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Outcomes and impact for the students of the International School, Workshops, and other E&T events of the TANDEM Project

Authors : Stefano LORENZI (POLIMI), Camilla Boix (ENEN), Andrea Pucciarelli (CIRTEN - UniPi), Gabriel Pavel (ENEN), Claire Vaglio-Gaudard (CEA)

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Author(s)	Stefano LORENZI, Camilla Boix (ENEN), Andrea Pucciarelli (CIRTEN - UniPi), Gabriel Pavel (ENEN), Claire Vaglio-Gaudard (CEA)
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Summary

The main impact metrics resulting from the implementation of the designed E&T actions will be evaluated and analysed. In addition, to ensure the long-term availability of the training materials and resources developed in this Task, an online platform will be appointed to host the majority of the learning materials.

Approval

Date	By
2025-08-28 11:52:23	Gabriel Lazaro PAVEL (ENEN)
2025-08-28 12:28:23	Claire VAGLIO-GAUDARD (CEA)

D6.3 - Outcomes and impact for the students of the International School, Workshops, and other E&T events of the TANDEM Project

WP6 - Task 6.3

31/08/2025 [M36]

Stefano Lorenzi (CIRTEN – PoliMi), Camilla Boix (ENEN), Andrea Pucciarelli (CIRTEN – UniPi), Gabriel Pavel (ENEN), Claire Vaglio-Gaudard (CEA)

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Abbreviations and Acronyms

Acronym	Description
SMRs	Small Modular Reactors
E&T	Education and Training
MSc	Master of Science
NHES	Nuclear Hybrid Energy Systems
Q&A	Questions & Answers

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Executive Summary

This deliverable presents an overview of the Education and Training activities conducted within the TANDEM Project, including the summer school, two technical workshops, and a series of webinars. The document provides a detailed description of each event, along with key metrics on participation and impact. These initiatives combined lectures, practical exercises, lab visits, and expert discussions on SMR deployment, hybrid energy systems, techno-economic modeling, and nuclear hydrogen production, fostering knowledge transfer, international collaboration, and capacity building. Participant feedback emphasized the value of hands-on activities, technical depth, and networking opportunities, highlighting TANDEM’s role in advancing expertise and innovation in hybrid nuclear energy systems to support the energy transition. To ensure the long-term accessibility and usability of the educational materials, an online platform has been designated to host all learning resources.

Keywords

TANDEM Summer School, TANDEM Workshop, Webinars, Education and Training

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1 Introduction

The TANDEM project aims to support the safe and cost-effective integration of Small Modular Reactors (SMRs) into low-carbon hybrid energy systems, focusing on the assessment of their performance and safety compliance within the future European energy mix. The integration of SMRs into hybrid energy systems involves multidisciplinary challenges, including nuclear safety, energy system optimization, and the coupling of nuclear with renewable energy sources for both electric and non-electric applications such as district heating, hydrogen production, or industrial processes. At present, there is no higher education program dedicated to the combined topics of cogeneration and hybrid system integration of SMRs, leading to a critical skills gap in this emerging field. To bridge this gap, the Education and Training (E&T) activities within Work Package 6 were designed following the Systematic Approach to Training described in Deliverable D6.2. The goal is to develop knowledge, skills, and competences through a structured set of learning opportunities that combine theoretical lectures with practical, hands-on experiences. Under Task 6.2, several E&T initiatives were designed and subsequently implemented in Task 6.3, namely the ones listed below.

- The TANDEM Summer School – Held at the Lecco campus of Politecnico di Milano from June 24th to June 28th, 2024, the summer school aimed to provide a comprehensive overview of SMRs in hybrid energy systems, combining lectures with hands-on activities for participants.
- The Workshop on "Non-electric applications of SMRs, hybrid energy systems and their components" – Organized at CEA premises in Saint-Paul-lès-Durance from September 18th to 19th, 2024. The workshop focused on the potential for a nuclear reactor to provide downstream applications in addition to electricity—such as heat and hydrogen—and on how these outputs interact with other energy production units and storage systems.
- The Workshop on "Modelling and optimization tools to assess hybrid energy systems integrating nuclear reactors" – Hosted by the University of Pisa from February 20th to 21st, 2025, this workshop addressed the features and the challenges of the modelling tools employed in the analysis of hybrid energy systems.
- A series of six webinars have been organized in collaboration with University of Pisa, ENEN++ and TANDEM project on the nuclear desalination, nuclear batteries, system codes, technoeconomic modelling and simulation of integrated energy systems, non-electric application of nuclear energy.

For each event, the document provides a brief overview (e.g., scope, participant selection, program) along with participant analysis and follow-up actions to ensure long-term impact.

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2 TANDEM Summer School

The TANDEM International Summer School was organized from 24th to 28th June 2024 at the premises of Politecnico di Milano, in the city of Lecco, Italy, along the Como Lake. The event was held in combination with the Second International SMR Summer School, creating strong synergy between the two initiatives and offering participants a comprehensive training opportunity.

The Summer School was specifically conceived for MSc and PhD students, PostDocs, young and experienced researchers and engineers interested in deepening their knowledge of the potential role that nuclear hybrid energy systems (NHES) can play in the ongoing energy transition. A total of 33 participants from 14 different countries attended the school, reflecting its international dimension and the growing interest in advanced nuclear technologies.

The program of the TANDEM Summer School focused on the advantages, the safety concerns, and the techno-economic challenges associated with the integration of nuclear power plants with applications beyond conventional electricity generation. Thanks to the collaboration with the Second International SMR Summer School, participants were also provided with a general overview of SMR development and the main ongoing projects, with particular attention devoted to economic aspects, non-electrical applications such as hydrogen production and district heating, as well as licensing, regulatory challenges and the industrial perspective on SMR deployment.

In addition to lectures, the school included hands-on activities on the modeling and simulation of nuclear hybrid energy systems. These sessions were made possible thanks to the open-source Modelica library developed within the TANDEM project, enabling participants to acquire practical skills in the design and analysis of hybrid energy systems under various operating conditions.

Through this combination of theoretical lectures, industrial insights, and practical training, the Summer School equipped participants with both the knowledge and quantitative tools needed to assess the potential, the challenges, and the safety implications of nuclear hybrid energy systems in the broader context of the decarbonization of the energy sector.

The program of the School is reported from Figure 1 to Figure 5. While the event was primarily conceived as an in-person meeting to maximize interaction and collaboration, an online connection was made available for general-purpose presentations, excluding the hands-on activities to preserve the interactive nature and technical depth of the practical sessions.

JUNE, MON 24	TANDEM Summer School		
08:30 – 09:00	*Registration & Welcome*		
09:00 – 10:00	Current and future energy landscape, role of nuclear in the energy transition	Hal Turon (IAEA)	Room B.0.4
10:00 – 11:00	Status of SMR development in the World	Hadid Subki (IAEA)	Room B.0.4
11:00 – 11:30	*Coffee break*		
11:30 – 12:30	Economics of SMR and polygeneration projects	Giorgio Locatelli (POLIMI)	Room B.0.4
12:30 – 14:00	*Lunch*		
14:00 – 15:00	The TANDEM Project	Claire Vaglio-Gaudard (CEA)	Room M2
15:00 – 16:00	Nuclear - Hybrid energy systems for decarbonized energy production and cogeneration	Stefano Lorenzi (POLIMI)	Room M2
16:00 – 16:30	*Coffee break*		
16:30 – 17:30	Working Groups on "Modelling of NHES"	Stefano Lorenzi (POLIMI)	Room M2
20:00 – 22:30	*Social dinner – on the lake*		

Figure 1: TANDEM Summer School program, Day 1.

