ENEN contribution to the development of SMR human resource

G.-L. PAVEL

European Nuclear Education Network,

Rue d’Egmont 11, 1000 Brussels

Email: gabriel.pavel@enen.eu

K. PILIUHINA

European Nuclear Education Network,

Rue d’Egmont 11, 1000 Brussels

**Abstract**

The European Nuclear Education Network – ENEN is an association of more than 90 representatives of higher education institutions, research organisations, technical support organisations and nuclear industry.

In recent years the Small Modular Reactor – SMR technologies brought a new revival of the nuclear as environmentally friendly and clean energy source. The SMRs represented the innovation that new generations brought as a follow up of decades of safe utilization of well-known technologies used as large scale energy sources.

Today, the SMR technology is perceived as a solution to replace other environmentally unfriendly technologies or as a solution to bring energy to remote locations. Also, small communities can benefit of clear energy from a clean source.

At European level, several European Union – EU funded projects tackled the development of such technologies and important investments are made in this regard. In order to safely develop, build and exploit such technologies, qualified workforce is needed. Qualified work force is developed in a certain amount of time. depending also on the former specialization of an individual this amount of time can vary with quite some large margins. Some of these EC funded projects like TANDEM (study of methodology and consequences to fitting SMRs into power grid) or ECC-SMART (joint EU-Canada-China project tackling issues related to SCWr-SMR reactors) are trying to set the bass for future development.

The European Small and Advanced Training Academy – ESTA, an initiative developed in 2023 by ENEN targets to correlate the education and training initiatives at EU level in order to avoid redundancy and increase efficiency in educational actions targeting SMR reactors.

This paper intends to present the advancements in the TANDEM, ECC-SMART and ESTA projects and to present their outcomes.

## INTRODUCTION

The European nuclear energy sector is facing a new revival in the recent period, with significant developments in small modular reactors (SMRs) and other advanced nuclear technologies. This rapid development necessitates an important and highly skilled workforce to ensure safe, efficient, and innovative progress. As nuclear energy maintained it’s role in Europe's strategy to achieve carbon neutrality and energy security, the need for specialized human resources in this sector becomes increasingly critical.

Small Modular Reactors (SMRs) represent a promising advancement in nuclear technology and in recent years numerous initiatives were taking place. These reactors offer numerous advantages over traditional large reactors, including enhanced safety features, reduced capital costs, and greater flexibility in deployment. Based on their purpose and rather low power outputs, the SMRs could play a vital role in Europe’s energy transition, particularly in replacing aging power plants (especially those environmentally unfriendly) and complementing renewable energy sources of energy.

In addition to SMRs, Europe is also focusing on next-generation reactors such as fast neutron reactors and thorium reactors, which promise improved fuel efficiency and reduced nuclear waste. The diversification of reactor types requires a broad spectrum of technical expertise and specialized knowledge, underlining the need for an adaptable and well-trained workforce .

The expansion and modernization of Europe’s nuclear energy capabilities (see France targets in bringing at least eight new Reactors on the market in the near future - https://www.msn.com/he-il/news/other/french-president-macron-confirms-project-to-build-eight-new-nuclear-reactors/ar-BB1o4SXU) revealed several human resource challenges. According to the International Atomic Energy Agency (IAEA), there is an urgent need to develop a skilled nuclear workforce to address the entire lifecycle of existing nuclear facilities, (from design and construction to operation, maintenance, and decommissioning) and to this existing fleet new projects will add more pressure on the market. .

The European Commission's Joint Research Centre highlights the critical shortage of skilled professionals within the EU nuclear sector. The demand for Human Resource is spread across various roles, including nuclear engineers, reactor operators, safety specialists, and regulatory professionals. As the nuclear workforce ages, the impending wave of retirements further exacerbates the shortage, necessitating strategic efforts to attract and train new talent .

To address these challenges, comprehensive educational and training programs are essential. The IAEA emphasizes the importance of a systematic approach to human resource development (HRD) in the nuclear sector. This includes creating educational curricula that align with current and future industry needs, offering practical training opportunities, and fostering international collaboration to share knowledge and best practices .

Universities and other technical institutes across Europe are the major contributors expected to provide this needed Human Resource. Many European institutions (especially from France, the Netherlands but also Poland, Czech Republic or Romania) are expanding their nuclear engineering programs and forming partnerships with industry and governmental bodies to ensure that graduates are well-prepared for the demands of the modern nuclear workforce.

With the rise of SMRs and other advanced nuclear technologies, there is a pressing need for strategic human resource development. The challenges in this area are more stringent since there is no practical know-how on how to build and operate such reactors. Of course, the major topics present in the construction and operation of full/large scale reactors remains slightly unchanged but the actual operation of a different size nuclear power plant remains a challenge.

