PRO ALFRED: TOWARDS AN INCREASED ROMANIAN PARTICIPATION IN THE ALFRED INFRASTRUCTURE DEVELOPMENT

DANIELA DIACONU [1], MARIN CONSTANTIN [1], MIRELA NIȚOI [1], ILIE TURCU [1], DANIELA GUGIU [1], MINODORA APOSTOL [1], RADU PREDUȚ [1], DUMITRU CHIRLEŞAN [2], GABRIELA PLĂIAŞU [2], DANIEL DUPLEAC [3], MITICĂ DRĂGUŞIN [4], IONUȚ PURICA [5]

[1] Institute for Nuclear Research (RATEN ICN), Piteşti, Romania
[2] University of Piteşti, Romania
[3] University ″Politehnica″ Bucharest, Romania
[4] Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH), Bucharest, Romania
[5] Institute for Economic Forecasting (IPE), Bucharest, Romania
e-mail: daniela.diaconu@nuclear.ro

Abstract

The ALFRED infrastructure, consisting in the Advanced Lead Fast Reactor European Demonstrator (ALFRED), six supporting experimental facilities for research-demonstration-testing-qualification of the reactor components, methodologies and computing codes verification-validation, and a coordination Hub, is planned to be constructed in Romania, on the Institute for Nuclear Research (RATEN ICN) site, located in the Mioveni town. The ALFRED infrastructure is going to play an important role in increasing the sustainability of the nuclear energy field and in the development of innovative concepts with improved safety and economics characteristics. The national R&D project PRO ALFRED, funded by the Romanian Ministry of Education and Research, aims to prepare and consolidate the Romanian contribution to the ALFRED infrastructure construction and operation, contributing to the technological readiness of supporting experimental infrastructure and its long term sustainability, to the creation of the critical mass of specialists and competences necessary to build and operate this complex infrastructure of national and European interest. The project implementation will strengthen the national RDI capacity in the nuclear energy field, with emphasis on the development of Generation IV systems, and in particular of the Lead Fast Reactors (LFR) technology, as well as the cooperation between research, education, industry and business environment at national level. The project runs between September 2019 - November 2020 and is implemented in two stages, by a consortium that brings together the Romanian institutions with relevant activities in the nuclear energy field: the research institutes RATEN ICN, RATEN CITON, IFIN-HH and IPE, the University of Pitesti (UPIT) and University ″Politehnica″ Bucharest (UPB).

Keywords: *ALFRED, Generation IV, LFR technology, RDI capability, experimental infrastructure*

Introduction

Sustainable, secure, safe and affordable energy supply is the main challenge presently faced worldwide. Europe is strongly committed to lead the scene, with ambitious targets and policies [1]. In this scenario, nuclear can play an important role in the energy mix, demonstrating its capability to face the main challenges of the energy market. According to the European Commission (EC) long term vision [2], by 2050 the European electricity mix will be based on a significant renewable energy sources which, together with a nuclear power share, will be the backbone of a carbon-free European power system [3].

Progressing by research and innovation, Generation IV nuclear energy systems are materializing as a sound, competitive and mature answer to this challenge. From the six concepts selected by Generation IV International Forum (GIF) [4], Romania shares the European Union (EU) option in selecting the Lead-cooled Fast Reactor (LFR) as one of the most promising Generation IV technologies which could bring important advantages in:

- increasing efficiency of the natural uranium resources use (from 0.5% in the open fuel cycle technology of natural uranium, to over 80% in the case of LFR closed fuel cycle), extending therefore the time horizon of the current reserves by more than 1000 years;
- reducing 10 times the quantities of waste generated and their radiotoxicity;
- increasing the nuclear safety level and eliminating the need for off-site emergency response;
- increasing the economic performance;
- strengthening resistance to proliferation.