JUNE, MON 24	TANDEM Summer School		
08:30 – 09:00	*Registration & Welcome*		
09:00 – 10:00	Current and future energy landscape, role of nuclear in the energy transition	Hal Turon (IAEA)	Room B.0.4
10:00 – 11:00	Status of SMR development in the World	Hadid Subki (IAEA)	Room B.0.4
11:00 – 11:30	*Coffee break*		
11:30 – 12:30	Economics of SMR and polygeneration projects	Giorgio Locatelli (POLIMI)	Room B.0.4
12:30 – 14:00	*Lunch*		
14:00 – 15:00	The TANDEM Project	Claire Vaglio-Gaudard (CEA)	Room M2
15:00 – 16:00	Nuclear - Hybrid energy systems for decarbonized energy production and cogeneration	Stefano Lorenzi (POLIMI)	Room M2
16:00 – 16:30	*Coffee break*		
16:30 – 17:30	Working Groups on "Modelling of NHES"	Stefano Lorenzi (POLIMI)	Room M2
20:00 – 22:30	*Social dinner – on the lake*		

Figure 2: TANDEM Summer School program, Day 2.

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JUNE, WED 26	TANDEM Summer School		
09:00 – 10:00	Licensing and regulatory challenges of NHES	Sean Belyea (CNSC)	Room B.0.4
10:00 – 11:00	Nuclear Hydrogen production	Pierre Gavoille (CEA)	Room B.0.4
11:00 – 11:30	*Coffee break*		
11:30 – 12:30	Stakeholder needs and Public engagement for SMRs	Merja Airola (VTT)	Room B.0.4
12:30 – 14:00	*Lunch*		
14:00 – 15:00	Working Groups "SMR deployment and stakeholders' interaction"	Merja Airola (VTT)	Room M2
15:00 – 16:00	Working Groups "SMR deployment and stakeholders' interaction"	Merja Airola (VTT)	Room M2
16:00 – 16:30	*Coffee break*		
16:30 – 17:30	Working Groups on "Modelling of NHES"	Stefano Lorenzi (POLIMI)	Room M2

Figure 3: TANDEM Summer School program, Day 3.

JUNE, THU 27	TANDEM Summer School		
09:00 – 10:00	SMR for district heating: the TEPLATOR project	Radek Skoda (UWB)	Room B.0.4
10:00 – 11:00	Industrial interest on SMR & NHES : *Ansaldo Nucleare*	Michele Frignani (ANN)	Room B.0.4
11:00 – 11:30	*Coffee break*		
11:30 – 12:30	End-users interest on SMR & NHES	Christophe Schneidesch (Tractebel)	Room B.0.4
12:30 – 14:00	*Lunch*		
14:00 – 15:00	Energy system optimisation	Stéphanie Crevon (CEA)	Room M2
15:00 – 16:00	Working Groups on "Modelling of NHES"	Stefano Lorenzi (POLIMI)	Room M2
16:00 – 16:30	*Coffee break*		
16:30 – 17:30	Presentation of the Working Group projects	Stefano Lorenzi (POLIMI)	Room M2

Figure 4: TANDEM Summer School program, Day 4.

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JUNE, FRI 28	TANDEM Summer School	
8:00	*Departure from Lecco by bus*	
10:30	*Arrival at SIET labs (Piacenza)*	
10:30 – 11:00	Presentation of SIET labs & activities	Roberta Ferri (SIET)
11:00 – 12:30	Visit to the labs	
15:00 – 16:00	Summer School closure, certificates delivery	
13:00 – 14:30	*Lunch*	
14.30	*Departure from SIET*	
15:30/16:00	*Arrival at Milano*	
16:30/17:00	*Arrival at Lecco*	

Figure 5: TANDEM Summer School program, Day 5.

2.1 Technical aspects of the organization

To ensure high-quality learning conditions, the number of participants was intentionally limited. Each registration request was therefore subject to evaluation and approval by the organizing committee. A dedicated website was set up for registration (https://evenium.events/tandem-summer-school), and all personal data were handled in full GDPR compliance.

The registration form required applicants to provide:

- Personal information (first name, last name, email)
- Academic or professional status and job category
- A description of their experience in the nuclear field, current work activities, and motivation for attending the Summer School
- Whether they required financial support through the ENEN2+ project
- Whether they requested accommodation at the Adolf Loos PoliMi Residence
- Applicants requesting ENEN2+ financial support were asked to submit, as a single PDF file also the completed application form and a CV summarizing their academic and professional background

The evaluation was primarily based on the students' positions and backgrounds, with the aim of maximizing the summer school's impact on their careers and avoiding duplicate or unsuitable profiles. This structured registration and evaluation process ensured that participants met the academic prerequisites and allowed the school to maintain a high standard of interaction and teaching quality throughout the event

The materials from the lectures have been made available to the school participants and are also accessible on the ENEN website for long-term use (https://enen.eu/index.php/portfolio/tandem-project/).

2.2 Data analytics

The analysis of the registered institutions provides a clear picture of the highly inclusive environment that was created, with participants representing 14 different countries. Figure 6 offers a quick overview of the geographical distribution. The majority of registrations come from Europe, with a predominant presence of participants from Italy, France, and Poland. Additionally, two participants are from non-European countries, namely India and the United States.

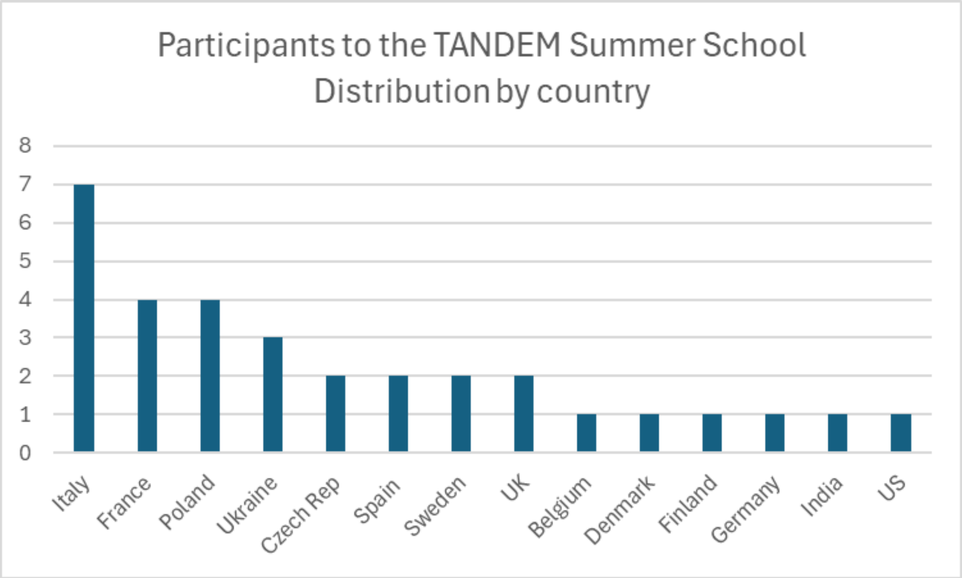

Figure 6: Distribution by country of the participants to the TANDEM summer school

The information provided in the registration forms also allows for analyzing the distribution of participants according to their position along the career path, as shown in Figure 7. It is noteworthy that a significant fraction of participants are Master of Science students, highlighting an early interest in the topic during the initial stages of their education and training. PhD students also show strong participation, alongside representatives of other categories grouped under the term “Senior”, which includes young professionals engaged in the topic for their future careers.

