Investigation on Human Resources Needs and Competences Building for ALFRED Implementation in Romania

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**Abstract**

The paper presents the outcomes of the investigation on human resources needs for ALFRED demonstrator implementation in Romania developed in the frame of national funded PRO ALFRED project. The jobs estimation was accounted for the ALFRED infrastructure research and development (R&D) activities, operation and realization of the specific activities in the experimental facilities and hub, as well as for the operation of the ALFRED demonstrator itself. For each identified job, the appropriate specializations and the minimal competences have been defined. To see how the existing Romanian educational programs cover the minimal competences required by the ALFRED infrastructure, an expert judgment evaluation was performed at the University of Pitesti and the University Politehnica of Bucharest.

## INTRODUCTION

One of the six reactor technologies selected by the Generation IV International Forum (GIF) which may significantly contribute to an enhanced sustainability of the nuclear energy is represented by the lead-cooled fast reactor (LFR). It is considered a promising technology, having the potential to excel in sustainability, economics, safety and reliability, as well as proliferation resistance and physical protection (the main goals of Generation IV (Gen IV) nuclear energy systems, defined by GIF) [1].

The LFR technology development faces various challenges including: (1) R&D open issues (such as development and behaviour of the structural and cladding materials, lead and cover gas chemistry control, development of the instrumentation and control, fuel and fuel cycle, deterministic and probabilistic analyses, thermal-hydraulics of large pool configuration of molten lead, etc.), (2) the novelty of the licencing process and (3) ensuring the human resources with a high degree of specialization.

Romania is deeply involved in LFR technology deployment, by expressing the availability to host and implement ALFRED, the demonstrator of this technology. The Romanian interest in the ALFRED project stems from its ambition to effectively address the energy security, industrial development, research leadership and socio-economic development [2]. There are many strategic documents which support this challenging project, demonstrating a firm governmental commitment and a broad national stakeholders’ involvement [3]. An early expression of interest dates back to 2011, when the Government approved a Memorandum of the Minister of Economy expressing Romania’s availability to host ALFRED. This declaration was also notified through an official letter to the European Commissioner for Energy. The commitment was reaffirmed and reinforced in 2014 by the Romanian Government which approved a Memorandum for ALFRED construction in Romania. Mioveni nuclear platform was selected as reference site for this purpose and the Institute for Nuclear Research Pitesti (RATEN ICN) was nominated as operator, leveraging on its longstanding experience in the safe operation of TRIGA research reactor and participation in European research projects devoted to LFR technology [4]. In December 2013, the international consortium FALCON (Fostering ALFRED Construction) aiming the ALFRED demonstrator implementation in Romania was founded by RATEN ICN, ENEA (Italy) and Ansaldo Nucleare (Italy) which are well-known players in the European nuclear sector.

In support of ALFRED implementation, an advanced research infrastructure is planned to be built on the Mioveni nuclear platform aimed to support the development, up to full demonstration of the LFR technology. This unique research infrastructure will complement the already existing facilities from Brasimone Research Center (Italy), and will represent the largest and the most advanced research infrastructure, with a pan-European dimension.

## A WORLD CLASS INFRASTRUCTURE

The planned ALFRED infrastructure will address the R&D priorities of the LFR technology not yet investigated in the existing centre of excellence on lead technology located in Italy. Therefore, all aspects of the LFR technology advancement will be covered by the ALFRED infrastructure in a systematic and integrated approach.

The infrastructure will have the ALFRED demonstrator as a distinguishing element and will include six experimental facilities (ATHENA, ChemLab, ELF, HELENA2, Meltin’Pot, HandsON) together with a hub for coordination, logistics, and promotion purposes. A lead school will be integrated in the hub and will provide education and training (E&T) activities for students and young researchers, as well as dissemination actions for the benefits of the large public. The experimental facilities will bridge the gap of the LFR technology towards demonstration by testing and qualifying large-scale components and systems, and by verifying and validating the computational methods and tools. They are going to be constructed long before the starting of ALFRED construction phase in order to support the licensing process.

