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E&T Gap Analysis in the domain of safety of SMRs and hybrid energy systems

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Summary

E&T Gap Analysis in the domain of safety of SMRs and hybrid energy systems. The knowledge, skills and competences required by the domains addressed in the TANDEM project will be firstly classified and categorized to identify the training needs required to address the core topics. Then, an analysis on what courses are available that may address them will be conducted. This will allow to find areas where new or further E&T would be required on the basis of either low supply coverage (i.e.: few options currently available) and/or partial coverage (i.e.: only a subset of the knowledge, skills and competences are addressed), hereby constituting the gap analysis between the E&T needs and how they can be covered.

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Abbreviations and Acronyms

Acronym	Description
AMR	Advanced Modular Reactor
CFD	Computational Fluid Dynamics
CTU	Czech Technical University
CU	Comenius University
E&T	Education & Training
HR	Human Resources
HTO	Human Technology Organisation
IT	Information Technology
IAEA	International Atomic Energy Agency
ICTP	International Centre for Theoretical Physics
LUT	Lappeenranta-Lahti University of Technology
MIT	Massachusetts Institute of Technology
NPP	Nuclear Power Plant
POLITO	Politecnico di Torino
PSA	Probabilistic Safety Assessment
SMR	Small Modular Reactor
TUM	Technical University of Munich
UB	University of Bucharest
UG	Ghent University
UNIPI	University of Pisa
UPB	University Politehnica of Bucharest
UPS	Université Paris-Saclay
UZ	University of Zagreb
WP	Work Package

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Executive Summary

The aim of this deliverable is to identify the current and expected needs with respect to Education and Training (E&T) related to SMR safety including the implications of their coupling with hybrid energy systems. Whenever mentioned within this deliverable, the SMR technologies being taken into consideration are based on light water reactor types. Advanced Modular Reactors (AMRs) are innovative, fourth generation (GEN IV) reactors. They produce a lower output than large scale reactors. These reactors are expected to implement a set of upgrades in comparison with existing commercial reactors. Some conclusions for E&T needs related to SMRs can be extended to AMRs

The first step would be to analyse what are the actual needs of the industry when it comes to Small Modular Reactors (SMR). An important challenge in following this objective will consist in the fact that currently, at EU level, there is no SMR installed that produces energy for the general population. This fact gives future operators of such Nuclear Power Plants (NPP) only limited choices when it comes to expressing the needs for future Human Resources (HR). Such needs can only be estimated taking into account the existing fleet of large-scale reactors. Another source of information when it comes to needs in terms of HR that should be taken into account by future SMR operators, is thorough discussions with possible SMR providers.

This step is followed by an analysis of the current providers of courses dedicated to SMRs and the extent to which these existing E&T activities fulfil the demand of future SMR employees. This analysis allows us to identify areas where new or updated E&T courses would be required on the basis of either low supply coverage (e.g. few topics available) and/or partial coverage (only a subset of the knowledge, skills and competences are addressed).

Keywords

Skills, knowledge, competences, education, training, SMRs, AMRs

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1 Introduction

The development of SMRs and their integration within hybrid energy systems may require new skills and thus the development of relevant education and training courses. This deliverable focuses on the knowledge, skills and competences required by the domains addressed in the TANDEM project.

As a starting point, the skills required have been identified with the goal to help characterise the training needs required to address the core topics. This is complemented by an analysis on what options are available that may already meet specific E&T needs. Based on this, work has then been undertaken to identify areas where new or further E&T would be required on the basis of either low supply coverage (i.e.: few options currently available) and/or partial coverage (i.e.: only a subset of the knowledge, skills and competences are addressed), hereby constituting the gap analysis between the E&T needs and how they can be covered.

In order to support future planning of E&T efforts, an assessment is also made of the main challenges and recommendations. Expectations on future needs by industry and academia of expertise in the fields of SMR safety and hybrid energy systems have been considered and the experience collected through the implementation of the TANDEM E&T actions, including students' feedback, will be taken into account in the future.

2 Assessment of skills needed

This section focuses on the skills which may be required in the future regarding SMRs and their integration within a hybrid energy system.

