small Modular Reactors (SMRs). This event showed a growing interest across the EU in this technology and innovative business model, which is gaining momentum world-wide, and confirmed its potential to play a role in the overall decarbonisation efforts and security of energy supply.

A major outcome of this workshop was the endorsement of a "vision paper"[1] widely supported by the stakeholders, including a proposal for a European SMR Partnership in the form of a collaboration scheme involving industrial stakeholders, research & technological organisations, interested customers, as well as European policymakers and regulators with the aim at creating enabling conditions for the first SMRs to start operating in Europe by the early 2030s.

The first phase of the Partnership, called pre-Partnership, was coordinated by a Steering Committee (SC), which provided general direction to enable the drafting and rolling out of a roadmap – shared and endorsed by all the relevant stakeholders – to facilitate the development and deployment of SMRs in Europe. This Steering Committee was supported by five Work Streams (WSs), essential for the SMR technology outlook, and safe deployment in the EU: market integration and deployment; licensing; financing and partnership; supply chain adaptation and innovation, research and development. Each WS organised its activities in line with the duties and areas of responsibilities of the organisations involved, but extensive exchanges took place between the WSs allowing to get a better common understanding of the issues at stake.

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. The nuclear safety regulators are neither involved in promoting or stimulating SMRs deployment, nor discouraging such projects.

The European Commission was closely associated with this initiative as a facilitator of a wide stakeholder involvement.

The present document summarizes the progress reached since the launch of the European SMR pre-Partnership. The analyses and associated reports are based on the work of more than a hundred experts across Europe from many different stakeholders covering a wide range of disciplines such as: SMR designers, nuclear reactor utilities, supply chain representatives, finance and economics actors, policy makers, intensive users, regulators, research, and innovation organisations. As a result, it outlines a strategy for the actions to be undertaken with Member States, European Parliament members, regulators, industrial actors, etc. to support the launch of a European SMR collaboration initiative before the end of 2023. The present document complements the reports from individual workstreams to provide an overarching narrative for wide stakeholder scrutiny.

This document covers the areas indicated mainly by those EU Member States who signed a support letter to the attention of the European Commission for the launch of a European SMR initiative[2]. It addresses however many different topics which are of interest to a much wider group of EU Member States, as well as other stakeholders, such as R&D and industrial capabilities considering that the EU needs the effort of all sectors and to combine all possible solutions to enable a transformational change towards becoming the first climate-neutral economy while also ensuring energy security, efficiency, affordability, and strategic autonomy.

In the following chapters of this document, SMR stands both for the Small Modular Reactors (electrical power output lower than 300 MW[3]) which are cooled by water (LW-SMR) and for Advanced Modular Reactors (AMRs) which represent future reactor technologies and are also small reactors but cooled by other means than water.

[1] https://energy.ec.europa.eu/topics/research-and-technology/small-modular-reactors_en
[2] https://www.ecologie.gouv.fr/sites/default/files/nuclear%20alliance%20statement_VEN.pdf
[3] https://nucleus.iaea.org/sites/smr/Shared%20Documents/SMR%20High%20Level%20Booklet%20(2957)%20FINAL%20web.pdf

Possible contributions from SMRs to 2050 decarbonisation targets in Europe

SMRs could help enabling the transformational change needed in Europe to become the first climate-neutral economy while also ensuring energy security, efficiency, affordability, and strategic autonomy. Together with Renewable Energy Sources (RES), SMRs could significantly contribute to Europe delivering a Net-zero energy mix with a high level of safety and at a stable and affordable price.

The analysis in the frame of the European SMR pre-Partnership highlighted the potential markets for SMRs deployment in Europe in different sectors: electricity, hydrogen production, heat demand for industrial processes and district heating.

Indeed, global energy needs which could be supplied by SMRs are considerable. They represent between 17 GW to 50 GW by 2050. The corresponding deployment workload is between 2 and 8 reactors of 300 MWe each / year to be connected to the grid between 2030 and 2050. This means that many possibilities for different technologies and different vendors exist (see WS1 report).

One key advantage of SMRs is their small size as well as their modularity. They can be delivered in series of reactors. The SMRs industry would present some similarities with the aerospace industry where a limited number of identical aircraft is delivered worldwide. On the one side, series effect is a characteristic that enables enhancing safety, quality, performance, low construction risks and affordable prices. On the other side, savings based on series effects are largely depending on upfront, material and non-material investments in the Supply Chain. At a certain extent the SMR business model is transferring substantial part of the usual nuclear project costs (mainly construction uncertainties) to the Supply Chain manufacturing.