A short description of the ALFRED infrastructure is further provided [5], [6] to highlight its complexity and significance in addressing the key aspects of ALFRED demonstrator safety and licensing.

ATHENA is an electrical heated pool type multipurpose facility (the largest lead pool facility in the world), designed to investigate R&D needs regarding the lead technology, to test at large to full scale the main components and systems meant for ALFRED and to qualify them in representative conditions. Testing and qualification will cover normal operation (the assessment of components/systems behaviour in a pool configuration) and anticipated accidental conditions (e.g., steam generator tube rupture), providing significant elements in support to the demonstrator’s design licensing.

ChemLab is a laboratory for heavy liquid metal (HLM) chemistry and is designed for materials compatibility with HLM investigations, and for development, qualification and certification of oxygen monitoring and control systems. The experiments to be performed will support the design and qualification of the ALFRED coolant chemistry and control system.

ELF, a pure lead pool facility, will operate in natural or forced circulation mode being designed for system integration and operation tests, endurance qualification and reliability assessment. The outcomes of the experimental campaigns performed in ELF will demonstrate the long-term operation of ALFRED’s primary system.

HELENA2 is a lead loop designed to perform corrosion experiments in flowing lead or erosion tests on the pump impeller, and to test and qualify components (fuel assembly, control and shutdown devices, etc.) at large to full scale and in fully representative conditions. The experimental results will support the core design qualification and the validation of the core analysis software tools.

Meltin’Pot is designed to focus on the severe accidents of LFR technology. Fuel-coolant interaction tests in accident conditions will be performed, to support the design of accident management provisions and to validate the associated software analysis tools. The experiments will focus on the chemical interaction between fuel elements, fission products and activation products (e.g., polonium) with lead, as well as on the behaviour of fuel fragments once dispersed in the coolant pool.

HandsON is a pool type facility which uses pure lead and is devoted to simulate the fuel handling operation of sub-assemblies (in particular fuel assemblies) from the core of a pool-type LFR. Validation of fuel handling procedure and equipment, addressing the reliability and robustness of the design solution of the handling machine and testing the insertion and extraction of deformed sub-assemblies represent the main goals of HandsON experimental infrastructure.

ALFRED is a 125 MW(e) pool type reactor, aimed to accomplish the demonstration of the LFR technology. It will be connected to the grid in order to produce a powerful proof of its economic and technological viability. In the last years, the interest of the industry to invest on medium term, made FALCON’s vision on the LFR deployment to add a new objective: ALFRED as a prototype for a commercial lead-cooled fast-neutron-spectrum small modular reactor (SMR).

The ALFRED infrastructure will include a hub aimed to integrate the cooperation for an efficient use of the infrastructure at the level of FALCON partners, to manage the open access option, as well as to ensure the scientific management including the collaboration with other international partners. The lead school will be hosted by hub and will provide both education and training for students and young researcher, and general dissemination for public at large. A special attention will be paid to the local community, Mioveni town being located at around 2 Km far from the nuclear platform.

## hUMAN RESOURCES NEEDS FOR ALFRED IMPLEMENTATION

A significant number of high qualified personnel has been identified as necessary to perform the R&D activities and to exploit the ALFRED infrastructure. In this context, the human resources development including the competences building process are considered as crucial factors for the success of the ALFRED implementation in Romania.

The investigation on human resources needs for ALFRED implementation was performed in the framework of PRO ALFRED project (September 2019 – November 2020, coordinated by RATEN ICN and funded by Romanian Ministry of Research) [4]. The needs (in terms of jobs number) were identified for the R&D activities to be performed in ALFRED infrastructure, operation and experimental support facilities specific activities, hub tasks, as well as for the further safe operation of the ALFRED demonstrator. For each identified job, the specializations and the minimal competences were also established.