In the process of developing the National Integrated Plan for Energy and Climate Change (NECP) [5], in the frame of EU energy and climate actions, Romania assumes the nuclear energy as a base component of the energy mix. As regarding Research, Innovation and Competitiveness dimension of the Energy Union [6] Romania has included the development of the ALFRED demonstrator among the national objectives, and supports its implementation as a mandatory strategic step, serving a threefold purpose:

- demonstrate the performances achievable by the LFR technology, as a cornerstone for the deployment of next generation nuclear energy systems;
- provide the largest and most relevant set of experimental facilities, accessible to European scientists and technicians for fundamental and applied research;
- support, in the long-term, innovation for the safe and sustainable operation of future plants, sustaining the continuous upgrade of nuclear standards to higher and higher scores port, in the long-term, innovation for the safe and sustainable operation of future plants, sustaining the continuous upgrade of nuclear standards to higher and higher scores,

Following the participation of the Institute for Nuclear Research (RATEN ICN) in a large number of Euratom research projects dedicated to LFR under the Framework Programmes FP6 and FP7, and the improvement of research capabilities, the Government of Romania expressed, through Government Memorandums No. 1925 / 03.02.2011 and 21104 / 07.01.2014, the availability to host the ALFRED demonstrator in Romania. Mioveni nuclear platform was selected as reference location due to its advantages: nuclear facilities already operating on the site, the existence of utilities and physical protection elements, proximity of specialists, a good public acceptance at the local community level. Based on long-standing experience in the operation of many nuclear installations (TRIGA research reactor, post-irradiation laboratories, installations for the production and testing of nuclear materials, components, equipment, etc.), RATEN ICN was nominated as operator of this infrastructure.

In December 2013, the International Consortium FALCON (**F**ostering **AL**FRED **CON**struction) was established for the implementation of ALFRED in Romania, having ANSALDO NUCLEARE, ENEA (Italy) and RATEN ICN as founding members.

Making the decision to host the ALFRED demonstrator on the Mioveni nuclear platform, Romania has assumed obligations regarding the adequate preparation of its implementation, including the development of the national capacity for experimental analysis, testing, qualification, validation and verification required by the licensing process, and generation of the full spectrum of competencies associated to LFR technology.

The ALFRED infrastructure

Building of ALFRED demonstrator will be preceded by the construction and operation of a set of six supporting experimental facilities: ATHENA, ChemLab, HELENA2, ELF, HandsOn, Meltin'Pot, and a Coordination Hub, intended for specific research devoted to LFR technology (thermal-hydraulic regimes, chemical control of oxygen and impurities, corrosion and erosion of structural materials, transport of chemical elements and species in molten lead and in the cover gas), as well as for testing, demonstration and qualification of ALFRED. At the same time the infrastructure will serve, in the future, to qualify the commercial LFR components, and to validate and verify new computing tools and methodologies. Synergistic research with other energy-related areas (such as nuclear fusion, the use of LFR systems for energy storage, etc.) is also envisaged.

In short term, each facility of the supporting experimental infrastructure, designed for testing full scale components, equipment and systems in relevant operational conditions (in terms of lead temperature, flow regime, impurities concentration) will address key aspects related to ALFRED reactor safety and licensing. Therefore:

- ***ATHENA*** is designed to test the behaviour of full scale components in liquid lead, with a particular focus on the investigation of the steam generator tube rupture, the fluid-structure interaction, lead stratification and freezing in a pool configuration system.

- ***ChemLab,*** a laboratory specialized in the chemistry of lead and cover gas, will allow a better understanding of the oxygen and other impurities control and monitoring in both environments.

- ***HELENA2***, a loop type installation, will be designed to test and demonstrate the thermal-hydraulic behaviour in pure liquid lead of full scale ALFRED fuel assemblies and of the safety and control rods, in normal and forced flow regimes.

- ***ELF,*** a pure lead pool installation operated in natural or forced circulation mode, will be designed for endurance tests of the operation of components, equipment and systems to be used in by ALFRED demonstrator, as well as for the measurement of the reliability characteristics.

- ***Meltin'Pot,*** is needed for the investigation of the phenomenology associated to severe accidents in a LFR reactor system by complex studies on the interaction between fuel, cladding and coolant, including fuel dispersion during a severe accident, fission products retention in pure lead, etc.

HandsON will be devoted to test the handling of the full scale fuel assemblies and control rods of the ALFRED demonstrator, in operational conditions.

The Hub will coordinate the research activities in synergy with a network of additional facilities distributed in Europe, while the Centre of Excellence - Lead School, hosted by the HUB, will deliver world-class education and training to researchers, technicians and students, as well as lectures and dissemination events for the general public.