2.1 Data collection

In order to conduct this assessment, TANDEM project partners were invited to provide feedback on whether the development of SMRs will require new knowledge and skills. Furthermore, a questionnaire was sent to contacts within the nuclear industry asking for feedback on the following:

- Are the SMR 'knowledge needs' met by existing courses/training programmes?
- Which job categories will be needed to construct and operate SMRs?
- What are the skills required in order to meet the needs of these job categories?
- What additional 'knowledge' needs to be developed?

2.2 Survey results

In total, 12 people responded to the survey questions relating to SMRs and E&T needs. 41% of respondents were utilities, 66% were involved in Design, engineering, manufacturing and maintenance, 33% were involved in fuel cycle activities and 16% were involved in transport activities. It should be noted that some respondents were involved in several of the activities listed.

Based on the results of the survey, just over half of respondents found that existing education and training courses do not meet the so-called 'knowledge needs' related to SMRs (most notably 60% of 'utilities' and 62% of those involved in design/engineering/manufacturing activities).

Nevertheless, it should be noted that this depends also on the type of technology used. For example, one respondent noted that the most advanced and earliest-in-the-market SMRs are based on traditional light water technology. This means that issues related to, for example, the technology itself, radiation safety, radiation production and radioactive waste management are similar to those of traditional nuclear power plants.

2.2.1 SMR job categories

According to the results of the survey, the following job categories will be required for the construction and operation of SMRs (Table 1):

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All engineering disciplines	All technician disciplines (electrician, welders, etc)
Large project management & project control disciplines (including cost control & planning)	Nuclear safety
Licensing, permitting and procurement	Operations management (procedures, instructions, practices, etc)
Information technologies	Digitisation
Waste management	Chemistry
Physics	

Table 1: Identified job categories needed for the construction and operation of SMRs

2.2.2 Skills needed

Based on the job categories identified above, respondents were invited to identify both the 'Hard' and 'Soft' skills required to meet the needs of these job categories in relation to SMRs in particular. The responses can be summarised as follows, in Table 2:

HARD SKILLS	SOFT SKILLS
Nuclear safety	Problem-solving and analytical skills
Nuclear security & safeguards	Organisational ability
Licensing	Excellent spoken and written communication skills
Component performance	Ability to visualise complex processes
Electrical engineering	Creativity and persistence in work activities
Civil engineering	Ability to order information logically and clearly so others can follow their lead and instructions
Construction	Accountability
Welding	Teamwork
Non-Destructive Examination	Questioning attitude
Project management	Work Autonomy
Maintenance and inspections	Adaptability
Planification and cost estimation	Resilience
Mathematical and computer skills	

Table 2: Skills needed for the construction and operation of a SMR

2.2.3 Additional knowledge requirements

Further to the information provided above, respondents were asked to identify any areas where additional knowledge and skills need to be developed. Based on the feedback received, the following areas could benefit from improved and/or additional education and training activities:

- Increased focus on skills falling under the 'Soft' category (see above)
- Development of new skills tailored specifically to:

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    - SMRs - related to project integration, prefabrication, modular construction
    - AMRs (advanced nuclear technologies) - fast reactors and related technologies
- Inclusion of ‘onsite training and experience’ within the education and training modules for new engineers
- Update and optimize existing education & training courses in order to take into account that with SMRs much of the knowhow and support will be outsourced (i.e. fleet services). As a result, this will lead to geographical skills & competences and support centres – operators may therefore no longer have too in-depth engineering/maintenance teams. In this respect, simplification and optimization will be key.

2.3 Broader skill set requirements

One of the key focus areas of this project is the incorporation of SMRs within the future integrated energy system. As a result, consideration should be given to the development of dedicated modules within existing education & training programmes which focus specifically on the integrated energy systems of the future and how SMRs will operate within such systems.

Furthermore, SMRs are expected to provide more than just power applications, including heat, hydrogen and water desalination. SMRs will be “hybridised” with other energy sources, energy/electricity storage systems, applications to transport heat (heat networks) and to produce energy carriers (such as hydrogen) and feedstocks (such as demineralized and fresh water). A holistic vison of the future integrated energy system is under development, taking into account all the energy production methods which can help to decarbonize the energy of the residential, industry and transportation sectors.