LW-SMRs based on Light water reactor technology is the most mature technology. First reactors could be put in service by 2030, and fleets of these reactors could thereafter be swiftly deployed in Europe. The maturity and the accumulated operational experience of the light water technologies are unequalled in Europe and in the world.

Advanced Modular Reactors (AMR), small reactors based on innovative technologies, can produce heat at high temperature for specific industrial sectors. Some AMR technologies and designs can also have physical capacities to optimize access to fresh uranium resources and to cope with long life radioactive wastes reduction, thus contributing to long term sustainability of the nuclear industry.

Four main families of advanced technologies are under consideration: sodium cooled, lead cooled, molten salt and high temperature gas reactors. Several industrial initiatives are underway in Europe to promote these technologies with various designs inside a same family. Efforts should be joined at European level to reduce time-to-market for a demonstrator in the technologies that will be identified as the most appropriate for Europe.

Challenges and way forward to support SMRs development in Europe

The development of a first series of reactors presents several challenges:

- Establishment of schemes for developing costs sharing and risks sharing, up to the successful deployment of the first units.
- Collaboration among regulators of those countries which will host this series of identical SMRs and the way to perform their safety assessments through enhanced inter-regulator exchanges, while maintaining their full sovereign responsibilities.
- Capacity of the supply chain to deal with increased manufacturing and construction workload among several European providers with homogeneous industrial practices.
- Capacity of R&D to address the knowledge R&D gaps (depending on technology) and to provide elements for the SMRs safety demonstration and performance.

For each of these challenges, a WS has identified the key elements (or enabling conditions) required to ensure successful SMRs development.

Risk sharing (see WS3 report and annex)

The overall financial burden of a first series of SMR development is in the order of magnitude of a billion euros per reactor design / technology. It may be higher for AMR as their technology is less mature. In addition, and particularly in most of the AMR designs, brand new fuel – very often the High-Assay Low-Enriched Uranium (HALEU) – supply could be necessary. The development costs of such fuel factories are at least of the same order of magnitude as the reactor development itself. This additional cost is not necessary for SMR-LWR using conventional fuel.

Therefore, key questions arise related to costs and risks sharing in different areas: e.g., research, development and engineering costs of the reactor design and manage the construction and manufacturing risks of the first units.

The objective of the European initiative would be to propose tools (i.e., « enabling conditions ») to organize knowledge, risks and cost sharing among European stakeholders interested in SMRs development. The overarching principle of this share is threefold:

a. To promote multilateral specific initiatives among interested stakeholders belonging to several countries on first series of SMR design or technology in Europe.

b. To establish support mechanisms for these initiatives recognizing the global interest for the EU to develop such first series, given that the corresponding design or technology could be later deployed by other stakeholders with lower costs and risks.

c. To share R&D developments and infrastructures and corresponding Intellectual Property through the European initiative (see WS5 report)

Alongside the goal of maintaining European technology leadership, risks and costs sharing should not be limited to private investors, but should possibly involve public stakeholders, as well as the EU countries which have already decided to support SMR development in their own country, and at European Union level. If other European stakeholders or countries would be willing to enter at later stage this should also assure a broader involvement of the supply chain from all around the European Union.

Public support in Europe, to be decided at different levels and at proper stage, would be limited to the reactors whose design or technology has not yet been built in Europe. It would apply to the whole first series of identical reactors of each of these specific designs or technologies.

The form of such European support (e.g., grants, loans, loan insurances, investment detaxation, etc.) could, and should be flexible without prejudice to applicable State aid guidelines, and, as a function of the different needs of different types of SMRs

Licensing (see WS2 report)

In view of further supporting efforts to facilitate SMRs pre-licensing in Europe, several steps forward would be needed:

- Engage early dialogue between designers - licensees and regulators on main elements of the design options.
- 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.
- Identify in an early phase potential blocking points in the safety requirements or licensing processes and arrangements for convergence.

Such type of initiatives has already started in 2022 with the collaboration between ASN (FR)- STUK (FIN) – SUJB (CZ) on the Nuward SMR (FR) design. Other European nuclear safety regulators are willing to join this initiative or to create other combinations to analyse together other SMRs designs.