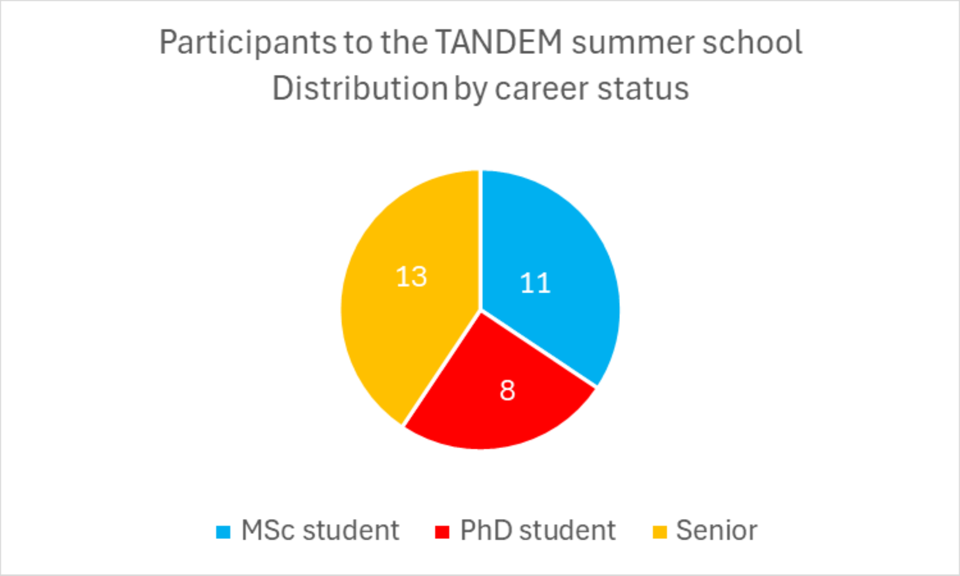

Figure 7: Distribution by career status of the participants to the TANDEM summer school

2.3 Survey results

The questionnaire developed to evaluate the TANDEM Summer School—its format, the appropriateness of the curriculum, the quality of information provided, and other aspects as perceived by participants—is presented below. The survey was distributed to attendees at the end of the school to collect feedback, and a total of seven responses were received. The following questions have been asked:

- A general evaluation of the school as a whole focusing on
- Practical information, logistic
  - Time management
  - Number of trainees
  - Interactive elements
  - General quality of teaching, lectures
  - Interest of virtual lab visits
  - Interest of workshops
  - Your Teaching tools
  - Quality of handouts
  - Interest on the practical exercises
- Evaluation for each lecture

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    - "Your interest in the topics presented" and
    - "Importance of know-how and knowledge transfer"
- Evaluation for the hands-on/exercises
    - exercises reflect the information received during lectures
    - evaluation of the usefulness of the exercises
- evaluation of the exercises (content and organization)
    - suggestion for exercises
    - additional topics should be included in the exercises
- Evaluation for the lab visit
    - interest in the topics presented in the lab visit
    - evaluation of the usefulness of the lab visit
    - evaluation of the lab visit (content and organization)
    - suggestion for organization of lab visit
    - additional topics/experiments should be included in the lab visit?
- Suggestions to be implemented for future events and additional topic to be covered

In terms of general evaluation, the Summer School received positive feedback, with the majority of students rating most aspects as Excellent or Good (see Figure 8). The interactive modules were particularly appreciated, as they gave participants the opportunity to apply the theoretical knowledge acquired. This preference for the practical component was also evident in the positive ratings for practical exercises and virtual lab visits.

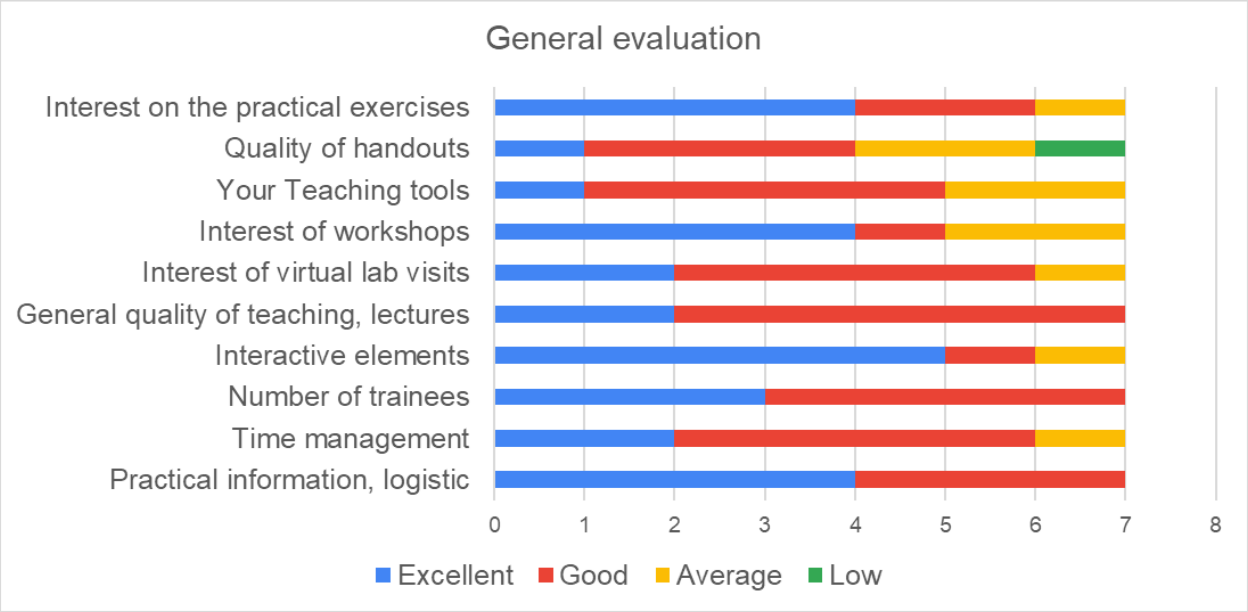

Figure 8: Replies to the general evaluation of the TANDEM Summer School.

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The results for the 15 lecture topics are summarized in Table 1. In general, participants found the lectures useful and insightful. The highest interest ratings were given to topics such as:

- Current and future energy landscape and the role of nuclear energy
- Status of SMR development worldwide
- Nuclear–hybrid energy systems for decarbonized energy production
- Energy scenario modeling

	Your interest in the topics presented			Importance of know-how and knowledge transfer			
	High	*Average*	*Low*	*Excellent*	*Good*	*Average*	*Low*
Current and future energy landscape, role of nuclear in the energy transition	7	0	0	6	1	0	0
Status of SMR development in the World	7	0	0	4	3	0	0
Economics of SMR and polygeneration projects	3	4	0	4	3	0	0
Nuclear - Hybrid energy systems for decarbonized energy production and cogeneration	7	0	0	4	2	0	0
SMR development and deployment in Canada	3	4	0	5	2	0	0
SMR development and deployment in Europe: the NUWARD project	4	2	0	1	5	0	0
The EU nuclear community and its strategy on SMRs	5	2	0	2	5	0	0
How to model a Country energy scenario	7	0	0	5	2	0	0
Licensing and regulatory challenges of NHES	4	2	1	3	4	0	0
Nuclear Hydrogen production	6	0	1	2	4	0	1
Stakeholder needs and Public engagement for SMRs	2	4	1	2	3	0	0
SMR for district heating: the TEPLATOR project Radek Skoda	3	2	2	3	4	0	0
Industrial interest on SMR & NHES : Ansaldo Nucleare	6	1	0	2	5	0	0
Industrial interest on SMR & NHES: Tractebel	5	2	0	1	5	0	0
Energy system optimisation	6	1	0	2	4	0	1

Table 1. Evaluation provided by the participants to the single topics.

Topics such as the economics of SMR projects, SMR deployment in Canada and Europe, and industrial perspectives also attracted significant attention, though with slightly more varied levels of interest. In terms of know-how and knowledge transfer, most topics were rated Excellent or Good, confirming that participants found the lectures informative and relevant. Industrial presentations and stakeholder engagement topics received slightly lower ratings but were still considered valuable. Overall, the feedback highlights a highly engaged audience with a strong interest in both the technical and strategic aspects of nuclear and hybrid energy systems.

The evaluation of the exercise sessions, shown in Figure 9, indicates that the majority of respondents found them well balanced and consistent with the content presented in the lectures. Quizzes were generally rated positively, although several suggestions for improvement emerged. These included the incorporation of scenario-based questions to strengthen the practical application of knowledge, the better spacing of quizzes across the course, the introduction of more group work opportunities, and some adjustments to the schedule—such as shorter breaks—to allow more time for meaningful discussion and real-world case studies. Participants also suggested including exercises on economic analysis, regulatory frameworks, international safety standards, and historical nuclear events, as these would help develop critical thinking and problem-solving skills.

The evaluation of the SIET laboratory visit, illustrated in Figure 10, was also very positive. Students recommended providing preparatory materials before the visit and summary documents afterwards to reinforce learning. They also suggested including short practical sessions and real-time demonstrations, such as the monitoring and control of nuclear reactors or safety and emergency procedures, to increase engagement and enhance the learning experience.