In order to ensure that the workforce of the future has the skills needed to help in the development and deployment of such additional applications, courses and modules dedicated to these should be incorporated within the curriculum.

3 Analysis of the current E&T offer at EU level and surrounding countries – existing European context

The aim of this analysis is to identify to which extent EU countries have implemented E&T programmes capable of satisfying the needs in terms of Human Resources required for development, implementation and operation of SMRs together with their integration into hybrid energy systems.

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3.1 Nuclear power in Europe – an educational analysis

In general, technical education in Europe has the same approach. When it comes to energy, engineering faculties have to a large extent a similar curriculame. General or major topics are comparable. The topics addressed by the E&T institutions followed the technologies implemented in their respective countries of residence and were in accordance with the human resources needs at the moment of implementation of energy production using NPPs.

At EU level there are two types of countries that deal with nuclear education: states that have an ongoing nuclear programme with operational NPPs (Belgium, Bulgaria, Czech Republic, Finland, France, Hungary, Netherlands, Romania, Slovakia, Slovenia, Spain and Sweden) and countries that do not have operational NPPs but do have a nuclear education programme implemented at the University level. In some instances, it is worth noting that they have a very strong educational programme even if they have no NPPs in operation (e.g. Germany, Italy, etc.).

A third category of countries to be considered is those with Research Reactors. There are currently about 223 research reactors in the world located in 53 countries. The following EU countries host research reactors currently under operation [10][11]:

- Germany: 5
- Italy: 5
- Belgium: 3
- Czech Republic: 3
- France: 3 (+1 under construction)
- Netherlands: 3 (+1 under construction)
- Hungary: 2
- Austria: 1
- Greece: 1
- Poland: 1
- Romania: 4
- Slovenia: 1
- Ukraine (non-EU): 3
- United Kingdom (non-EU): 1

Even so, when dealing with this third category we will not consider a separate in-depth analysis since these reactors are meant for research purposes and therefore do not fall under a dedicated analysis targeting education programmes.

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3.1.1 Education in countries with operational NPPs

This type of countries can be considered to have strong and traditional educational programmes which were developed several decades ago. Countries like (in alphabetical order) Belgium, Bulgaria, Czech Republic, Finland, France, Hungary, Netherlands, Romania, Slovakia, Slovenia, Spain and Sweden have decades of experience in creating highly skilled generations of "nuclear experts".

As an example, the general and particular topics addressed by the University Politehnica of Bucharest (UPB) can be associated to the needs of the nuclear industry as described under section 2 are the following:

BACHELOR LEVEL	MASTER LEVEL
Applied informatics	Advanced NPPs
Physics	Physics and computational software used for NPPs
Chemistry	NPP simulators- dynamics
Computer-aided design	Advanced numerical models
Computer programming	Probabilistic Safety Assessment (PSA)
Mechanics	Nuclear Fuel
Economy	Fast reactors
Fluid Mechanics	Radiation protection
Materials	Computational Fluid Dynamics (CFD) codes use for designing and analysis of an NPP
Fundamentals of energy engineering	Thermal-hydraulics of NPPs
Financial resources and economic analysis	Environmental impact
Numerical methods	NPP control and command
Heat and mass transfer	Nuclear Waste
Thermal equipment and installations	
Hydraulic machinery	
Electrical equipment	
Energy and environment	
Fundamentals of nuclear reactors theory	
Dosimetry and radiation protection	
Electrical and thermal power generation	
Electrical grids	
Internship	
Reliability	
Law and legislation in energy	
Nuclear power plants	
Thermal-hydraulic of nuclear installations	
Nuclear materials and technologies (e.g. welding techniques)	

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Kinetics and dynamics of nuclear reactors	
Management in energy	
Systems in nuclear power plants	

Table 3: Topics addressed by the curricula of UPB

Similar illustrations of curricula from nuclear engineering schools in Europe can be found in Annex 1 to this document.