Supply chain (see WS4 report and appendix 1 , appendix 2 + annex A, annex B and annex C)

Key elements related to the supply chain which are needed to ensure that SMRs development will be a success are the following:

- Suppliers should be involved very early in the development of specifications, the choice of technical solutions, the analysis of manufacturing and the demonstration of conformity for SMRs. Interactions with vendors should be enlarged to the broad European supply chain, both to give them maximum visibility of SMR business opportunities and to maximize the European added value.
- Factory manufacturing and assembly of SMRs (in comparison to large NPPs which are mainly built on site) is set to bring the focus of the future licensee and the regulatory body from the site to the vendor's manufacturing facilities as well as transferring substantial part of the usual nuclear project costs (mainly construction uncertainties) to the supply chain. This is an area where national regulators (or their accredited inspection agencies) could successfully collaborate to perform oversight activities in local factories abroad.
- Lack of business outlooks on medium and long perspective in nuclear build strain supply chain companies in the sector to make a substantial investment effort for maintaining their skills and manufacturing tools dedicated to nuclear. There is a strong need of sufficient predictability of business viability in order to maintain or to develop skills and industrial capacities.
- Insufficient human resources are possibly the most important bottleneck for SMR development and deployment: it could be important to request a planned and structured preparatory program involving Member States, universities, and research centres to support SMR development and deployment.
- Decisions related to both front-end and back-end - including logistics – challenges should be made early in the development phase: the risk being that the EU fuel cycle value chain does not have sufficient signals to implement the necessary investment decisions on time.

Research, development, and Innovation (see appendix WS5 report)

To support the SMRs development, the key elements are the following:

- Establishment of an R&D programme to demonstrate the feasibility and the performance of envisaged innovations for SMRs and their associated benefits.

- Maintenance of the existing experimental infrastructures and further development of new ones is key not only for the test, demonstration, and qualification of innovative technologies but also for the education and training in Europe. Emphasis is made especially on the need for Material Testing Reactors and irradiation facilities (for AMR), large scale thermal-hydraulic test facilities, and demonstration prototypes for the integration of SMRs into an energy mix;
- Development of computer simulation codes, digital twins, robotics, artificial intelligence technologies, advanced materials, etc. are as well essential for innovation.

Potential structure for a European SMR collaboration initiative

The preliminary analyses performed on advantages and challenges of the different structures available at EU level for an initiative on SMRs highlight that Industrial Alliances (IA) and Joint Undertakings (JU) could constitute, subject to securing the requisite political support, adequate structures (see **WS3 report**).

Both options have pros and cons. Joint Undertakings, especially created through the Euratom Treaty, benefit from a defined legal structure that grants them consistency over time. However, they do not benefit from the same flexibility as Industrial Alliances. The latter do not have a fixed legal basis and can therefore suit different needs and be organized to fit the participants' expectations.

Based on this preliminary review, it is proposed to further assess the opportunity and feasibility of setting up an SMR "Industrial Alliance" at EU level to support the development and deployment of SMRs in those EU Member States wishing to be involved in SMR deployment.

The opportunity to complement this framework with JUs could be considered later on, depending on specific needs.

Nuclear safety regulators will not participate in the IA because of their independent and neutral role towards the promotion of SMRs. The interest of nuclear safety regulators in the development of SMRs is aiming at warranting their safety. Engagement with the industry helps to accomplish this goal. A mechanism will need to be developed to enable continuous engagement with the developments in industry and in R&D&I.

The European Commission has been associated from the start as a facilitator of this stakeholders' initiative. These analyses and the resulting concept of this initiative need to be subject to wide public scrutiny and validation after which the European Commission will consider its further involvement, and the modalities of its possible support to this initiative.

Benefits of such an SMR Industrial Alliance (IA):

1. Support for individual projects: facilitating project financing

The purpose of the IA could be to:

- Bring together vendors, customers, suppliers and subcontractors, fuel cycle, as well as potential investors to structure SMR projects in Europe, and in particular to gather cross-participation from players in different countries.
- Assist in identifying suitable sources of EU funds, within and outside the Euratom program.