### Human resources needs for ALFRED infrastructure related R&D activities

Currently, around 60 researchers of RATEN ICN are involved in R&D activities dedicated to LFR technology like: reactor physics, nuclear safety, thermal-hydraulics, fuel and fuel cycles, materials and technologies for advanced nuclear systems, lead technology, instrumentation and control (I&C), reactor systems and components, components and nuclear systems design, spent fuel management, radioactive waste management, radiation protection. The competences have been developed mainly through the participation in European projects such as: ELSY, LEADER, ADRIANA, MATTER, SEARCH, NEWLANCER, MAXSIMA, MATISSE, ESNII Plus, ARCADIA, FASTNET, GEMMA, PIACE, PASCAL, etc. Besides the already existing expertise, new competences and skills on LFR technology should be developed in order to perform the planned R&D activities.

 Thus, for the main domains (reactor physics, thermal-hydraulics, nuclear safety, lead and cover gas chemistry, materials, I&C, fuel, spent fuel and waste management, radiation protection, decommissioning, scientific management) an estimation of needs was performed. A number of 66 high-education job-positions are envisaged to be open in the very next future. Since all the positions will involve some peculiar activities, each domain was divided into sub-domains, identifying both the needed specializations and the minimal competences required. For illustration, Table 1 presents the reactor physics domain which was divided in four sub-domains. Three specializations were identified as suitable for the seven jobs estimated for reactor physics, the LFR technology being one of the minimal competences required.

TABLE 1. MINIMAL COMPETENCES FOR R&D ACTIVITIES IN REACTOR PHYSICS AND ITS SUB-DOMAINS

| Domain | Job | Specialization | Minimal competences required for domain | Sub-domains | Minimal competences required for sub-domain |
| --- | --- | --- | --- | --- | --- |
| Reactor physics | Physics engineerorPhysicistorNuclear power plant engineer | Technological physicsorPhysicsorNuclear engineering | Neutron dataReactor steady-stateReactor dynamicsReactor controlFast reactors physicsLFR technology | Nuclear data | Data libraries |
| Nuclear data processing |
| Evaluation and adjustment |
| Reactor steady-state calculations | Diffusion and transport computer codes |
| Reactor dynamics calculations  | Computer codes for rapid and slow transients |
| Coupled 3D calculations (neutronics - thermal-hydraulics) | Neutronics computer codes |
| LFR thermal-hydraulics |
| Thermal-hydraulics computer codes |

 The R&D activities that will be carried out within the ALFRED infrastructure in support of LFR technology development involve specializations such as: nuclear engineering, nuclear power engineering and nuclear technologies, materials and nuclear technologies, technological physics, automatic, electronics, chemical engineering, environmental engineering, physics, chemistry. For almost all domains knowledge of LFR technology is essential.

### Human resources needs for the LFR experimental facilities

Starting from the R&D priorities and experimental campaigns (oxygen pumps characterization, cold trap experiments, erosion and fretting tests, corrosion and erosion tests in lead, forced and natural circulation tests, fission products dispersion and retention, steam generator tube rupture experiments, performance and material assessment, material and coating characterization, etc.) envisaged for the ALFRED safety demonstration program and the licencing application [7], an estimation of the needed jobs for operation and the experimental campaigns in the six support facilities was performed. Therefore, for ATHENA, ChemLab, ELF, HELENA2, Melin’Pot and HandsON, a number of 63 jobs (persons with higher education and 22 persons with secondary education) were accounted for. The personnel holding university degree consist of 41 engineers having the following specializations: analytical chemistry, inorganic chemistry, chemical engineering, science and engineering of oxide materials, machines, materials and electrical actuations, technological physics, metallic materials science and physical metallurgy, electrical systems, nuclear engineering, materials and nuclear technologies, and physics. For all these specializations, the minimum required competences were established, to support the future hiring process of the personnel for facilities operation and experimental activities completion. In Table 2 the minimal competences for nuclear engineering specialization are presented. The graduates of this specialization might be candidates for job positions in ATHENA, ELF, HELENA2 or Meltin’Pot [8].