As a general conclusion when analysing the needs of the industry and considering what educational systems provide both at Bachelor and Master level it is clear that nuclear engineering schools can provide to some extent the knowledge, skills and competencies of future NPP (including SMR) employees. The educational system must take into consideration also other nuclear sectors (e.g. medicine, regulators, etc) and must adapt their programme accordingly. Specific SMR topics are either addressed at Master levels through specific courses, either as part of Specializing Masters or they are continued during PhD programmes with in-depth analysis performed during thesis development. At the same time, there are other aspects which it may be beneficial to include as part of the E&T curricula. First of all, broader courses relating to integrated energy systems in general, in order for students to have a greater understanding of such a system and the synergies linked to SMRs. And subsequently, the other benefits which an SMR can bring to such a system that extends beyond power, such as heat, hydrogen and water desalination. All of these are important elements which should be incorporated into the curricula.

3.1.2 Education in countries without operational NPPs

Within this category we can include two types of countries: those that do not have any nuclear reactors which are used for the purpose of generating energy, such as Italy or Germany, and so-called 'Newcomer Countries' who are considering investing in nuclear capacity in the future, such as Poland.

According to the Impact assessment of the Euratom Research and Training Programme for the period 2021-2025 [1] up until today, Germany and Italy are the top two users of funds dedicated to research and education in the nuclear field. These countries have invested significantly in education and research in nuclear at all levels. Their educational programmes are vast and cover the majority of nuclear topics such as (but not limited to):

BACHELOR LEVEL At this level an engineering student follows general information courses with little or no specificity to nuclear	MASTER LEVEL Nuclear engineering
Mathematics	Radiation detection and measurement
Fundamentals of experimental physics	Reactor physics
Fundamentals of mechanics	Reliability
Statistics	Radiation detection
Fundamental of Management and industrial Engineering	Protection against radiation
Power systems fundamentals	Radiochemistry
Hydraulics and thermal machinery	Artificial Intelligence (AI) and Simulations in nuclear
Energy Systems and Environmental impact	Nuclear Reactor Kinetics
Analytical and Numerical methods for Engineering	CFD for Nuclear Engineering
Microgrids	Nuclear Design and Nuclear Technologies
Introduction to Nuclear Engineering	Transport of radioactive contaminants
Radiation protection	Advanced reactors

Table 4: Topics addressed by the curricula in Germany & Italy

Poland is a good example of a country which is about to start its nuclear programme and underlines the importance of investing in education specifically dedicated to SMRs. According to [8], Polish Universities with state support have begun an ambitious programme with a focus on SMRs since the country plans to build 79 new such reactors and currently has no large scale NPP under operation.

3.1.3 Summer Schools and other E&T projects

In addition to existing bachelor's and master's degree programmes, there are a series of other E&T courses which cover (or have covered) SMRs specifically. Below is an overview of some of these programmes:

- Nuclear–Renewable Integrated Energy Systems: Phenomenology, Research and Development. This course ran in October 2021, and was jointly organised by the International Centre for Theoretical Physics (ICTP) and the International Atomic Energy Agency (IAEA). It focused on integrated energy systems which include nuclear and renewable, from a decarbonized energy production and cogeneration perspective. The course also enabled a sharing of knowledge on these technologies, designs and related innovations.
- International Summer School on Early Deployable SMRs. This course ran in July 2022, and was organised as part of the ELSMOR EU funded project (which is dedicated to the

European licensing of SMRs). Some of the topics dealt with as part of this course included international experience in the licensing of SMRs, innovative and advanced safety systems of Light Water SMRs and technologies under development.

- Summer School on SMRs. This course runs in August 2023, and is being jointly organised by OECD Nuclear Energy Agency (NEA) and the Halden HTO Project. The main focus of this course is Human Technology Organisation (HTO) view on SMRs in relation to the basics of SMRs, important principles in the regulation of new advanced reactors, and the different SMR designs.

The IAEA also offers a series-of e-learning courses relating to SMRs, which are aimed at all levels from beginner to experts. The courses on offer cover a range of topics, including hybrid energy systems, and different reactor technologies.