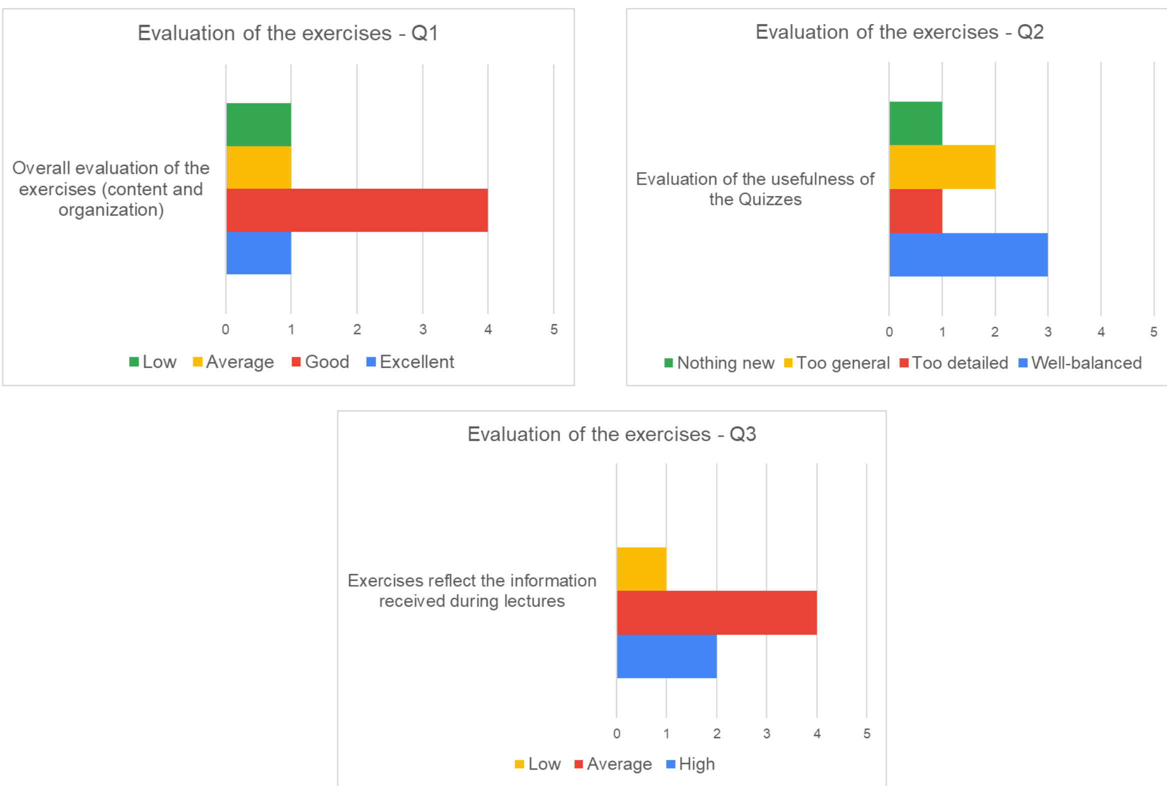

Figure 9: Evaluation provided by the participants to the exercise sessions.

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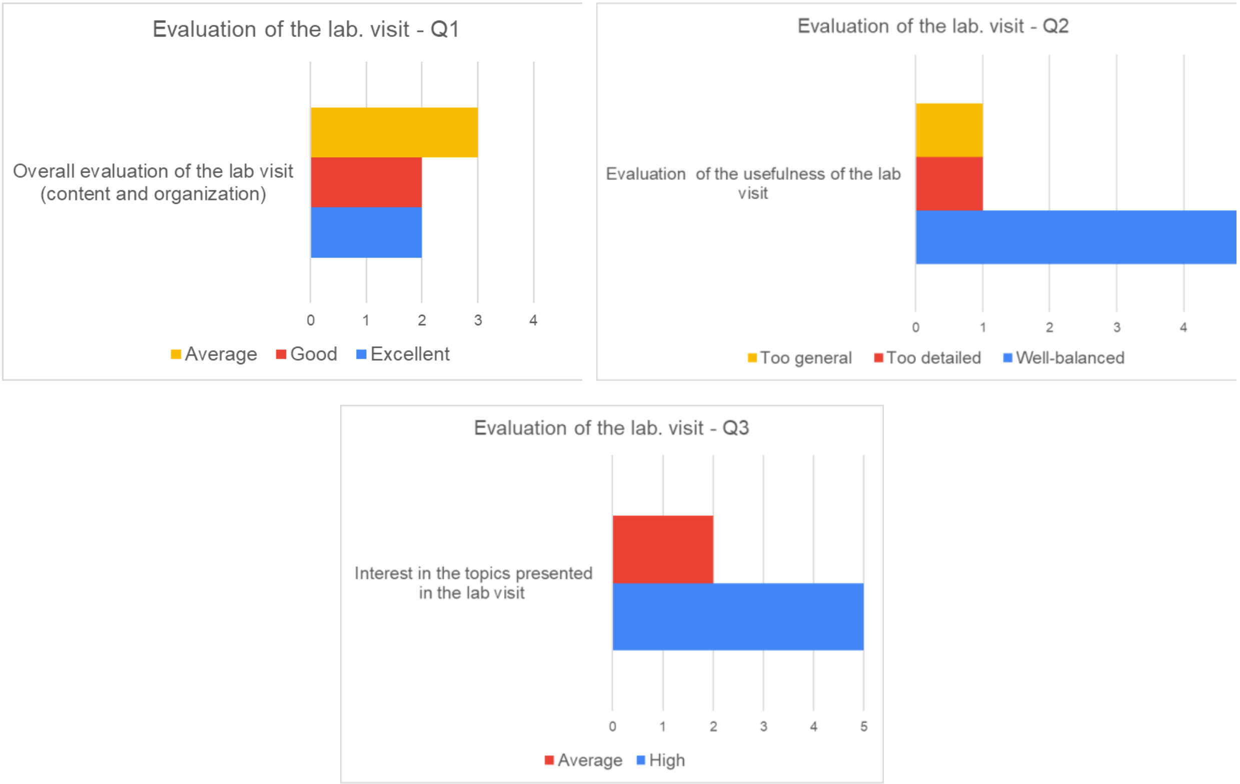

Figure 10: Evaluation provided by the participants to the lab. visit.

When asked for suggestions for future editions, participants recommended making lectures more engaging by reducing text on slides in favor of visuals, incorporating real-world examples to clarify theoretical concepts, allowing for deeper coverage of complex topics, and introducing interactive question-and-answer sessions as well as additional practical exercises following the theoretical components. They also expressed appreciation for the diversity of perspectives, particularly those provided by guest speakers from outside the European Union, and suggested involving more international experts in future events.

Finally, attendees proposed expanding the curriculum to include more specialized technical topics such as thermal energy storage for nuclear applications, modeling and optimization techniques, and renewable–nuclear energy integration. They highlighted the importance of addressing both the successes and failures of projects, for example in combined heat and power systems, to provide a balanced perspective. Emerging areas such as nuclear waste management and recycling were also recommended, reflecting the participants' interest in gaining a comprehensive understanding of current and future energy strategies.

2.4 Takeaway messages and follow-up actions

As a follow-up, a brief summary of the recommendations provided by the attendees is presented below. Participants suggested improving the Summer School by making the exercises more accessible, for example by using tasks that do not require software installation and by sharing exercise materials in advance. They also recommended balancing the lecture content by including a greater focus on economics alongside the existing emphasis on regulatory topics. To strengthen group work activities, attendees proposed clearly assigning roles for technical tasks such as calculations. Moreover, they emphasized the value of incorporating more interactive, hands-on activities and providing structured feedback sessions after workshops to enhance engagement and ensure continuous improvement.

Most attendees expressed strong interest in attending webinars on the topics covered during the school, particularly on SMRs, hybrid energy systems, cogeneration, hydrogen and synthetic fuel production, and the economics and optimization of energy systems. There was specific enthusiasm for webinars focusing on nuclear hydrogen production and global developments in SMR deployment. A few respondents, however, indicated no interest in further webinars. Overall, the feedback highlights a clear demand for deeper exploration of these technical and strategic topics in an online format.