ALFRED is a 300 MWth pool reactor system aimed to demonstrate the European LFR technology viability for its use in future commercial power plants. It is designed as close as possible to the reference European Lead Fast Reactor (ELFR), but using proven and already available solutions making possible its construction in a short term.

At national level, the ALFRED infrastructure is endorsed as a project of national importance in the National Strategy for Research, Development and Innovation [7, 8], as well as in the Smart Specializations Strategy of the South Muntenia Region [9]. In 2017, the ALFRED infrastructure was included in the National Roadmap for Research Infrastructures [10].

At European level, ALFRED demonstrator is included in the SNETP SRIA and its deployment strategy 2015 [1].

The ALFRED infrastructure will be added to a set of unique infrastructures in Romania, located on the Mioveni platform (TRIGA nuclear research reactor, post-irradiation laboratories, material testing laboratories, nuclear fuel manufacturing, testing and performance assessment, and radioactive waste treatment plant).

At the national level, the scientific community will benefit of: (1) a modern, high-performance research infrastructure for the development of GenIV nuclear systems; (2) a model of international collaboration oriented towards applied sciences, innovation and technological development in a cutting-edge field; (3) a centre of excellence attracting young talents and providing training of future specialists; (4) an increased capacity for innovation and technological development; (5) an increased number of scientific papers that can be published, with high potential for visibility and citation; (6) the reduction of disparities between the Romanian regions, (7) the reduction of the gap between our country and the western countries in the field of innovative technologies.

The ALFRED infrastructure will be implemented in a staged approach. So far, with the participation of RATEN, the following objectives have been already achieved:

- elaboration of the conceptual project of the ALFRED demonstrator (through the European project FP7 LEADER) [12];
- investigation of the feasibility of ALFRED demonstrator construction in Romania (through the European project FP7 ARCADIA [13]);
- definition, by the FALCON consortium, of the Action Plan, the implementation plan and the roadmap (FALCON Roadmap);
- definition of the infrastructure needed for nuclear systems development [14];
- feasibility studies for two of the supporting experimental infrastructure (ATHENA and ChemLab) and the application for their funding and construction (under evaluation);
- initiation of the dialogue for the authorization process, including the local community participation in the decision making process.

The staged implementation of the infrastructure has certain advantages, consisting in the compliance with the existing budgets, progressive accumulation of information from experiments and further expertise from their analysis.

PRO ALFRED project - *Activities for the Preparation of the ALFRED Research Infrastructure Development in Romania* is part of this staged approach. Financed by the National RDI programme (PNCDI III), Sub-programme 5.5 – The ALFRED Project, PRO ALFRED aims at the preparation of the Romanian capacity for an increased national participation in the implementation of the ALFRED Infrastructure.

PRO ALFRED was launched in September 2019, under the coordination of RATEN (State Owned Company ″Technology for Nuclear Energy″), with a duration of 15 months and a budget of about 2,500,000 euro [15].

PRO ALFRED project objectives

The project objectives address the main priorities in building the national capability making Romania a real contributor to the development of the LFR technology, namely:

- increase of the Romanian scientific and technological potential by developing the ALFRED Infrastructure based on the preparation of infrastructure elements, by developing the necessary concepts for modelling processes and associated phenomena, by demonstrating the level of safety, as well as by acquiring, analysing, processing and storing specific data for knowledge capitalization;
- substantiate and increase the readiness level of the ALFRED infrastructure implementation by feasibility analysis, elaboration of technical documentation, establishment of operational requirements for the experimental installations, conducting studies for economic, social and technical-scientific impact assessment at local, regional and national level;
- prepare the research-development-innovation programs running on the ALFRED supporting experimental infrastructure by elaborating a national RDI agenda starting from the requirements and priorities generated by the implementation and perspectives of using this strategic infrastructure;
- strengthen the competencies in correlation with the requirements of the ALFRED infrastructure by identifying the training needs (technical, scientific, managerial) for its construction and developing specific training actions;
- ensure cooperation between research, education, industrial and economic institutions in Romania and potential international partners in the field of Generation IV technologies and nuclear safety development by widening and strengthening collaboration, preparing the use of supporting experimental infrastructure in joint programs, and achieving an efficient and operative e-management system to facilitate the infrastructure operation.