3.2 Education dedicated to Small Modular Reactors (SMR) – a European context

Worldwide, there are several universities that offer nuclear education programmes related to SMRs. Most of these universities offer courses dedicated to SMR and/or AMR technologies and these are integrated within their existing curricula. Below is an overview of some of these higher E&T institutions:

- University of Tennessee-Knoxville, which has a Nuclear Engineering programme that offers courses in SMR design, licensing, and economics.
- The Massachusetts Institute of Technology (MIT) has a Nuclear Science and Engineering programme that offers courses in nuclear reactor design and operation, including SMRs.
- The University of Idaho offers a Nuclear Engineering programme that includes courses on advanced nuclear reactor concepts, including SMRs.
- The University of New Mexico offers a Nuclear Engineering programme that includes a course on SMRs and advanced reactor designs.

We must consider that these courses, in both cases, if we are referring to EU or non-EU countries have been recently introduced. When it comes to state-funded E&T institutions, they must respect some approved curricula which is usually assigned/regulated by the relevant Ministry. Such curricula are periodically analysed and approved and modification of the educational curricula must follow some specific rules and regulations. Last, but not least, this takes time to implement.

When it comes to the European context, several universities have already introduced courses related specifically to SMRs and a selection of such programmes is presented below:

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- The Technical University of Munich (TUM) in Germany has a Nuclear Engineering programme that includes courses on advanced reactor systems, including SMRs.
- The Czech Technical University (CTU) in Prague has a Nuclear Power Engineering programme that includes a course on Small Modular Reactors.
- The University of Pisa (UNIPI) in Italy has a Nuclear Engineering programme that includes a course on Small Modular Reactors.
- Politecnico di Torino (POLITO) in Italy has a Nuclear Engineering programme that includes courses on nuclear reactors, including SMRs.
- The Technical University of Denmark has a Nuclear Engineering programme that includes courses on reactor technology, including SMRs.
- The University of Groningen in the Netherlands has a Nuclear Physics and Engineering programme that includes courses on nuclear reactor technology and safety, including SMRs.
- The Lappeenranta-Lahti University of Technology (LUT) in Finland has a Nuclear Engineering programme that includes courses on advanced reactor technologies, including SMRs.
- The École des Mines de Nantes in France has a Nuclear Energy Engineering programme that includes courses on reactor physics and technology, including SMRs.
- The Université Paris-Saclay (UPS) in France has a Nuclear Engineering programme that includes courses on nuclear power plant design and operation, including SMRs.
- Comenius University (CU) in Bratislava, Slovakia has a Nuclear Physics programme that includes courses on nuclear reactor technology, including SMRs.
- Ghent University (UG) in Belgium has a Nuclear Engineering programme that covers various aspects of nuclear technology, including SMRs.
- University of Bucharest (UB) in Romania has a Nuclear Engineering programme that includes courses on advanced reactor concepts, including SMRs.
- University Politehnica of Bucharest (UP) has a Nuclear Engineering programme under the Department of Energy and at master level it offers SMR and AMR courses.
- University of Zagreb (UZ) in Croatia has a Nuclear Engineering programme that covers nuclear power plant design and operation, including SMRs.
- The KTH Royal Institute of Technology in Stockholm, Sweden has a Nuclear Energy Engineering programme that includes courses on advanced reactor concepts, including SMRs.

Non-EU E&T institutions, but which are still connected to the EU, include:

- The University of Manchester in the UK has a Nuclear Engineering programme that includes courses on nuclear power systems, including SMRs. They also have research groups that focus on SMRs and advanced nuclear systems.

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- The Imperial College London in the UK offers a Nuclear Engineering programme that includes courses on nuclear reactor systems, including SMRs
- The University of Birmingham in the UK offers a Nuclear Engineering programme that includes courses on nuclear power generation, including SMRs.
- The University of Surrey in the UK offers a Nuclear Engineering programme that includes courses on nuclear reactors and energy systems, including SMRs.