TABLE 2. MINIMAL COMPETENCES PROPOSED FOR NUCLEAR ENGINEERING SPECIALIZATION

| Specialization | Minimal competences |
| --- | --- |
| Nuclear engineeringNuclear engineering | Nuclear power plant systems |
| Equipment and systems in Gen IV |
| LFR technology |
| Nuclear safety |
| Nuclear industry codes and standards |
| Instrumentation and control in nuclear systems |
| Thermal-hydraulics in nuclear systems |
| Computer codes and thermal-hydraulics analyses |
| Sub-channel flow regimes |
| Computer codes and sub-channel thermal-hydraulics analyses |
| Endurance equipment operation |

Also, for each identified job needed for operation or for experimental activities in the support facilities, the specializations and minimal competences were established. An illustrative example is presented in Table 3 for Meltin’Pot facility.

TABLE 3. SPECIALIZATIONS AND MINIMAL COMPETENCES FOR JOBS NEEDED TO PERFORME ACTIVITIES IN MELTIN’POT

| Nr. | Job | Specialization | Minimal competences |
| --- | --- | --- | --- |
| 1 | Chemistry engineer | Analytical chemistry | Advanced analytical methods in liquid metal systems |
| LFR technology |
| Mass transfer of chemical species |
| Lead and cover gas chemistry |
| Fission products chemistry |
| 2 | Physics engineerorPhysicist | Technological physicsorPhysics | Use of standard laboratory equipment for conducting research experiments |
| Electronic microscopy |
| Optical microscopy |
| X-ray diffraction |
| Use of informatic systems for data processing and management |
| 3 | Thermal-hydraulics engineer | Nuclear engineering | Thermal-hydraulics in nuclear systems |
| LFR technology |
| Computer codes and thermal-hydraulics analyses  |
| 4 | Electromechanical engineer | Electrical systems | Electrical systems theory |
| Instrumentation and control in nuclear systems |
| Pumps for liquid metals |
| 5 | Laboratory technician  | Secondary school or post-secondary school education in chemistry or physics | Performing physical-chemical analyses |
| Preparation of solutions for chemical species |
| Concentration measurements and data acquisition |
| 6 | Operator | Secondary school or post-secondary technical studies | Hot cell operation |
| LFR technology, pool and loop types circuits |
| 7 | Technician | Secondary school or post-secondary technical studies | Electrical and mechanical equipment maintenance and operation |
| Gas circuit operation and maintenance |

### Human resources needs for hub

The hub is intended to coordinate the experimental activities to be carried out in ATHENA, ChemLab, ELF, HELENA2, HandsON and Meltin'Pot, as well as in the ALFRED demonstrator. Both the collaboration with other experimental centers in the world and the open access aspects are envisaged. The center will provide the necessary logistics for coordination and will ensure the education and training process of researchers, technicians and students at a high level, but also informing the general public.

A need for 8 positions (3 managers, 2 assistant managers, 2 information technology specialists and 1 responsible for cleaning), having higher and secondary education, respectively, was identified to cover the hub’s intended activities. The specializations and minimal competences of each position are presented in Table 4.

TABLE 4. SPECIALIZATIONS AND MINIMAL COMPETENCES FOR THE JOB POSITIONS ENVISAGED FOR HUB

| Nr. | Job | Specialization | Minimal competences |
| --- | --- | --- | --- |
| 1 | Scientific manager | Physical engineeringorPhysicsorChemistryorChemical engineeringorNuclear engineeringorEnvironmental engineering | Authorization legislation |
| Labor legislation |
| Communication methods |
| Nuclear systems |
| LFR technology |
| Project management |
| Risk analysis |
| Scientific activities management |
| 2 | Information technology specialist | Computers and information technologyorInformatics | Information technology |
| Computer systems and networks |
| 3 | Assistant manager | Communications orAdministrationorEconomics | General management |
| Digital competences |
| Communications methods and ways |
| 4 | Responsible for cleaning | Secondary school | Management of the necessary hygienic-sanitary materials |
| Work spaces hygiene (ensuring an optimal level of cleaning in offices, laboratories and other work spaces) |