PRO ALFRED project consortium

The implementation in Romania of the ALFRED infrastructure requires the synergistic involvement of research organizations, industry and university education in the development of the LFR technology, while contributing to achieving the European Union's objectives on nuclear excellence.

Therefore, the Consortium created to reach the above mentioned objectives provides relevant expertise in nuclear and socio-economic research, in undergraduate and postgraduate education needed to initiate the construction and development of the national capability in the field of innovative nuclear systems and to progress in the ALFRED infrastructure implementation.

PRO ALFRED Consortium brings together teams of specialists from research organizations, with proven expertise in their fields of activity, namely:

- RATEN - institution having competence in the LFR technology gained in a large number of European projects (ELSY, LEADER, ARCADIA, MARISSA, MAXSIMA, ESNII Plus, ADRIANA, MATISSE, MATTER, SEARCH, GEMMA, PIACE) and also member of the FALCON international Consortium. RATEN is the main catalyst for expanding research both nationally, by involving Romanian organizations with research potential in this field and internationally, by mobilizing, through FALCON Consortium, European efforts around ALFRED, in order to achieve optimal conditions for infrastructure implementation;
- University ″Politehnica″ Bucharest and University of Pitesti - main suppliers of technical personnel for the nuclear field in Romania, interested in the development and implementation of high-performance educational methods for students education and training;
- Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH) Bucharest - entity with expertise in the decommissioning of nuclear installations and in the implementation and promotion of a pan-European research infrastructure (ELI NP);
- Institute for Economic Forecasting Bucharest - specialized in the field of socio-economic forecasts and analyses, key elements in supporting the financing of ALFRED from European funds.

As result of PRO ALFRED project implementation, it is expected that this kernel of expertise will grow up, attracting other national contributors from research, education, industry or business environment around the ALFRED infrastructure.

PRO ALFRED project structure and activities

The project is organized in 7 Work Packages (WP), each package grouping activities needed to achieve the proposed objectives (Fig.1), presented in the following.

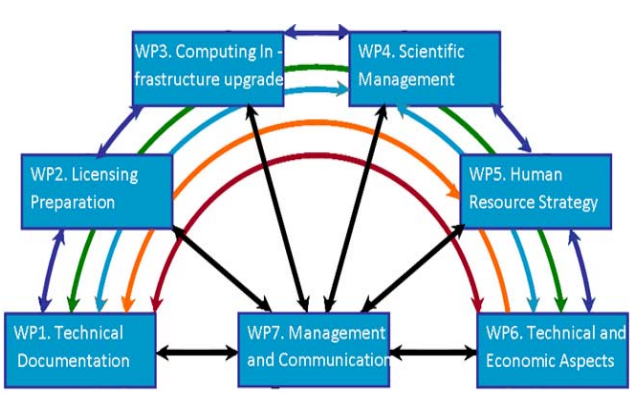


Fig.1. PRO ALFRED project structure

Preparing technical documentation for research - development - testing - demonstration supporting infrastructure: HELENA2, ELF, Meltin'Pot, HandsON, Hub (WP1)

As stipulated in the European strategic documents for the development of the innovative Generation IV systems (SNETP Research Agenda, ESNII Roadmap) and the strategic documents for LFR technology and ALFRED implementation elaborated by the FALCON International Consortium, there are still open aspects related to the fuel assembly and other components behaviour in different thermo-hydraulic regimes in loop and pool configurations, and long term operation (endurance regime). Therefore, there is a need for dedicated experimental facilities such HELENA2 and ELF for testing, qualification, validation / verification, as well as for further investigation of the scientific open issues.

Demonstrating complete control of all phenomena involved in normal or accidental operation plays a crucial role in the authorization process. In these demonstrations, the formation of the term source is of major importance. Investigation of fission products retention in the lead pool must be performed to study their transfer and deposition/ accumulation characteristics in pure, molten lead environment using a designed experimental installation (Meltin'Pot).

Fuel handling in liquid lead encounters several major differences compared to light/heavy water technologies: lead opacity, high viscosity, buoyancy. For the licensing process, a facility demonstrating the safe handling of the fuel assembly, according to the insertion/removal schedule (HandsOn), is also mandatory.