One should strongly note that these courses provide general information about SMRs and are at Master Level. Integration of various power production technologies into the national or regional power grid is dealt with during early university years and set in place by general-knowledge professors, possibly with little to no insights into the in-depth specificities of more recent technologies or recent advancements. This situation is amplified by the process of changing the existing curricula which can be very time-consuming in some countries since universities are supported by the state. Even so, one must consider that universities do have a certain degree of freedom but must follow quality assurance protocols to certify their high level of education. SMR–related courses are conceived as advanced courses, thus in no situation have any such courses been identified at bachelor level. This situation limits the possibility of an institution to have more dedicated topics or analyse, in-depth, a specific topic such as SMRs and their coupling with other systems or their behaviour under hybrid systems. Such analysis is often dealt with at PhD level and is subject to high level research.

Also, one must consider the fact that a series of Specializing Masters have been created or could be created. This type of education focuses on specific topics and is usually based on close collaboration with industry. Even with Specialized Master programmes a full coverage of the skills and competences required by the industry is difficult to accomplish due to the lack of such a broad spectrum of specialists under only one institution.

3.3 Gaps

Generally speaking, many of the E&T topics of relevance to SMRs and AMRs are covered by the existing curricula, especially in relation to SMRs based on existing reactor technology.

However, there are certain gaps which have been identified in terms of E&T linked to the development and deployment of SMRs.

First of all, whilst Engineering programmes (eg Bachelor level courses) do touch upon the integration of nuclear power plants into the energy system, as many of these course are conducted by non-nuclear professors. As such, there is a risk that these courses do not take into account the latest developments when it comes to the potential for SMRs, in particular the additional benefits which these technologies can provide in terms of heat, hydrogen etc.

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Secondly, there is currently no Master programme which is dedicated specifically to SMRs and AMRs. In future it may be worth considering the inclusion of some courses tailored towards new reactor technologies.

Thirdly, given the changing landscape, all students could benefit from E&T courses which provide a wider vision of what the future hybrid energy system will look like. This will enable students to gain a greater insight into different aspects which go beyond ‘pure nuclear’ topics, including the provision of electricity and heat for hydrogen production, district heating purposes, sea water desalination, etc. A greater understanding of the economics associated to the future hybrid energy system could also prove beneficial.

And finally, more should be done to encourage people to work with experts coming from a different field, so that they can gain a greater insight into the potential of a hybrid energy system. This could already be foreseen at university level, for example, by encouraging students studying different, but related, fields to work together on projects dedicated to the development of a low-carbon energy system.

Given this, it can be concluded that the existing curricula only covers part of the knowledge and skills which the nuclear workforce will require in the short, medium and long-term.

4 Conclusion

Small Modular Reactors are perceived as one of the newer types of power production methods which can replace many of CO2-emitting power sources (such as coal or oil-derived products).

In recent years multiple start-up companies have designed and developed different types of SMR reactors that can be adapted and built on new sites as well as existing ones which currently host another source of electricity production method.

Although some of these technologies are known or already implemented in large-scale reactors, a series of particularities makes dedicated education for such types of NPPs a must. Education in this case is needed either to adapt the career path of an existing employee working in a different field or for the brand-new workforce. These two options make it clear that a full educational programme in Energy Engineering and, more specifically, in nuclear engineering is required.

Such programmes take an important amount of time to develop and implement, as is the case for other industries. The education and training of a full workforce covering all the skills needed to run a power plan in general, and a nuclear power plant (including SMRs) in particular, can be covered by multiple educational programmes such as Energy Engineering, Civil Engineering, Chemistry related programmes, IT schools and a multitude of other disciplines required for technicians.

At EU level, SMR specific nuclear topics are mostly covered by Specialization Master courses which have been issued in recent years, or by General Master Programmes which have adopted the specific topics required in the field of SMRs and Advanced Modular Reactors (AMRs) and that have been implemented in the existing curricula. These Masters and Master topics mostly cover general aspects of SMRs technologies used for various SMR types and general issues and advancements.

Currently there is no Master programme strictly dedicated to SMRs or AMRs that covers all the needs of the industry. Therefore, we can consider that even existing E&T programmes provide only partial coverage of the knowledge, skills and competences needed.