2. Promoting generic tools for the involvement of European industry in the entire value chain

This could involve organizing:

- The provision of experimental facilities likely to facilitate the development of SMR (see SNETP work).
- The development of a European production capacity for SMR/AMR fuels
- The development of an industrial capacity for in-plant manufacture of SMR components.

3. Strengthening training programs

Create skills centres or network of skills centres dedicated to SMR training. Most European IAs have developed a skills development program for their sector (ie. the European Battery Academy) and the Net-Zero Industry Act plans to generalize this approach for each of the strategic clean tech sector.

4. Specific risk & cost sharing support that could be envisaged:

- Preliminary identification studies and / or "coordinating activities" could be directly supported by EC financial contributions.

- Dedicated Euratom programs could strengthen the support to SMR/ AMR safest development.
- The current SMR development financing possibilities through European instruments should benefit from an in-depth evaluation.
    - Access to existing EU funding opportunities for SMR technologies.
    - New opportunities should also be explored within as well as outside the Multiannual Financial Framework.
- As several EU Member States have already decided to support SMR development in their own countries, a preliminary goal of an IA could be to enhance sharing of these upfront developments between similar technologies of reactors to make the best use of these national supports.
- This could cover topics such as (i) sharing common detailed licensing costs or (ii) preliminary supply chain investments for long lead equipment or (iii) training of necessary human resources or (iv) PWR fuel adaptation and manufacturing.
- Given the order of magnitude of SMR development costs, adequate financing support could be put together from several Members States involved in the "Nuclear Alliance" and sharing similar objectives

5. Advise the European Commission in view to set-up the necessary policy conditions conducive to the safe development of an SMR sector.

The IA could organize a discussion among stakeholders on EU policy initiatives likely to foster the emergence of a European SMR value chain:

- Monitor and analyse existing programs in other parts of the world (National Reactor Innovation Center, and IRA in the USA; national programs in the UK, Canada, etc.) to leverage them for SMR developments in the EU.
- Identification, in the wake of the Net Zero Industry Act (NZIA), of policy adaptations to accelerate projects, stimulate demand, ...

6. R&D support

The Industrial Alliance could become the forum for drawing up a strategic research agenda for SMRs, based on the work of WS5, to be implemented in a coordinated way by industrial actors and interested EU Member States.

For instance, the development of an SMR digital twin could be an action funded by the Horizon Europe program or the Euratom Research and Training Programme.

Conclusion and next steps

The results of the different analyses performed in the frame of the European SMR pre-Partnership show that SMRs could help enabling the transformational change needed in Europe to become the first climate-neutral economy while also ensuring energy security, efficiency, affordability, and strategic autonomy. Together with Renewable Energy Sources (RES), SMRs could significantly contribute to Europe delivering a Net-zero energy mix, with a high level of safety and at a stable and affordable price.

To support this process and to ensure openness and full transparency in the preparation of this European SMR initiative two actions are now forecasted:

- To open this executive note and the five WS reports to public comments on different websites (nucleareurope, ENSREG, SNETP).
- To present this executive note and the five WS reports to the Nuclear Alliance Members States

Comments that will be collected will be an integral part of the debate at a "Stakeholders' Forum" which would be composed of representatives from EU Member States, ministries and other national administration bodies, MEP, civil society, etc. which have an interest in the topic.

This "Stakeholders' Forum" is to be organised on the 26th of October 2023.

Following this "Stakeholders' Forum", the European SMR initiative could be launched in a format and with objectives resulting from the conclusions of the WSs together with the debates and conclusions resulting from the Stakeholders' Forum on a suitable occasion in late 2023 (to be decided) by the Members States which have joined.

Disclaimer

This document has been drafted by the Steering committee of the EU-SMR pre-partnership composed by:

- Yves Desbazeille (Chair), nucleareurope Director General
- Bernard Salha, President of SNETP
- Jan Panek, EC DG ENER D Director
- Marco Brugmans, ENSREG representative, ANVS
- WS1: Anicet Touré, ENGIE- Tractebel
- WS2: Sylvie Cadet-Mercier, ASN
- WS4: Roberto Adinolfi, Ansaldo Nucleare
- WS5: Sylvain Takenouti, EDF R&D

With the support of the SC Secretariat:

- Berta Picamal Vicente– nucleareurope
- Abderrahim (Abdou) Al Mazouzi – SNETP /EDF
- Ghislain Pascal – EC DG ENER D2