### Human resources needs for ALFRED demonstrator

The development of the ALFRED demonstrator represents a crucial step towards the commercial deployment of the LFR technology and also for the development of the LFR SMR. ALFRED is a pool type lead cooled fast reactor. All the reactor coolant system (RCS) components are installed inside the reactor vessel (RV) providing for a compact configuration. The RV is surrounded by an external safety vessel, ensuring primary system cooling also in the case of leak from the RV. Starting from core inlet, the lead is heated in the channels of the assemblies to exit at its hot temperature above the core. From there, the coolant is pumped through the pump channels to the upper hot pool from where it enters the steam generators (SGs) to transfer the heat to the secondary side. From SGs outlet, lead flows upward following the internal structures (IS) up to the free surface where it enters a series of windows in the IS to reach the RV and descends to the bottom, before entering again the core. The RCS is equipped with two diverse, redundant, independent and totally passive decay heat systems conceived to remove the decay heat in case of design basis accidents [9].

The balance of plant is based on a turbine with two stages, one of high pressure (HP) and one of low pressure (LP). There are three extractions lines in the HP turbine and three more in the LP turbine, with an axial outlet. An auxiliary lead heating system is added. This system would work when the power cycle is not in operation, to ensure the minimum temperature of the lead by transporting heat from the secondary system if it is needed [3].

To have a more realistic estimation of the number of positions needed for the successful operation of the ALFRED demonstrator, they were categorized into four groups, as follows [10]: job positions needed for the operation itself, for the administrative activities, for carrying out the technical support activities, and positions needed for maintenance activities.

The operating personnel will work in 5 shifts, and consists in qualified personnel able to ensure the safe operation of the demonstrator. Considering as a good practice the operating experience of the TRIGA research reactor located on the Mioveni nuclear platform, 4 shifts will work monthly, one being out of work, by rotation. For a shift, the operating personnel will consist of: the shift manager, 2 main control room operators, 23 system engineers (covering both the systems of primary and secondary circuits), 15 field operators and 13 persons involved in surveillance or intervention activities. A total of 270 people were accounted for the 5 shifts that will ensure the safe operation of the ALFRED demonstrator (54 positions per shift). Among them, 130 higher education positions and 140 secondary education positions (field operators, technicians, electricians, electromechanics, plumbers and chemical operators) are required.

A number of 41 positions were identified as needed to ensure the administrative support activities. Among them, 24 holding higher education will cover the following job positions: the head of reactor, the deputies, the chief engineer, the economist, assistant managers as well as persons responsible for authorization, nuclear safeguard, quality assurance, radiation protection, environment, waste management, physical protection and operation planning. The laboratory technicians performing physical-chemical analyses, the commodity expert and the responsible for cleaning represent 17 positions with secondary education needed to carry out administrative activities related to the operation of ALFRED.

The third category of personnel is represented by the technical support staff having skills in reactor physics, thermal-hydraulics, nuclear safety, fuel, reliability and maintenance. Also, the staff competences cover aspects related to reactor simulator, data acquisition, information technology and emergency situations simulation. Thus, a number of 34 positions with higher education are needed to perform the related technical support activities of the ALFRED operation.

The last category is represented by the personnel ensuring the plant maintenance. Among the 13 identified jobs, 8 positions with higher education and 5 with secondary education (electromechanical technicians, electronics technicians/measuring and control devices, and chemical technicians) are needed to carry on the maintenance activities.

For each identified job, the specializations and minimal competences were also established, being presented in Table 5 as examples for some of the positions needed for the technical support related activities.

TABLE 5. SPECIALIZATIONS AND MINIMAL COMPETENCES FOR THE JOBS REQUIRED IN TECHNICAL SUPPORT RELATED ACTIVITIES

| Nr. | Job | Specialization | Minimal competences |
| --- | --- | --- | --- |
| 1 | Reactor physics analyst | Physical engineeringorNuclear engineering | Fast reactors physics |
| Reactor physics computer codes |
| LFR technology |
| Nuclear systems |
| Fast reactors nuclear safety |
| 2 | Thermal-hydraulics analyst | Nuclear engineering | Thermal-hydraulics |
| Thermal-hydraulics computer codes |
| LFR technology |
| Fast reactors nuclear safety |
| 3 | Safety analyst | Nuclear engineeringorPhysical engineering | Deterministic and probabilistic safety analyses |
| Deterministic and probabilistic safety analyses computer codes |
| LFR technology |
| 4 | Fuel analyst | Nuclear engineeringorPhysical engineeringorMaterials and nuclear technologies | Reactor physics |
| Materials and nuclear fuel |
| Materials and nuclear fuel computer codes |
| Fast reactors nuclear safety |
| LFR technology |
| Reliability and maintenance |