Furthermore, the integration of an NPP into a country/regional power grid is tackled by general courses found at early stages of an Engineering programme such as Bachelor level courses. Most of the time these courses are developed by non-nuclear professors thus the relevance of the information related to advancements of SMR integration into the power grid could lack updated information and these professors might not be up to date with the most recent advancements in the field since it does not form part of their day-to-day activities.

Whilst combined power generation (heat and electricity) is well advanced in studies involving classic energy sources (based on coal or oil-derived products), there is little (when it comes to large scale NPPs)[2,3] to none (when it comes to SMRs) included in widely available studies. When it comes to the latest developments, only in recent years has an increase in the interest of researchers been noted [4,5,6,7, 9] and steps are being undertaken in this regard. It is clear that at this stage more in-depth studies related to the coupling of SMRs within hybrid energy systems is necessary for the safe and cost-effective operation of such units.

As mentioned, students could also benefit from working with other students from different fields, in order to gain a greater insight into the potential of a hybrid energy system. This can be achieved at university level, for example, by bringing these students together to work on a project dedicated specifically to envisioning a decarbonised energy system.

When it comes to legislation-related know-how, this can be easily integrated into existing courses and no specific effort in this sense is found to be relevant for further studies.

Together with dedicated nuclear topics, a broad range of "soft skills" are required by the industry. These soft skills are either provided by general courses (limited impact for Engineering schools)

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or by dedicated Educational Institutions. These skills required by industry can only be met at the necessary level by cooperating with other Educational and Training institutions, other than those which focus solely on nuclear.

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Annex I – Example curricula from nuclear engineering schools in Europe

Full files available upon request

BELGIUM

All programmes > Programme > Course of study : Master of Nuclear Engineering (Leuven et al)

Master of Nuclear Engineering (Leuven et al) (60 ECTS)

Master of Science

Admission requirements 2023-2024

Admission requirements 2022-2023

Programme

Schedule

Stage1

Expand Reset

This group contains all courses. Students are required to take all courses offered.

Compulsory Courses

Students are required to take all courses.

3 ECTS	Nuclear Energy: Introduction	H02G2A
3 ECTS	Introduction to nuclear physics and measurements	H02G3A
3 ECTS	Radiation protection	H02H1B
6 ECTS	Nuclear reactor theory and experiments	H02G4B
5 ECTS	Nuclear Thermal Hydraulics	H02G5B
5 ECTS	Safety of Nuclear Power Plants	H0S27A
3 ECTS	Nuclear Fuel Cycle	H02G8A
3 ECTS	Nuclear Materials	H02G9A

Elective Courses

Students are required to choose three courses from the list below.

3 ECTS	Advanced Nuclear Reactor Physics and Technology	H0S28A
3 ECTS	Advanced Nuclear Materials	H0S29A
3 ECTS	Advanced Radiation Protection/ Radiation Ecology	H0S30A
3 ECTS	Advanced Courses of the Nuclear Fuel Cycle	H0S31A
3 ECTS	Nuclear and Radiological Risk Governance	H0S32A
3 ECTS	Advanced Course Elective Topic	H02H2B