As already mentioned, the E&T material of the TANDEM Summer school is available at the ENEN website (https://enen.eu/index.php/portfolio/tandem-project/)

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3 Workshop on "Non-electric applications of SMRs, hybrid energy systems and their components"

The workshop was held at the premises of the French Alternative Energies and Atomic Energy Commission (CEA) in Cadarache (Saint Paul-les-Durance), in the South of France, on 18–19 September 2024.

This technical event was specifically designed for MSc and PhD students, postdoctoral researchers, as well as young and experienced researchers and engineers who were interested in deepening their understanding of the potential role that hybrid energy systems—including SMRs—can play in the ongoing energy transition. The workshop aimed to create a collaborative environment where academic participants, industry professionals, and research experts could exchange knowledge and explore new ideas. A total of 23 participants attended in person, while additional 35 participants registered for online participation, ensuring a broad and diverse audience.

The programme focused on the non-electric applications of SMRs, covering topics such as district heating, hydrogen production, seawater desalination, and synthetic fuel production. It also explored the coupling of SMRs with renewable energy sources, the role of energy storage systems, and the design of integrated hybrid energy configurations capable of providing both electricity and other energy vectors in a flexible and sustainable manner. By addressing both the technological aspects and the strategic importance of SMRs in decarbonization pathways, the workshop aimed to provide participants with a comprehensive perspective on the challenges and opportunities in this field. The workshop programme is shown in Figure 11.

The presentations were delivered mainly—but not exclusively—by partners of the TANDEM project, ensuring that the content was directly linked to ongoing research and development efforts. This approach allowed the workshop to combine high-level conceptual discussions on the role of SMRs in future energy systems with the presentation of concrete technical results obtained within the project. Several sessions included case studies, simulation outcomes, and examples of potential industrial applications, offering participants a balanced view of both theoretical foundations and practical implementations.

In addition to the lectures, the workshop provided opportunities for interactive discussions and Q&A sessions, enabling participants to engage directly with experts, clarify complex concepts, and share their perspectives on the presented topics. This interactive format helped fostering networking and knowledge exchange among participants with different academic and professional backgrounds, further enriching the learning experience.

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Day			Activity	Speakers
Day 1	Morning	8h00	Formalities at the main CEA entrance (with your ID document)	-
		9h00	Welcome	Workshop organizers (CEA + ENEN)
		9h10	Brief presentation of the TANDEM project: objectives, activities, expected outcomes, status	C. Vaglio (CEA)
		9h45	Future energy structures needed for the energy transition	C. Schneidesch (Tractebel)
		10h45	Coffee break	
		11h00	How to use nuclear energy for decarbonization of industry?	M. Fütterer (EC-JRC, NC2I/GIF/GEMINI4.0 representative)
		12h00	Lunch break	
	Afternoon	13h15	Design of multipurpose reactors (SMRs, AMRs)	F. Morin (CEA)
		14h45	NUWARD^{TM} project	NUWARD project
		15h15	Coffee break	
		15h30	Hydrogen production from nuclear energy	G. Rodriguez (CEA, IEA representative)
		16h30	Flexibility of electricity production	C. Bono (EDF), G. Simonini (EDF)
		17h30	End of Day 1	
Day 2	Morning	9h00	Power conversion system and electrical grid (including impact of new sources on grid)	M.A. Evans (EDF), D. Jouret (Tractebel)
		9h45	Desalination	M. Kanniche (EDF)
		10h45	Coffee break	
		11h00	District heating	A. Rantakaulio (Fortum)
		11h30	Synthetic fuel production with SMRs	Ph. Amphoux, L. Bertier (CEA)
		12h00	Thermal and electrical storage. Options for coupling with SMR	S. Sholomitsky, O. Sevbo (Energorisk)
		12h30	Lunch Break	
	Afternoon	13h30	Organized tours in the CEA center	
		16h45	End of Day 2	

Figure 11: Cadarache workshop program

3.1 Technical aspects of the organization

The approach used for the TANDEM Summer School was used also for the workshop in order to select students with a reasonable background in the nuclear system. The number of students were limited to 30 and the registration was possible through the TANDEM website.

The registration form required applicants to provide:

- Personal information (first name, last name, email)
- Academic or professional status and job category
- A description of their experience in the nuclear field, current work activities, and motivation for attending the Workshop
- Whether they required financial support through the ENEN2+ project
- Applicants requesting ENEN2+ financial support were asked to submit, as a single PDF file also the completed application form and a CV summarizing their academic and professional background

The evaluation was primarily based on the students' positions and background. The materials from the lectures have been made available to the workshop participants and are also accessible on the ENEN website for long-term use (https://enen.eu/index.php/portfolio/tandem-project/).

3.2 Survey Results

The evaluation of the workshop considered several aspects, including the quality and relevance of the materials presented, the overall scientific content, and organizational and logistical aspects. Specifically, participants were invited to provide a general evaluation of the entire workshop as well as feedback on selected components. They were asked to rate, on a scale from 1 (lowest score) to 5 (highest score), a series of topics aimed at assessing both the scientific and practical dimensions of the event:

- General satisfaction of the workhsop and relevance and usefulness of the workshop to the field of work and study
- Evaluation on the following topic
    - Practical information, logistic;
    - Time management;
    - Number of trainees/participants;
    - Interactive elements;
    - General quality of teaching;
    - Interest of virtual lab visits;
    - Interest of workshops;

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  - Teaching tools;
  - Quality of handouts and
  - Interest on the practical exercises
- Evaluation on the single lectures

A total of seven responses were collected. In terms of the general evaluation, the workshop received positive feedback, with all participants indicating that they were either satisfied (4) or very satisfied (3). Six participants considered the workshop to be very balanced, while one participant noted that some sessions were too detailed. The evaluation of the specific topics is presented in Figure 12, which shows that even the lowest overall scores remain quite positive. The workshop received particularly high appreciation for the quality of teaching, the appropriate number of participants in the room, the practical information provided, the high relevance of the topics covered, and the practical exercises. One of the lower scores was related to time management, as participants felt that more time could have been allocated to certain topics. Additionally, participants expressed a desire for more interactive elements throughout the two days of the workshop to further enhance engagement and learning.

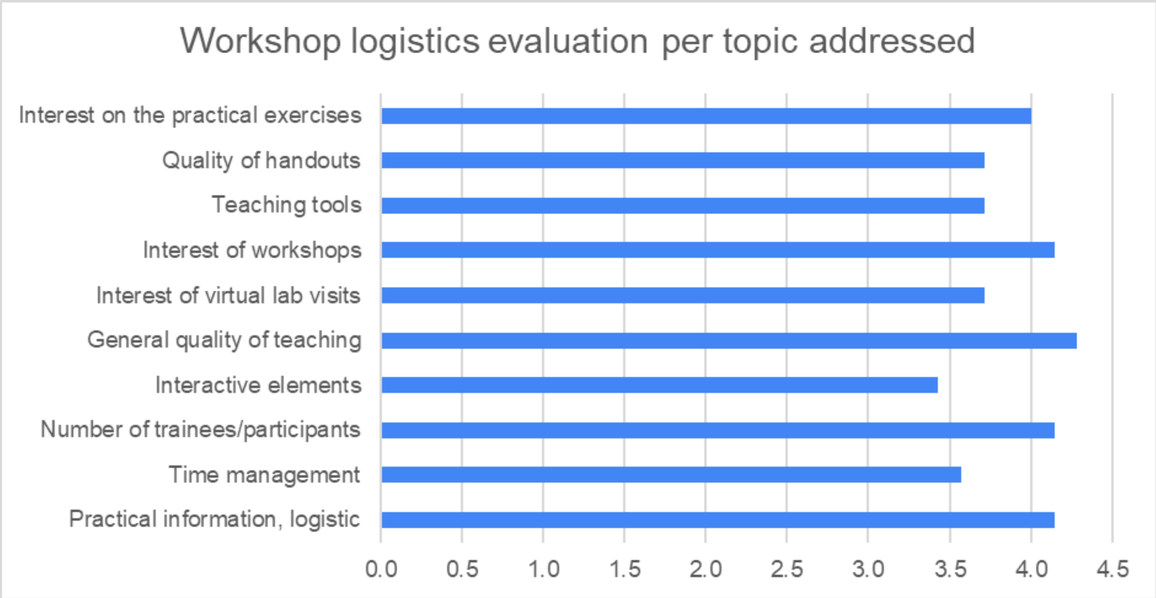

Figure 12: Average evaluation for single topic regarding the Cadarache workshop logistic.