At European area, both the European Commission but also other institutions involved in Education, Training and Development of SMRs already started the research in the field.

Among these initiatives supported by the European Commission, it is worth mentioning the TANDEM and ECC-SMART projects.

*TANDEM*

The EC funded TANDEM project aims at analyzing how the integrating Small Modular Reactors (SMRs) into hybrid energy systems, presents a significant opportunity for the European Union to meet its ambitious climate-neutrality goals by 2050. By developing assessments and tools for safe, secure, and efficient integration of these reactors into smart, low-carbon hybrid energy systems, TANDEM aims to address the technical, economic, and societal challenges associated with this integration. SMRs and AMRs can be hybridized with other energy sources, storage systems, and energy conversion applications to provide electricity, heat, and hydrogen. This hybridization is a novel R&D topic that promises to enhance energy decarbonization efforts significantly. SMRs, in particular, offer advantages such as smaller physical footprints, reduced capital investment, and flexibility in site locations, making them ideal for integration into diverse energy systems.The TANDEM project focuses on light-water SMR technologies for near-term deployment (by the 2030s) while also considering the integration of AMRs for a longer-term perspective (by 2050). The project emphasizes the safety issues associated with SMRs within hybrid systems, recognizing that new safety protocols must be developed to address interactions between SMRs and other hybrid system components. This includes considering new initiating events and the potential impacts of non-nuclear systems on SMR safety.

One of TANDEM's primary goals is to develop an open-source "TANDEM" model library in the Modelica language, enabling the creation of a hybrid system simulator. This simulator will extend the capabilities of existing tools and support the comprehensive assessment of SMR safety, operational flexibility, and techno-economic performance. The Modelica-based simulator will allow for detailed modeling of hybrid system components and their interactions, facilitating accurate and holistic evaluations.

The project is focusing on two main study cases reflecting European energy policy trends: a district heating network and power supply in an urban area, and an energy hub serving regional energy conversion systems, including hydrogen production. These cases will help demonstrate the feasibility and benefits of hybrid systems incorporating SMRs.

A key component of the TANDEM project is its emphasis on societal acceptance and citizen engagement. Understanding and addressing public concerns about SMR technology and its safety is crucial for successful implementation. To this end, TANDEM is planning to conduct workshops in multiple European countries, including (but not limited to) France, Italy, Spain, Belgium, Ukraine, Finland, Germany, and the Czech Republic. These workshops will involve housing associations, city employees, and other stakeholders, fostering a dialogue on SMR integration and its societal implications.

The project aims to produce technical, economic, and societal recommendations and policy briefs to guide industry, R&D teams, regulatory bodies, NGOs, and policymakers. By raising awareness and interest among non-nuclear stakeholders and the general public, TANDEM seeks to build a broad coalition in support of SMR and AMR technologies.

SMRs in hybrid systems must be capable of flexible energy production to accommodate the intermittency of renewable energy sources and variability in power demand. TANDEM aims to demonstrate that SMRs can achieve the necessary flexibility while maintaining economic and environmental efficiency. This involves developing new safety design requirements and postulating new initiating events specific to hybrid systems.

*ECC-SMART*

The ECC-SMART project represents a joint effort focusing on the feasibility and safety features of a small modular reactor (SMR) cooled by supercritical water (SCW-SMR). This joint effort is done by entities coming from Europe, Canada and China. This project aims to bridge specific knowledge gaps and pave the way for future licensing and implementation of SCW-SMR technology. The collaborative effort, encompassing partners from the EU, Canada, and China, leverages international synergies and knowledge to push forward the development of a safe SMR design.

The ECC-SMART project aims to establish clear design requirements for SCW-SMR technology, develop comprehensive pre-licensing studies, and formulate guidelines for demonstrating safety. An important component of the project approach is addressing technical knowledge gaps, particularly regarding material behavior in supercritical water environments, irradiation effects, and reactor core design. These elements are planned to be explored through simulations and experimental.

One of the key innovations of the SCW-SMR design is its potential to significantly reduce capital costs compared to traditional pressurized water reactor (PWR) designs. The simplification of the reactor design leads to a more compact and cost-effective system. Additionally, the SCW-SMR proves to have a higher thermal efficiency, expected to be 1.2 to 1.45 times that of current light water reactors (LWRs), with potential thermal efficiencies reaching up to 48%. This not only reduces operational costs but also enhances overall performance.

As previously mentioned, the ECC-SMART represents a collective effort coming from teams from Europe, Canada, and China, incorporating findings from previous research efforts under the International Atomic Energy Agency (IAEA) and the Generation IV International Forum (GIF). This collaboration ensures a well-rounded approach to addressing technical challenges and advancing the SCW-SMR concept. The project also emphasizes the importance of passive safety features, aiming to eliminate the possibility of severe accidents and significant radioactive releases.