Master's Thesis

20 ECTS	Master's Thesis	H02H3B

CZECH REPUBLIC

Master´s Degree Program

Nuclear Engineering

Specialization Applied Physics of Ionizing Radiation **1st year**

Course	code	lecturer	win. sem.	sum. sem.	cr	cr
Compulsory courses:						
Quantum Physics	02KFM	Jizba	2+1 z, zk	-	3	-
Nuclear Safety	17JABE	Frýbortová, Sklenka	4+0 zk	-	5	-
Research Project 1, 2	16VUJI12	Trojek	0+6 z	0+8 kz	6	8
Advanced Experimental Neutron Physics	17PENF	Huml	-	1+3 kz	-	4
Advanced Topics in Nuclear and Radiation Physics	16PPJRF	Musílek, Urban	2+1 z, zk	-	3	-
Instrumentation for Radiation Measurements	16MERV	Průša	2+2 z, zk	-	4	-
Practicum in Detection and Dosimetry of Ionizing Radiation	16PDZNMS	Martinčík, Průša	0+4 kz	-	4	-
Accelerators in Medicine and Technology	16UMT	Augsten	1+0 kz	-	1	-
Monte Carlo Method in Radiation Physics	16MCRF	Klusoň, Urban	-	2+2 z, zk	-	4
Ionizing Radiation in the Environment	16IZZP	Štěpán, Vrba T.	-	2+1 z, zk	-	3
Integral Dosimetry Methods	16IDOZ	Ambrožová, Musílek	-	2+0 zk	-	2
Methods of Analytical Measurement	16AMMN	Pilařová, Průšová	-	2+0 kz	-	2
Excursion	16EX	Thinová	-	1 týden z	-	2
Optional courses:						
Radiation Effects in Matter	16REL	Pilařová	2+0 zk	-	2	-
Treatment of Experimental Data	16ZED	Pilařová	-	2+0 zk	-	2
Monte Carlo Method	18MEMC	Jarý, Virius	2+2 z, zk	-	4	-
Radiation Protection	16RAO	Vrba T.	4+0 zk	-	4	-
Practicum in Dosimetry of Ionizing Radiation	16PDIZ	Štěpán	-	0+4 kz	-	4
Digital Image Processing	01DIZO	Flusser, Zitová	-	2+2 zk	-	4
Fundamentals of clinical dosimetry	16ZKLD	Čechák, Hanušová, Novotný J.	-	2+0 zk	-	2

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GERMANY

25 Einträge vorhanden

Semester

LV-Nr	Sem.	Term.	Titel	Dauer	Art	Teil/Info	SPO P/W/S	Vortragende*r (Mitwirkende*r)
Wintersemester								
610702002	W		Kerntechnische Anlagen zur Energieerzeugung	4	VO		7/57/26	Starflinger J
610702003	W		Probabilistik und Monte-Carlo-Methoden	4	VO		0/9/44	Starflinger J
610702004	W		Radioaktivität und Strahlenschutz	2	VO		0/0/5	Starflinger J, Pohlner G
610702008	W		Seminar Kernenergietechnik für Studierende	2	SE			Starflinger J, Kulenovic R
610702100	W		Nukleare Abfälle - Grundlagen, Möglichkeiten und Konzepte	2	VO		0/0/400	Starflinger J
610702200	W		Reaktorphysik und -sicherheit	4	VO		0/20/19	Starflinger J
610702300	W		Simulation kerntechnischer Anlagen (Anlagendynamik)	4	VO		1/21/16	Buck M
610702400	W		Strahlenschutz	2	VO		0/41/41	Starflinger J, Pohlner G

FINLAND

Student Guide

- Main page
- Programmes, Minors and Courses
- Academic calendar
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- New students

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- About the programme
- Materials Physics and Quantum Technology major
- Advanced Energy Technologies major
- Minor
- Elective studies 25–30 cr
- Master's thesis 30 cr

FRANCE

Grenoble INP - Phelma is the school for scientific diversity. It offers its students courses in various fields with a promising future:

- **Microelectronics and nano-technologies** (electronics, nanosciences, materials, health),
- **Decarbonated energy** (nuclear energy, photovoltaic, electrochemical storage),
- **Information technology** (digital communication, image and signal processing, telecommunications, computing and networks, Internet of Things, artificial intelligence),
- **Innovative materials** (for aeronautics, automobiles, sport & leisures, health, microelectronics, energy),
- **Biotechnology and biomedical engineering** (medical imagery and therapy, implantable devices)
- **Sustainable development** (decarbonated energies, eco-processes, recycling, material durability, energy management, natural signal analysis).

Based in Grenoble in the heart of the French Rhône Alpes region, Phelma boasts a rich academic and industrial infrastructure. As the only teaching institute on the Minatec innovation campus, Phelma benefits from an exceptional Training / Research / Industry synergy.

SLOVENIA

1. year

Course
Elective courses 1
Elective courses 2
Nuclear, reactor and radiology physics +
Model analysis I
Master thesis research 1
Seminar I
Introduction to research work

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