The evaluation of the individual lectures during the two-day workshop was based on four criteria: clarity and understandability of the content, effectiveness of the presentation and materials, lecturer engagement and interactivity of the session, and participants' interest in the topics presented. Ratings were given on a scale from 1 (lowest) to 5 (highest). In Table 2, average value are provided.

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	How clear and understandable was the content presented?	*How effective was the presentation and the material?*	*How engaging was the lecturer and how interactive was the session?*	*Your interest in the topics presented*
Day 1				
Lecture 1: Future energy structures needed for the energy transition	4.4	4.4	4	4.4
Lecture 2: How to use nuclear energy for decarbonization of industry?	4.1	4.3	4.1	4.3
Lecture 3: Design of multipurpose reactors	4.3	4.1	4.0	4.4
Lecture 4: NUWARD project	3.9	3.6	3.4	3.6
Lecture 5: Hydrogen production from nuclear energy	4.3	4.3	4.1	4.4
Lecture 6: Flexibility of electricity production	4.4	4.4	4.3	4.4
Day 2				
Lecture 7: Power conversion system and electrical grid (including impact of new sources on grid)	3.7	4.0	3.7	3.7
Lecture 8: Desalination	4.3	3.7	3.6	3.7
Lecture 9: District heating -	4.4	3.9	4.4	4.4
Lecture 10: Synthetic fuel production with SMRs -	4.0	4.0	3.7	3.6
Lecture 11: Thermal and electrical storage. Options for coupling with SMR	4.0	4.0	3.9	3.9

Table 2. Evaluation provided by the participants to the single lecture of the Cadarache workshop.

On Day 1, the lectures were generally well-received. High scores were recorded for lectures on future energy structures needed for the energy transition, hydrogen production from nuclear energy, and flexibility of electricity production. The lecture on the NUWARD project received slightly lower scores, with ratings between 3.4 and 3.9, indicating that while the content was still positively perceived, some participants found it less engaging or clear compared to other sessions. Overall, participants expressed strong interest in the Day 1 topics, particularly those related to technical design and decarbonization applications.

On Day 2, lectures maintained generally positive evaluations. The session on district heating achieved the highest engagement scores, while lectures on power conversion systems and electrical grids and synthetic fuel production with SMRs received slightly lower ratings, suggesting that participants desired either more clarity, interaction, or time for these more complex technical topics. Lectures on desalination and thermal and electrical storage options for

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coupling with SMRs received solid scores, reflecting a good balance of content clarity, materials, and participant interest.

Overall, the lecture evaluations highlight that participants found the workshop content highly relevant and technically informative, with particularly strong interest in applications of SMRs for non-electric energy purposes, flexibility in electricity production, and practical system integration topics. Areas for improvement include enhancing interactivity and engagement for some of the more complex technical lectures.

3.3 Takeaway messages and follow-up actions

All attendees expressed high appreciation for the visit to the CEA facilities. When asked to rate the relevance of the lectures to real-world non-electric applications of SMRs, hybrid energy systems, and their components, all respondents unanimously indicated that the lectures were highly relevant. Participants also noted that it would have been valuable to have more opportunities for informal introductions and interaction with other participants, allowing for networking and knowledge exchange.

As already mentioned, the E&T material of the Cadarache workshop is available at the ENEN website (https://enen.eu/index.php/portfolio/tandem-project/)

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4 Workshop on “Modelling and optimization tools to assess hybrid energy systems integrating nuclear reactors”

The workshop took place at the “Le Benedettine” Congress Centre of the University of Pisa, Italy, on 20–21 February 2025.

This technical event was designed for MSc and PhD students, postdoctoral researchers, and both early-career and experienced engineers and researchers who wanted to deepen their understanding of modelling tools for analyzing the role that hybrid energy systems—including SMRs—can play in the transition toward low-carbon energy systems. The workshop aimed to foster a collaborative environment, where academic participants, industry professionals, and research experts could exchange knowledge and explore new ideas. A total of 24 participants attended in person, while an additional 37 participants registered for online participation, representing 8 different countries.

The programme (see Figure 13 and 14) focused on tools for modelling and optimizing hybrid energy systems integrating nuclear reactors, including the coupling of SMRs with other energy sources and energy storage solutions. Through a combination of theoretical insights and practical examples, participants gained a comprehensive view of how hybrid systems can be designed, analyzed, and optimized to efficiently provide electricity, heat, and hydrogen.

Being conducted toward the end of the TANDEM project, the workshop also highlighted the main achievements of the project, including the development of modelling tools for hybrid energy systems, ranging from dynamic system modelling and safety code analysis to techno-economic optimization. This allowed participants to see both the conceptual framework and the practical results generated by the project.

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Day		Activity	Speakers
		9:00 Registration	
Day 1	Morning	9:30 Welcome Addresses	M. Ricotti (CIRTEN and POLIMI) W. Ambrosini (UNIPI)
		9:45 – 10:00 Self Introduction of participants	All
		10:00 – 10:30: Brief presentation of the TANDEM project: objectives, activities, expected outcomes, status	Claire Vaglio-Gaudard, Coordinator (CEA)
		10:30 – 11:00: Coffee Break	
		11:00 – 11:30: Energy system scenarios in TANDEM	Christophe SCHNEIDESCH (TRACTEBEL - BELGIUM), WP1 Leader
		11:30 – 13:00: Panel on the future energy system scenarios according to Industrial and Utility Representatives: • Ansaldo Nucleare • ENEL • Edison	Michele Frignani (Ansaldo) Luca Mastrantonio (ENEL) Alberto Pasanisi (Edison)
		13:00 – 14:00: Lunch Break	
	Afternoon	14:00 - 14:50: Status of design and technology development of advanced reactors, including SMRs, and their applications	Frederik Reitsma (IAEA)
		14:50 – 15:10: Components of Hybrid Energy Systems with Advanced Nuclear Power Reactors, including SMRs	Frederik Reitsma (IAEA)
		15:10 – 16:00: Modelling SMRs in long-term energy system models for non-electric applications	Yunshu Li (IAEA)
		16:00 – 16: 30: Coffee Break	
		16:30 – 17:30: Non-Electric Applications of Nuclear Energy	Molly-Kate Gavello (IAEA)
		17:30 – 18:30: Tools for energy system design, optimization and analysis	Paul Talbot (INL)

Figure 13: Pisa workshop programme. Day 1.

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Day		Activity	Speakers
Day 2	Morning	9:00- 10:00: Nuclear Desalination	G. Caruso (Università di Roma Sapienza)
		10:00 – 11:00: Modelling Tools for NHES: Introduction to Modelica and BoP models	S. Lorenzi (POLIMI)
		11:00 – 11:30: Coffee Break	
		11:30 – 12:00: Coupling strategy between CATHARE and Modelica	A.De Angelis (UNIPI)
		12:00 – 13:00: Simulation of a load rejection and a loss of offsite power scenario in a cogeneration SMR	P. Olita (CEA)
		13:00 – 14:00: Lunch Break	
	Afternoon	14:00 - 15:00: Demonstration Exercise, Session with Modelica	G. Masotti (POLIMI), A. De Angelis (UNIPI), P. Olita (CEA)
		15:00 – 16:00: Coupled SMR Simulation with ATHLET and Modelica	S. Buchholz (GRS)
		16:00 – 16: 30: Coffee Break	
		16:30 – 17:30: Lesson Learned and Modelling tools to assess the safety of NPPs	S. Buchholz (GRS), S. Lorenzi (POLIMI), A. De Angelis (UNIPI), P. Olita (CEA)
		17:30 -18:00: Concluding remarks	All

Figure 14: Pisa workshop programme. Day 2.