## EDUCATIONAL PROGRAMS OF THE MAIN SUPPLIERS FOR THE PERSONNEL INVOLVED IN LFR TECHNOLOGY IN ROMANIA

Currently, there are six universities in Romania involved in E&T activities, which prepare the human resources in the field of nuclear energy: University Politehnica of Bucharest (UPB), University of Pitesti (UPIT), University of Bucharest, Babes-Bolyai University of Cluj, Constantin Brancusi University of Targu Jiu and Ovidius University of Constanta [11]. Among them, UPB and UPIT are the main suppliers of technical personnel for the nuclear field, being deeply interested and involved in the development and implementation of high-performance and attractive E&T methods.

UPB, through the Faculty of Power Engineering offers a bachelor’s degree in Power Engineering and Nuclear Technologies (PENT), a master’s degree in Nuclear Engineering (NE) and a doctorate degree in Power Engineering. UPIT, through the Faculty of Sciences, Physical Education and Informatics, offers a bachelor’s degree in PENT, a master’s degree in Materials and Nuclear Technologies (MNT), and a doctorate degree in Materials Engineering. Each year, around 40 students graduate the PENT specialization, 25 obtain a master’s degree in NE and 15 in MNT specialization.

The current educational programs are mainly focused on the current generation of thermal reactors (CANDU, PWR) and TRIGA research reactor located on Mioveni nuclear platform. In the light of opportunities created by the ALFRED infrastructure, the curricula at of UPB and UPIT was extended, by including specific courses on LFR technology. Therefore, the new curricular programme was approved by the Ministry of Education and Research in 2014 and became active since 2015 at the University of Pitesti. UPIT introduced in both the bachelor's and master's degree programs courses focused on the ALFRED demonstrator while UPB introduced in the master's program courses containing elements specific to Gen IV nuclear reactors.

To strengthen the national collaboration between the main actors in the fields of E&T and R&D, to boost these activities and given the need to ensure qualified human resources for ALFRED infrastructure implementation, in May 2017 a Partnership Agreement in the field of Research and Education for Advanced Nuclear Systems (CESINA) was signed [12]. Both UPIT and UPB are partners in this agreement coordinated by RATEN ICN aiming to provide national support for ALFRED implementation and to establish a general framework to support this project in official documents and communication.

## BRIDGING THE GAP BETWEEN ACTUAL EDUCATIONAL OFFER AND THE MINIMAL COMPETENCES REQUIRED BY THE ALFRED INFRASTRUCTURE

To see how the existing Romanian educational programs cover the minimal competences required by the ALFRED infrastructure, an analysis of the current curricula at UPB and UPIT was performed, targeting the contents of courses and the laboratory activities for three specializations: Environmental Engineering (bachelor program at UPIT), NMT (master program at UPIT), and NE (master program at UPB). Since the needed competencies have a high level of complexity, the analysis was focused on the maximum potential of these universities to produce graduates able to be employed. For this reason, it was assumed that a potential employee will necessarily be a master's graduate, considering that this program strengthens the basic knowledge gained during the undergraduate studies. For the positions related to environmental aspects, the Environmental Engineering (EE) bachelor's program was also considered, since there is no a dedicated master program and the environmental competencies are not completely covered by other educational programs.

The analysis involved the needed competences for the experimental support facilities, coordination hub and ALFRED demonstrator, in order to identify the useful elements and the missing ones in the existing educational offer – required competences relationship. Following the analysis undertaken by means of expert judgement evaluation type, different kind of competences were identified and evaluated. A score (from 1 to 5) with the following meaning was assigned:

1. totally uncovered competences (a complete lack of the necessary elements for the required competence building within the courses contents or their inadequacy to the specific topic of LFR technology);
2. slightly covered competences (there are general elements, but they cannot build the proposed competence);
3. partially covered competences (there are general and specific elements which can provide a part of the competence building, while others, such as practical/experimental skills, are missing or are poorly represented);
4. acceptable covered competences (the targeted competence can be covered by the educational program, but in order to obtain good results, a better adequacy to the LFR topics is needed, including the latest results of the R&D activities);
5. fully covered competences (competence is covered by the educational program for existing nuclear systems, providing a basis for a rapid professional training through integration into LFR work teams).