In order to achieve an efficient management of the ALFRED infrastructure, including the supporting experimental installations use in open access, and the coordination with activities carried out in other international centres for demonstration, testing, qualification, validation/verification, investigation of open aspects of technology, a coordination centre (Hub), hosting the Lead School and Conference and meeting Rooms, is planned to be built as well.

WP1 will develop the technical documentation needed in the preparation of funding applications for the experimental support facilities HELENA2, ELF, Meltin'Pot and HandsOn, and for the Hub.

A vision document, elaborated in the first stage of the project for each supporting experimental infrastructure and for the Hub (except for ATHENA and ChemLab for which the technical documentation for construction has been completed), defines in details: the role, experimental objectives, experimental and construction features, instrumentation, experimental field, functionality, interface with other installations and experiments.

Based on the vision elements, Conceptual Projects of HELENA2, ELF and Hub will be elaborated, which, in turn, together with the vision on the siting, will be further used in the elaboration of Feasibility Study of HELENA 2 and ELF. RATEN expertise will be complemented by expert consultancy on technical and design aspects specific to each type of installation.

Preliminary elements and studies for licensing the ALFRED demonstrator (WP2)

Generation IV demonstrators represent an important step on the way to the commercial stage of these innovative reactor systems. The construction of the demonstrators requests both the licensing of the project, as well as the site licensing. Given the innovative nature of the LFR technology and of the ALFRED reactor, the licensing activity represents a critical point in its implementation.

WP2 takes into account the challenges imposed in this particular case by the whole process of obtaining the necessary authorizations for the ALFRED construction and siting and proposes to elaborate preliminary elements for the preparation of the licensing applications. Activities carried on under this WP consist in:

- preparation of the ALFRED demonstrator licensing process, in order to demonstrate the control of all involved phenomena, in operational and accidental regimes, and achievement of an adequate safety level;
- elaboration of preliminary studies for the preparation of the licensing application;
- ensuring cooperation between research institutions in the field of Generation IV technology development and nuclear safety.

The vision elements on the validation process of the ALFRED demonstrator project, defined in the early stage of PRO ALFRED, identify the actors involved and their role, phenomena and important aspects in safety demonstration, requirements and validation elements for the project. The vision takes into account the phased approach in operation, setting out the validation steps. This document will be the basis to elaborate the validation application of the ALFRED demonstrator project, to be done beyond PRO ALFRED.

Other important element in the preparation of the authorization process approached by PRO ALFRED is the investigation of the existing nuclear codes and standards applicability for the ALFRED demonstrator from the perspective of their use in the authorization process. A seminar gathering the regulatory authority (National Commission for Nuclear Activities Control, CNCAN) and invited lecturers with international recognized expertise will discuss the proposed vision, codes and standards in order to strengthen the knowledge regarding the ALFRED project licensing process, both at RATEN (as applicant for authorization), as well as at CNCAN level.

Various aspects related to the demonstrator siting, part of the licensing application, are considered also in a number of studies dedicated to: seismic characterization of the entire area of the RATEN site; demography of the region; meteorological characteristics; pre-operational monitoring of environmental radioactivity of the site.

The radioactive and/or hazardous waste generated by the operation and decommissioning of the ALFRED demonstrator will be also assessed, and requirements regarding the safety management of radioactive waste, as well as a concept of the initial decommissioning plan of the ALFRED reactor will be proposed.

Developing the national research capacity for the implementation of the ALFRED Infrastructure (WP3)

The elaboration of the Feasibility studies for the supporting experimental facilities, either as part of this project (HELENA2 and ELF), or beyond PRO ALFRED (Meltin'Pot, HandOn, HUub, the definition of the testing conditions, as well as the processing of experimental data acquired during experiments need adequate computing infrastructure and skills. Procurement and development of computer codes adapted to the particularities given by a fast neutrons spectrum and liquid lead as coolant and adequate hardware systems is a pre-requisite for the participation of Romanian scientists in these activities.

PRO ALFRED will contribute to updating, enlargement and improvement of the computing infrastructure and of the national code database, by purchasing specialized computing systems (software and hardware) and by developing the design and the numerical calculation skills, necessary for the ALFRED infrastructure implementation.