4.1 Technical aspects of the organization

The approach used for the TANDEM Summer School and the Cadarache workshop was used also for the Pisa workshop in order to select a maximum of 30 students for the in presence attendance.

The registration form required applicants to provide:

- Personal information (first name, last name, email, affiliation)
- Educational Background and highest academic title possessed
- Requested in presence or online attendance

The evaluation was primarily based on the students' positions and background. The materials from the lectures have been made available to the workshop participants and are also accessible on the ENEN website for long-term use (https://enen.eu/index.php/portfolio/tandem-project/).

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A short video summarizing the characteristics of the workshop is available online at the following link: https://www.youtube.com/watch?v=hPxNbr8Yavs

4.2 Data analytics

The analysis of the registered institutions shows that the in-person audience represented eight different countries, reflecting a diverse yet regionally concentrated participation. Figure 15 provides an overview of the geographical distribution. The majority of registrations came from European countries, with a predominant presence of participants from Italy. This outcome can be considered reasonable, given the travel requirements and associated costs for attending a two-day workshop, which naturally favored participants from nearby locations.

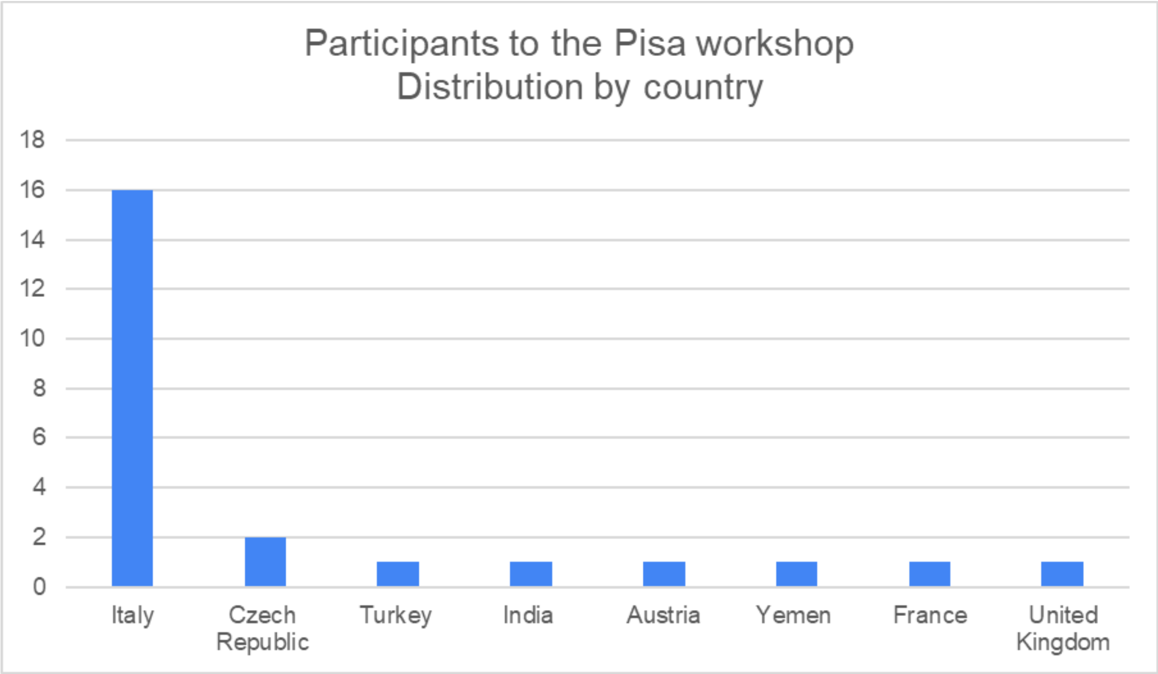

Figure 15: Distribution by country of the participants to the Pisa workshop.

The information collected through the registration forms also allowed for an analysis of the participants' distribution along the career path, as presented in Figure 16. A particularly interesting outcome of this workshop was the perfect balance among MSc students, PhD students, and senior participants. Such a balanced composition not only enhanced the quality of interactions and discussions during the workshop, but also promoted knowledge transfer across generations, an aspect fully aligned with the educational and networking objectives of the TANDEM project.

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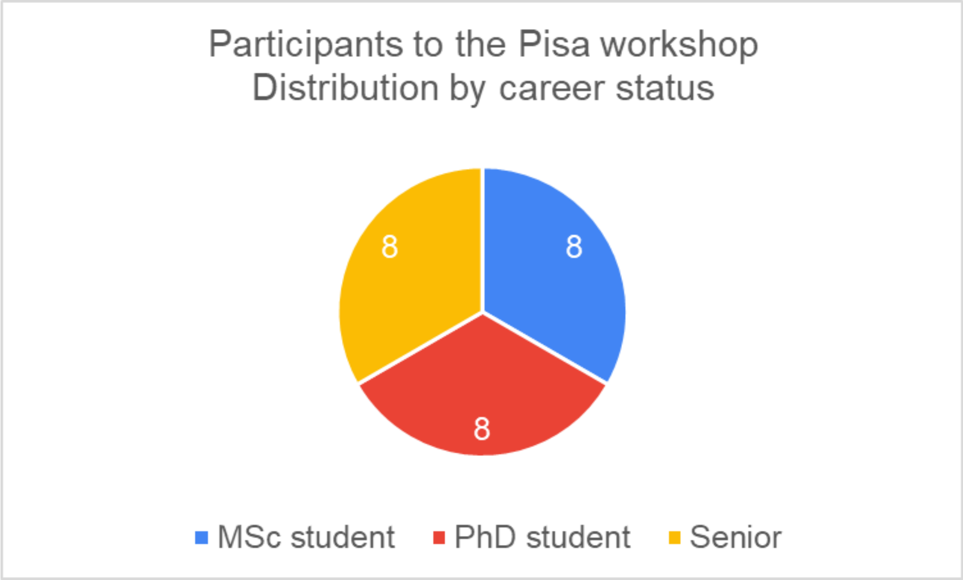

Figure 16: Distribution by career status of the participants to the Pisa workshop.

4.3 Survey Results

The evaluation of the workshop was conducted using an electronic survey, which collected 19 responses from both in-person and online participants. Similar to the survey implemented for the Cadarache workshop, the evaluation form addressed multiple aspects, including the quality and relevance of the materials presented, the overall scientific content, and organizational and logistical arrangements. Participants were asked to evaluate the following topics on a scale from 1 (lowest score) to 5 (highest score), providing a quantitative assessment of the workshop's effectiveness across these dimensions. The questions covered the following topics:

- General satisfaction of the workshop and relevance and usefulness of the workshop to the field of work and study
    - Evaluation on the following topic
    - Practical information, logistic;
    - Time management;
    - Number of trainees/participants;
    - Interactive elements;
    - General quality of teaching;
- Lecture appreciation

In terms of the general evaluation, the workshop received very positive feedback. All participants indicated that they were either very satisfied (15) or satisfied (3), with only one participant expressing a neutral opinion. Fifteen attendees considered the workshop to be very balanced, while three felt that certain sessions were either too advanced or too detailed, and one participant found parts of the workshop too general. The evaluation of the specific topics, presented in Figure 17, confirms these positive outcomes and demonstrates consistently satisfactory results across the programme. The workshop received particularly high appreciation for the quality of teaching, the appropriate number of participants in the room, the practical information provided, and the organization and time management. One area with comparatively lower scores was related to interactive elements throughout the two days of the workshop, suggesting that participants would have valued additional opportunities for engagement, discussion, and hands-on interaction.