As an illustration of the evaluation, Table 6 presents the list of critical competencies (score 1 and 2) for carrying out the specific activities in the experimental facilities and the coordination hub, not covered by the analysed specializations.

TABLE 6. CRITICAL COMPETENCES UNCOVERED BY SELECTED SPECIALIZATIONS

| Specialization | Critical competence | Score | Argument |
| --- | --- | --- | --- |
| MNT | Instrumentation and control in nuclear systems | 1 | The identified content is oriented to TRIGA research reactor |
| MNT | Physical-chemical analyses for material | 1 | No course contents were identified |
| MNT | Use of informatic systems for data processing and management | 1 | No course contents were identified |
| NE | Nuclear industry codes and standards | 1 | No relevant aspects were identified for codes and standards |
| NE | Instrumentation and control in nuclear systems | 1 | No relevant content items were identified |
| NE | Sub-channel flow regimes | 1 | No relevant content items were identified |
| NE | Computer codes and sub-channel thermal-hydraulics analyses | 1 | No relevant content items were identified |
| NE | Endurance equipment operation | 1 | No relevant content items were identified |
| NE | Authorization legislation | 1 | No relevant content items were identified |
| NE | Labor legislation | 1 | No relevant content items were identified |
| NE | Communication methods | 1 | No relevant content items were identified |
| NE | Project management | 1 | No relevant content items were identified |
| NE | Risk analysis | 1 | No relevant content items were identified |
| NE | Scientific activities management | 1 | No relevant content items were identified |
| EE | LFR technology | 1 | No course contents were identified |
| EE | Labor legislation | 1 | No course contents were identified |
| EE | Communication methods | 1 | No course contents were identified |
| EE | Project management | 1 | No course contents were identified |
| EE | Risk analysis | 1 | No course contents were identified |
| EE | Scientific activities management | 1 | No course contents were identified |
| MNT | Materials for Gen IV and LFR | 2 | The existing courses have educational objectives and contents aiming to cover the minimum competencies |
| MNT | Physical-chemical processes in LFR technology  | 2 | The identified content covers only the irradiation behaviour part, the other physical-chemical processes (corrosion, erosion, impurities transport, lead chemistry, etc.) not being approached in detail |
| NE | Equipment and systems in Gen IV | 2 | The contents reflect general aspects of Gen IV, without focusing on the detailed knowledge of equipment and systems, especially for LFR technology |
| NE | LFR technology | 2 | The aspects of LFR technology are general and have a small weight in the courses structure |

## CONCLUSIONS

Around 600 jobs were identified as needed for the operation of ALFRED demonstrator and its support infrastructure, the hub functioning, and for the R&D related activities. They offer an image on the human resources needs for ALFRED implementation in Romania. For each identified job, the specializations and the minimal competences were established. These competencies represent the minimum threshold for hiring. The staff hired through competition will definitely follow a training course that will include at least the following elements: LFR technology, lead and cover gas chemistry, LFR thermal-hydraulics, ALFRED infrastructure equipment knowledge, work procedures.

To cover the gap between the existing competences and specializations provided by UPB and UPIT, and the needed ones required for ALFRED infrastructure, short and long-term measures have been proposed. They refer to the introduction in the current curriculum of new information or disciplines related to LFR technology, the revision of the current disciplines and / or the introduction of new disciplines in the current curriculum, training based on the academic education received in universities and focused on LFR technology, developing of a master program dedicated to LFR technology as well as the correlation of the research activities to be performed in the six experimental facilities (ATHENA, ChemLab, HELENA2, ELF, HandsOn, Meltin'Pot) with the doctoral programs.

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