In this regard, a particular attention will be paid to the assimilation of those computational tools (such as ANSYS and RELAP) able to simulate the operating regimes of nuclear installations and the thermal-hydraulic processes in a liquid metal fast reactor, and those codes to be used in the safety assessments (RISKSPECTRUM PSA, RISKSPECTRUM HRA); at national level, this will create the necessary competence ensuring the Romanian involvement in the ALFRED infrastructure design and in the associated research-demonstration-testing-verification and validation activities.

Planning the scientific management of ALFRED infrastructure* (*WP4)

LFR has been selected by the GIF [4] as one of the most promising nuclear technologies for future generation reactors and is gaining increasing interest worldwide. The advantages of LFR technology reflected in a high level of safety are fully recognized by the international scientific community. Without prejudice to these advantages, a number of technological challenges need to be addressed and overcome, taking into account the operational experience gained in the existing heavy liquid metal testing facilities.

Although past and present research and development projects (supported by EU and national programs) have led to significant progress in understanding the phenomenology of heavy liquid metal behaviour and in identifying and developing solutions for materials, components and systems operating in molten lead environment, efforts are still needed to complete the development, up to qualification and demonstration, of these solutions, enabling the design, licensing and construction of these innovative nuclear systems [16-19].

The demonstration program in support to ALFRED licensing presents challenges on key scientific issues such as monitoring and control of coolant chemistry in the reactor pool, associated thermal - hydraulic issues or component qualification [20, 21].

European experience shows that the sustainability of a research infrastructure can be improved from the early stage of its concept by defining the objectives of the facility with sufficient flexibility, by a proper design and optimization taking into account the needs imposed by the evolution of technology. Flexibility mainly refers to margins on design parameters, which will translate into the possibility of a larger number of experiments. In addition, a key aspect of sustainability is the continuous monitoring of research and development trends and the anticipation of future needs.

Based on the key issues in ensuring the long-term sustainability of the ALFRED research infrastructure identified in the first stage of the project, operational requirements of the experimental facilities will be elaborated in line with the identified needs, priorities and future trends. The sustainability of the ALFRED research infrastructure will take into account of all the key aspects in ensuring long-term sustainability and the still open aspects specific to lead technology, highlighting the solutions, methods or techniques to address and solve them, as well as the role played by the ALFRED supporting experimental infrastructure in approaching these open issues.

WP 4 will also provide description of the experimental campaigns needed for the verification / validation process of the nuclear safety aspects, establishing operational requirements and the appropriate and efficient working methods to be applied in the experimental installations, compliant with the strict rules of the quality management system.

Finally, the national RDI Agenda for the LFR technology which defines the research-development-innovation programs to be carried out within the future ALFRED infrastructure will be elaborated.

In addition, the most appropriate formula for the scientific management of the ALFRED infrastructure will be proposed by defining an entity and a statute appropriate to the particular nature of this infrastructure.

Developing competence building strategy for ALFRED infrastructure construction and operation (WP5)

Design, construction, operation and management of the ALFRED infrastructure, as well as the implementation of the research and testing – demonstration – qualification - validation and verification programme will open a number of jobs requesting personnel with particular skills and competences in the very next future (4 to 7 years).

PRO ALFRED will prepare the training activities able to ensure the human resources needed for the construction and operation of the supporting experimental infrastructure and of the ALFRED demonstrator, having as main outcome a dedicated human resources strategy.

To reach this goal, as a first step, the current situation in terms of competence building (within the existing national framework) is analysed, by mapping the university institutions potentially participating in this process. Closely correlated to this activity, the human resources requested by the ALFRED infrastructure implementation are carefully identified, taking into account all necessary specializations involved in: materials science; lead technology; instrumentation and control; reactor systems and components; fuels and fuel cycles; deterministic and probabilistic safety analyses; thermalhydraulic aspects; neutronic, nuclear data, etc.

Based on these findings, methods and tools for competence building ensuring the necessary specialists for all activities related to the ALFRED infrastructure will be proposed and analysed to select the optimal ones, for which appropriate implementation methodologies will be elaborated. Two concepts - train the trainers and training for a new specialization will be further implemented in order to test their efficiency in competence building.

Elaboration of new curricula or reconfiguration of the existing one and development of a training and mobility plan, represent also important activities dedicated to WP5.

The outcomes of all proposed activities will eventually be integrated into RATEN's Human Resources Strategy for the ALFRED infrastructure development, implementation and operation.