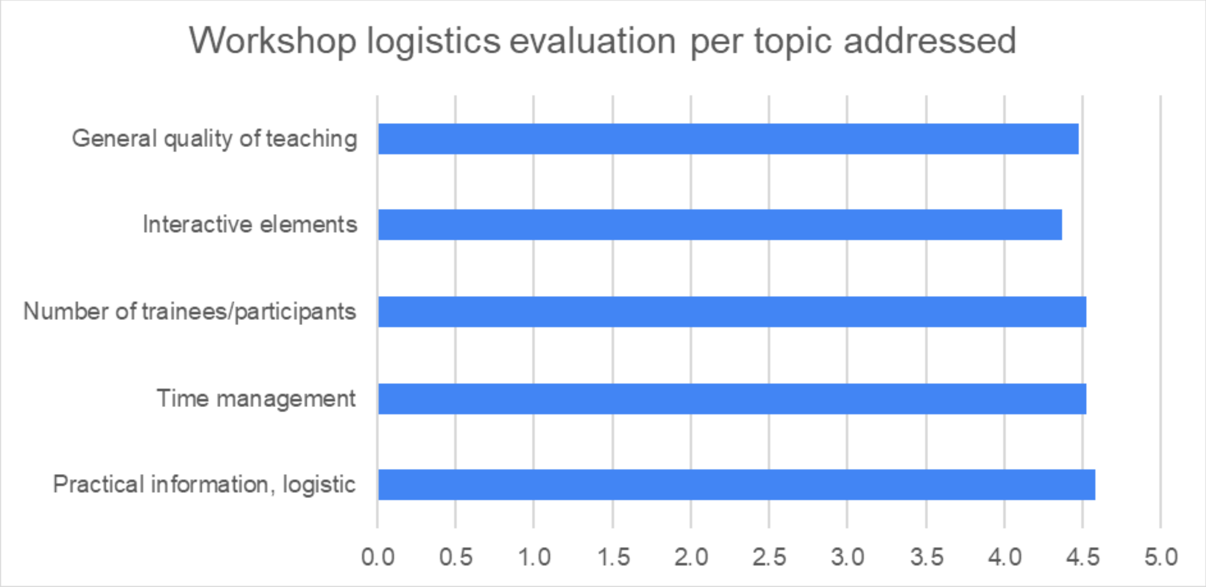

Figure 17: Average evaluation for single topic regarding the Pisa workshop logistic.

With regard to the individual lectures, particular appreciation was expressed for the sessions "Panel on the future energy system scenarios according to Industrial and Utility Representatives", "Non-electric applications of nuclear energy", and "Tools for energy system design, optimization and analysis" delivered on Day 1. These lectures were highly valued due to their strong alignment with participants' academic and professional interests, especially in areas related to SMR design, modelling, and data analytics. Attendees highlighted the technical depth and the direct relevance of the content to their ongoing research—particularly at the PhD level—as well as the opportunity to engage with experts actively working in the field. The lectures were considered not only informative but also directly applicable to participants' current and future work.

On Day 2, high appreciation was given to the sessions "Simulation of a load rejection and a loss of offsite power scenario in a cogeneration SMR" and "Demonstration Exercise: Session with

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Modelica". These contributions confirmed that the practical and hands-on components of the workshop were especially well received. Participants valued the opportunity to apply theoretical knowledge to realistic scenarios and to become familiar with advanced modelling tools.

4.4 Takeaway messages and follow-up actions

All attendees expressed high appreciation for the Pisa workshop. The evaluation and feedback collected highlighted the value of sessions that were closely aligned with participants' professional backgrounds and research activities, particularly those focused on modelling, desalination, and nuclear integration. The innovative aspects of the topics, combined with practical applications such as the use of the Modelica library, were considered especially valuable. Participants emphasized that the opportunity to link theory with practice and to address real-world challenges in hybrid energy systems made these sessions highly engaging and impactful. For future events, participants suggested placing greater emphasis on interaction among attendees and with the experts, to further enhance discussion, knowledge exchange, and networking opportunities.

As already mentioned, the E&T material of the Pisa workshop is available at the ENEN website (https://enen.eu/index.php/portfolio/tandem-project/)

5 Webinars

In the framework of the University of Pisa initiative "Past-student and Expert: Webinars in Nuclear Energy" (https://nucleare.ing.unipi.it/it/webinars/webinars-2023-2024), six webinars were jointly organized with the TANDEM project on topics directly relevant to the project:

- On 17 November 2023 at 15:00 CET, Gianfranco Caruso from Sapienza Università di Roma delivered a webinar on "Nuclear Desalination".
- On 15 December 2023 at 15:00 CET, Jacopo Buongiorno (MIT, USA) presented "Nuclear Batteries: a New Way in Energy".
- On 19 April 2024 at 15:00 CET, Dominique Bestion (CEA, France) discussed "What Must Be Known When Using System Codes for Reactor Design and Safety Analysis".
- On 26 April 2024 at 15:00 CET, Koroush Shirvan (MIT, USA) presented "Economy of Scale vs. Multiples: Bottom-up Cost Estimation of Nuclear Reactors".
- On 21 June 2024 at 17:00 CET, Elizabeth Worsham (INL, USA) delivered a webinar on "Technoeconomic Modeling & Simulation of Integrated Energy Systems: Overview of the Framework for Optimization of Resources and Economics (FORCE) Tool Suite".
- On 28 June 2024 at 15:00 CET, Francesco Ganda (IAEA) presented "Non-electric Applications of Nuclear Energy".

The webinars were attended by a variable but generally large number of interested persons, as detailed in the following list:

- webinar by Gianfranco Caruso: 94 attendants;
- webinar by Jacopo Buongiorno: 81 attendants;
- webinar by Dominique Bestion: 100 attendants;
- webinar by Koroush Shirvan: 62 attendants;
- webinar by Elizabeth Worsham: 30 attendants;
- webinar by Francesco Ganda: 33 attendants.

It must be noted that the above numbers refer to the total number of persons who connected at least once during the duration of the webinars. The lower number of attendants at the last two webinars is likely to be due to their delivery in the month of June, as necessary for the limited time availability of the lecturers, i.e., in a not completely ideal period for attendance.

Considering the general purpose of these webinars and the broad target audience, no specific data collection or surveys were conducted for the TANDEM project. However, recordings of all webinars are available online at https://nucleare.ing.unipi.it/it/webinars/webinars-2023-2024.

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6 Conclusions

The TANDEM project has successfully delivered a comprehensive suite of education and training activities, encompassing the TANDEM Summer School, in-person workshops, and webinars, all aimed at enhancing knowledge and skills in hybrid energy systems and the role of SMRs in the energy transition. The TANDEM Summer School brought together MSc and PhD students, postdoctoral researchers, and senior professionals from 14 different countries, providing a highly interactive learning environment. Participants benefited from lectures, virtual lab visits, practical exercises, and discussions on topics ranging from SMR deployment and hybrid energy systems to energy scenario modeling and nuclear hydrogen production. Received feedback highlighted the strong interest in practical exercises, hands-on activities, and the relevance of the topics to participants' research and professional development.

In addition, technical workshops were organized at CEA Cadarache and the University of Pisa, combining high-level theoretical presentations with practical demonstrations, exercises, and lab visits. These workshops reinforced the educational objectives of TANDEM, allowing participants to engage with experts, explore advanced modelling and optimization tools, and connect theoretical knowledge to real-world hybrid energy applications. Participants consistently appreciated the quality of teaching, the technical depth, and the opportunity to interact with a diverse, international audience, while suggesting improvements such as enhanced interactivity and networking.

Complementing these in-person activities, six webinars were jointly organized as part of the University of Pisa "Past-student and Expert Webinars in Nuclear Energy" initiative, in cooperation with the ENEN++ project, covering topics such as nuclear desalination, SMR design, technoeconomic modeling, and non-electric applications of nuclear energy. These webinars extended the reach of TANDEM's training efforts to a broader audience, providing accessible, high-quality resources and recordings for continued learning.

Overall, the TANDEM education and training activities demonstrate a strong commitment to capacity building, knowledge transfer, and international collaboration, effectively engaging both early-career researchers and experienced professionals. The combination of the summer school, workshops, and webinars has provided a rich, multi-format learning experience, fostering expertise in hybrid nuclear energy systems and supporting the advancement of research, innovation, and practical applications in the energy transition.

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