The project addresses also the importance of public perception and the need for transparency in communicating the safety and economic benefits of SCW-SMR technology. To this end, ECC-SMART has developed a dissemination strategy aimed to reach a broad audience, including the general public, academic researchers, regulatory bodies, and industry stakeholders. The dissemination strategy includes both scientific and general communication channels. For the academic and scientific community, the project targets to produce safety standard guidelines, white papers, and peer-reviewed publications. Participation in conferences and scientific exchanges will further enhance the visibility and impact of the project’s findings. For broader public engagement, the project is maintaining a dedicated website and utilize new media platforms to reach younger audiences. This approach ensures continuous online presence and accessibility to project information, fostering a transparent and informed dialogue with the public. For the scientific community, ECC-SMART is developing two specialized workshops focusing on materials and chemistry issues, as well as thermal-hydraulic and neutronic challenges related to SCW-SMR. These workshops will present findings from pre-licensing studies and safety guidelines, providing a platform for knowledge exchange and collaboration. Additionally, the project will host the International Symposium on Super Critical Water Reactors (ISSCWR), a major scientific conference that brings together global experts to discuss the latest advancements in SCWR technology.

*European SMRs/AMR Training Academy – ESTA*

ESTA is an initiative of the European Nuclear Education Network – ENEN, which started getting shape at the beginning of 2022. One of the major ideas of ESTA was the creation of a geographically distributed “Academy” that should respond to the society needs in terms of qualified workforce for the future SMR and AMR reactors. As mentioned, these types of reactors are planned to replace environmentally unfriendly sources of energy and/or being installed in remote areas. Often, these situations can be met in areas where a source of energy already exists and, for environmental issues this needs to be replaced. We, therefore, need to consider that such a polluting source of energy is already ran by qualified people. These people will require re-training in order for them to cope with the demands of a Nuclear Power Plant. Another topic that needs to be considered are the new and highly qualified workforce. This category is represented by youngsters who already have a general education and training and need some specialized courses and research. Last but not least is represented by the regulators and the decision makers. This third category of target group needs also specific training since their positions are of crucial importance for the first phases of the implementation of the SMR technology. The ESTA initiative is based on four geographical pillars: Czech Republic, France, Italy and Romania. Besides geographical reasons, in these countries one can find also relevant institutions that are able to provide attendees with hands-on exercises. Up to now, the actions planned and developed under ESTA contained two components: one theoretical component and one practical component. The theoretical components were planned in such a way that the attendees should know from the beginning the topic of the course, the targeted audience and the Agenda. The theoretical component had also to take into consideration offering different technology developers equal time to present their work. In the same time, purely scientific topics were addressed by renown speakers. /the practical component consisted either rom working visits to facilities involved or planned to support the deployment of SMR/AMR rectors; practical and computational exercises or simulator time (as it is the case for Romania with the NuScale simulator).

## ACHIEVEMENTS

All presented initiatives are already producing effects and results. All presented initiatives are consisting of several members coming from different countries so that each project can attain at least an European dimension.

*TANDEM*

During project implementation several steps were already started and concluded.

One of them was the analysis of the key features of the future EU energy market and associated regional/national landscapes. This was lead by Partner nucleareurope and one of the main conclusion was that if we maintain the target to have the first SMR deployed in Europe by 2035 then the most viable solution is to consider both the potential of electricity and heat production.

The status report on safety analysis in Europe from the operational flexibility and cogeneration viewpoint contained an European analysis from the operational and cogeneration point of view. It was noted than not only the inclusion in a cogeneration application, but also the interfacing with an electrical grid dominated by intermittent renewable energy sources and storage systems will need to be carefully assessed for the consequences that both may have on the safety margins of the nuclear reactor.

For the description and techno-economic characterization of the hybrid system components, as mentioned only the light water reactors were considered. The analysis was performed considering two hybrid energy systems (one energy hub in Southeastern Europe and District heating in Northern/Central Europe)

From the scientific points of view, several steps were done: definition of Modelica models requirements for the "TANDEM" library development; defining the modelling requirements with safety codes; Definition of case studies for techno-economic analyses including some environmental aspects; Identification of potentially impacted safety margins and methodology for safety analysis of a SMR integrated in a hybrid system.

The project performed also a comprehensive analysis of education and Training (E&T) Gap Analysis in the domain of safety of SMRs and hybrid energy systems, at European Level Several important findings were presented. Among the conclusions we can observe that as of today, there is no specific or dedicated full educational program that can fulfil the SMR needs in terms of qualified workforce. Several E&T institutions are offering dedicated E&T programs based only on demand. With respect to E&T ne must tae into consideration that obtaining a qualified person takes time. During the same analysis, the knowledge, skills and competences required by the SMR domains wee identified and presented. One can observe from this that besides the purely technical topics, in order to fully develop, construct and operate an SMR, a series of other soft skills are required.