Technical-economic evaluations of the LFR technology from the perspective of the future national energy market (WP 6)

The evaluation of the competitiveness of a LFR commercial reactor compared to other technologies for energy production in the Romanian energy mix is an important element in promoting the ALFRED demonstrator both at national and European level and receiving the necessary support for its construction.

WP6 will contribute to the necessary studies for the analysis of the economic, social and technical-scientific impact at local, regional and national level, as well as to the assessment of the energy and scientific services market evolution. The WP 6 objective is to provide the necessary elements for the future applications for European funds on feasibility and economic viability of the ALFRED demonstrator, and specific elements for the necessary strategic documents to be issued in the next period: National Research Strategy 2021-2027, Partnership Agreement with the EC for 2021-2027, Operational Programs. Using methodologies, analysis and computation models specific to technical-economic and cost-benefit analyses, using existing studies, strategic papers and statistical data, WP 6 will identify the best worldwide practices regarding the financing mechanisms of similar projects.

In a first step, a synthesis of national, European and international strategy documents on climate goals, taking into account the energy market developments and trends, will identify the trends in the development and implementation of carbon-free technologies.

A forecast of the electricity market evolution will be further performed considering the expected advantages in terms of cost reduction, increase of nuclear safety, security of supply in the context of increasing the intermittent renewable sources share or proliferation resistance.

In order to fulfil the obligations regarding the assumed climate change prevention, it is necessary to develop an energy mix having an increased share of renewable energies and nuclear energy in Romania. In this approach, the competitiveness of a commercial reactor using LFR technology will be performed based on the INPRO methodology (IAEA) and the evaluation tools developed within IAEA.

The economic impact of LFR/ALFRED technology in relation to the achievement of environmental and climate objectives (reduction of greenhouse gas emissions, external costs and their internalization, benefits in the EU-ET system, other measures taken at national and global level dedicated to climate change prevention) will be assessed and compared with the carbon-free technologies.

Various innovative financing structures for the LFR technology implementation will be also investigated in order to identify viable financing mechanisms for the commercial development of fast lead - cooled reactors. Using the results regarding the costs, benefits and risks associated with the development and implementation of LFR technology, sensitivity analyses of the possible financing scheme will be performed and based on them the elements necessary to develop a viable business model will be ensured.

Promoting ALFRED infrastructure for a sound national and international support (WP7)

Acquiring the national and European support for the construction of the ALFRED infrastructure and attracting and involving the national potential depend to a large extent on the effectiveness of communication process and on the successful promotion of this infrastructure.

WP7 will dedicate activities to increase the awareness of the national R&D and E&T institutions, nuclear industry and business environment on the ALFRED infrastructure construction and on the potential offered by this infrastructure, in order to stimulate their interest and strengthen national cooperation in the development of the LFR technology.

Two important outcomes are expected to be provided in this purpose: the White Book and the Communication and Promotion Strategy of the ALFRED Infrastructure.

The White Book on ALFRED Infrastructure, seen as one of the most important communication vectors both at national and international level, will provide information on the components and particularities of the ALFRED infrastructure, on the RDI opportunities offered by its supporting experimental facilities, on the benefits for the national and international R&D programs, so that interested scientific, academic and industrial communities can easily identify aspects of interest, potential contributions and future involvement.

A communication, promotion and dissemination plan of the PRO ALFRED project, elaborated in the beginning of the project, sets out the guidelines, the framework and the specific requirements for carrying out the further dissemination and promotion activities. It identifies the target groups and establishes the policy, the communication strategy during the project, modern and efficient means and methods of communication, dissemination and promotion.

PRO ALFRED communication plan will be implemented during the entire project through: creation of mixed scientists – journalists communication group of in the field of nuclear energy science, elaboration of promotional and exhibition materials, organising discussions with the identified target groups, production and distribution in the Romanian and European media of short news on the ALFRED infrastructure, its status and benefits at national and European level. The final project conference ″ALFRED: Looking ahead″, planned for September 2020, will widely disseminate the main achievements of the PRO ALFRED project.

Having as major objectives the efficient dissemination of ALFRED Infrastructure on short and medium term, as well as enlargement of the involvement of the scientific, university and industrial communities from Romania and the EU, the Communication Strategy will make use of all modern and efficient means such as: attractive website, dedicated leaflets, 3D models, promotional events, participation in scientific events with exhibition stands and dedicated presentations at national and European level.

The project's work packages are closely correlated with each other, requiring a continuous and efficient exchange of information. The competence existing at the consortium level will be complemented by expert consultancy in order to ensure that the PRO ALFRED outcomes will benefit of the highest level of knowledge and expertise in LFR technology existing at this moment in the world.

Current status

The project was launched on September 25, 2019 with participation of the Ministry of Research and Innovation representatives and the project partners (Fig.2); its first implementation stage was completed by November 2019.



Fig.2. PRO ALFRED participants in the kick-off meeting

Concrete progress has been made in the technical documentation development by elaborating detailed conceptual schemes of the supporting experimental installations HELENA2, ELF, MELTIN'POT and HANDS ON, as well as for the coordination and training centre (HUB).

In the preparation of the licensing process of the ALFRED demonstrator, the seismological characterization of the reference site was performed, and the elements of the authorization process in the ″design safety″ approach, including the concept of staged operation of the ALFRED reactor at a power level has been defined.

Regarding the ALFRED Infrastructure sustainability, the key aspects in ensuring its long-term viability have been identified, and the specific aspects of lead technology to be addressed with this infrastructure and further integrated in a Strategic RDI Agenda dedicated to LFR technology development have been addressed.

As a first step towards ensuring the necessary human resources, the national educational program was evaluated, the needs for research, qualification, design, authorization and operation of the ALFRED infrastructure were quantified, and the required competencies associated to these jobs and the most efficient building means have been identified.

The outcomes regarding the trends in the development and implementation of carbon-free technologies in the conditions of energy market evolutions, resulting from the analysis of strategic documents for energy and climate change, allowed the establishment of data for modelling the evolution of the Romanian energy system and of the impact of LFR Small Modular Reactors implementation. The predictions of the developed models will be the basis of the proposal of the financing scheme of the ALFRED demonstrator and of a business model.

The major milestones and means of promotion of the infrastructure were established, with a special emphasis on the vision elaboration of the White Paper on ALFRED Infrastructure.

Last but not least, the acquisition of ANSYS and AUTOCAD licenses and appropriate hardware contributed to the upgrade of the national computing infrastructure necessary for the design activities associated with the ALFRED Infrastructure.

Conclusions

The ALFRED infrastructure consisting in the LFR demonstration reactor, a kernel of supporting experimental facilities (ATHENA, ChemLab, ELF, HELENA2, HandsOn and Meltin'Pot) and the coordination Hub hosting the Centre of Excellence - Lead School is planned to be implemented, in a staged approach, on the Mioveni nuclear platform, in Romania.

The supporting experimental infrastructure is needed for testing - demonstration - qualification of processes, materials, components and systems to be used in the ALFRED demonstrator construction, as well as for the verification and validation of computational tools and methods used in its design and safety demonstration.

PRO ALFRED project supports the Romanian decision to host this infrastructure, contributing to the preparation of the national participation to its implementation/ construction.

The expected outcomes of the project will consist in:

- development of the feasibility studies for research support infrastructures;
- setting-up the elements for licensing process, including the assessment of the contents of the safety demonstration plan requested by the regulator to fill the gaps in codes and standards with experimental evidence for the future licensing application;
- preparing the supporting experimental infrastructure construction, including human resources strategy and policies, and planning for longer term competence building;
- supporting ALFRED demonstrator as ″Major Project″ through compilation of key strategic documents for the Romanian government and EU Commission;
- improving the education and training programme, involving Romanian universities and exchanges/ collaboration with European research centres;
- strengthening collaboration at national level, and increasing the potential for international cooperation.

By implementing the ALFRED infrastructure, Europe and Romania will get a complex research capability, unique in the world, which will support the research, development and qualification of the LFR technology, assuring for the European scientific community a remarkable position in the top of the nuclear field.

Romania will fully benefit from this international openness, the increase of research performance being stimulated by: (1) achieving an optimal synchronization between national and European research, (2) creating international work teams, (3) consolidating international contracts, on a bilateral basis or in consortia, and (4) using high-performance installations in the specialists training.

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