*ECC-SMART*

Several important achievements were accomplished so far. The coordination between China-Canada and Europe proved that the combined expertise put together can support a faster development in the field securing this way a faster deployment of the technology. The project itself is deeply designed as a research project. In this regard, several reports were presented, summarizing the basic characterization of Materials and Specimens Machining, especially provides the summary and the description of the basic characterization of candidate materials such as stainless steel 310S and alloy 800H.

Another objective of the Project was to is to study the design and safety-related neutronic parameters and reactor physics behaviour of the SCW-SMR conceptual design, perform preliminary core design calculations to optimize core loading patterns, and examine the impact of burnup on the reactor physics behaviour of the SCW-SMR. In order to incorporate the aforementioned objectives to model the complex behaviour of the SCW-SMR, proper neutron/reactor physics codes are needed. An SCWR fuel computational benchmark model was provided by CNL as a common basis for comparing simulation results and to provide guidance in selection of computer codes for SCW-SMR reactor physics modelling.

When it comes to safety related features of the SCW-SMR concept one can say that a special characteristic of SCW-SMR is the mixed design – it can be considered as a light water cooled reactor (practically similar to Gen III BWR technology), while being part of the set of typical Gen IV designs offering high core outlet temperatures. On the other hand, the SMR size results in special features – usually more favourable safety parameters, but less advantageous neutronics.

*ESTA*

ESTA was intended from the beginning to support the coordination of E&T actions targeting SMR technologies in such way to try to avoid overlapping activities, topics and geographical distribution of respective E&T actions. In this regard we tried to keep contact with EC funded actions in the field of E&T for SMRs. On ENEN’s website [1] a series of events are presented there are two categories of events: the first category is represented by E&T events developed directly by ESTA and the second one is represented by events supported by ESTA. For the later, one could mention the TANDEM summer school which will take place in Italy, between 24-28th of June 2024 [2] or the SASPAM International Workshop on SMR Safety for a Sustainable Short-term Deployment which will take place between October 17-18, 2024 [3].

From the list of ESTA in-house developed actions we can mention:

* PILSMR – the Pilsen International SMR Workshop [4], an event organized on 23-27 th of October 2023 and attended by approximately 20 persons
* 2nd International Summer School on Early-Deployable Small Modular Reactors, an event organized in Lecco lake between 24-28th of June 2024. At this event about 30 participants are expected. [5]
* SMR summer school that will take place during the first week of September 2024, in Bucharest, Romania (registration open at: <https://nuclear-education.eu/>

## CONCLUSIONS

At European Union (EU) eve there are several initiatives aimed at increasing the human resource both in quantitative and qualitative forms when t comes to Small Modular Reactors. In recent years there have ben noted an important contribution coming from the European Commission in support of SMR development, in general. The EC is supporting both the development of the technologies (financing advancements in research but also facilitating the interactions with decision makers) but also in the human resource.

EC funded Projects such as ECC-SMART or TANDEM represent a coordinated effort coming from multiple consortium members which sometimes come from different continents) in support of various SMR technologies. Various studies and experiments were conducted, ranging from materials used for the SMRs and moving to analysing their behaviour in complex and hybrid energy systems-when they are coupled to an actual energy grid where they need to interact with other energy producers and with the variations of energy consumption.

Human resource is qualified in a specific amount of time. Having enough human resource to build and operate SMRs takes also time. The actors involved in the creation of the human resource are very well aware of this situation and are already acting and reacting according to future industry needs. Several SMR related summer schools were organized. Several workshop and other actions related to SMRs were, again developed and continue t be developed. Actions like ESTA aim at creating an efficient environment for obtaining the qualified human resource by involving highly profiled professionals and by trying to avoid duplication of actions when not needed.

ACKNOWLEDGEMENTS

The ECC-SMART project is funded by the European Commission EURATOM H2020 – NFRP-2019-2020 program, under grant number: 945234

The TANDEM project is funded by the European Commission HORIZON-EURATOM-2021-NRT-01 program, under grant number: 101059479

References

1. <https://enen.eu/index.php/what-is-enen/esta-the-smr-amr-european-training-academy/> on 12.06.2024
2. <https://enen.eu/index.php/2024/03/14/smr-ss-june24/> on 12.06.2024.
3. <https://www.saspam-sa.eu/open-workshop/> on 12.06.2024.
4. <https://enen.eu/index.php/2023/08/01/pilsmr-the-pilsen-international-smr-workshop/> on 12.06.2024.
5. <https://enen.eu/index.php/2024/03/14/smr-ss-june24/> on 12.06.2024.