ESNII

European Sustainable Nuclear
Industrial Initiative

Implementation Plan 2013-15

**A contribution to the EU
Low Carbon Energy Policy:**

**Demonstration Programme
for Fast Neutron Reactors**

This document has been prepared by the ESNII Executive Board
established within the Sustainable Nuclear Energy Technology Platform.
Contact: secretariat@snetp.eu

Table of contents

1. Objectives of this plan 3
2. Detailed action plan 4
2.1. ESNII-1 (SFR) - ASTRID project (Advanced Sodium Technical Reactor for Industrial Demonstration) 6
2.1.1. Priority actions for 2013-2015 6
2.1.2. Budget for 2013-2015: 10
2.1.3. EU added value 11
2.1.4. Risk 11
2.2. ESNII-2 (Fast spectrum research reactor) - MYRRHA Project (Multipurpose Hybrid Research Reactor for High-tech Applications) 13
2.2.1. Priority actions for 2013-2015 13
2.2.2. Budget for 2013-2015 15
2.2.3. EU added value 16
2.2.4. Risk 16
2.3. ESNII-3 (LFR) - ALFRED Project (Advanced Lead Fast Reactor European Demonstrator) 17
2.3.1. Priority actions for 2013-2015 17
2.3.2. Budget for 2013-2015 19
2.3.3. EU added value 20
2.3.4. Risk 21
2.4. ESNII-4 (GFR) - ALLEGRO Project 22
2.4.1. Priority actions for 2013-2015 22
2.4.2. Budget for 2013-2015 25
2.4.3. EU added value 25
2.4.4. Risk 25
3. Coherence with EERA 26
APPENDIX 1 28
APPENDIX 2 31

1. Objectives of this plan

One of the major concerns of society with regard to the implementation of nuclear energy is the high-level nuclear waste. Fast spectrum reactors with closed fuel cycles will allow a significant reduction in high-level nuclear waste radiotoxicity and volume. Fast reactors will also allow an increase in natural resource (uranium) utilisation by a factor of 50. In this way, it is clear that the use of fast reactors with a closed fuel cycle approach will allow more sustainable implementation of nuclear energy.

For the development of these fast reactors within ESNII, it is of paramount importance to excel in safety, reliability, radiological protection and security.

The main objective of ESNII is to maintain European leadership in fast spectrum reactor technologies that will excel in safety and will be able to achieve a more sustainable development of nuclear energy. With respect to the 2010 evaluation of technologies, sodium is still considered to be the reference technology since it has more substantial technological and reactor operations feed-back. The Lead(-bismuth) Fast Reactor technology has significantly extended its technological base and can be considered as the shorter-term alternative technology, whereas the Gas Fast Reactor technology has to be considered as a longer-term alternative option. The main goal of ESNII is to design, license, construct, commission and put into operation before 2025 the Sodium Fast Reactor Prototype reactor called ASTRID and the flexible fast spectrum irradiation facility MYRRHA.

ASTRID will allow Europe to demonstrate its capability to master the mature sodium technology with improved safety characteristics responding to society's concern of having the highest possible level of safety. Therefore, the design of ASTRID focuses on meeting the challenges in terms of industrial performance and availability, improved waste management and resource utilisation and a safety level compatible with WENRA objectives for new nuclear build, whilst at the same time achieving the Generation IV goals. An associated R&D programme will continue to accompany and support the development of ASTRID to increase the lines of defence and robustness of this technology, and allow the goals of the 4th generation to be reached, not only on safety and proliferation resistance, but also on economy and sustainability.

With MYRRHA, Europe will again operate a flexible fast spectrum irradiation facility in support of the technology development (in particular for material, components and fuel irradiation tests) of the three fast reactor systems (SFR, LFR and GFR). Also, MYRRHA will offer a wide range of interesting irradiation conditions for fusion material research. Since MYRRHA will be conceived as an Accelerator Driven System, it will be able to demonstrate the ADS technology, thereby allowing the technical feasibility of one of the key components in the double strata strategy for high-level waste transmutation to be evaluated. Due to the fact that MYRRHA will be based on heavy liquid metal technology (namely lead-bismuth eutectic), it can serve the role of Lead Fast Reactor European Technology Pilot Plant (ETPP) as identified in the LFR roadmap. An associated R&D programme will accompany and support the development of MYRRHA.

For the financing of the total investment cost of these facilities, it will be of paramount importance to establish the appropriate consortium structure and legal basis, allowing candidate consortium members to identify the added value of the facility for their own interest.

In parallel to the realisation of ASTRID and MYRRHA, activities around the Lead Fast Reactor technology and the Gas Fast Reactor technology should be continued, taking into account their specific needs.

For the development of the Lead-cooled Fast Reactor, maximum synergy of activities will be sought with the MYRRHA development to optimize resources and planning. For the LFR demonstrator ALFRED, the main focus should be on design activities typical for a critical power reactor connected to the grid, as well as on R&D activities on the lead coolant, addressing the specific characteristics that differ from lead bismuth. Design activities and support R&D shall be performed in the next years to the maximum extent compatible with available resources and taking full advantage of feedbacks, where applicable, from the on-going design of MYRRHA and related R&D programmes. These activities will allow the LFR consortium to reach the level of maturity needed to start the licensing phase and then the construction of ALFRED, provided that adequate financial resources are made available.

In addition to the closure of the nuclear fuel cycle in a sustainable manner, the Gas Fast Reactor has the potential to deliver high temperature heat at ~800 °C for process heat, production of hydrogen, synthetic fuels, etc.. The Helium cooled Fast Reactor is an innovative nuclear system having attractive features: helium is transparent to neutrons and is chemically inert. Its viability is however essentially based on two main challenges. First, the development and qualification of an innovative fuel type that can withstand the irradiation, temperature and pressure conditions put forward for the GFR concept. Secondly, a high intrinsic safety level will need to be demonstrated for this GFR concept. This will imply dedicated design activities followed probably by out-of-pile demonstration experiments. These high priority R&D activities should be embedded into an overall R&D roadmap in support of the development of the Gas Fast Reactor concept. For the development, guidance and implementation of this R&D effort, a GFR centre of excellence will be created. This centre could develop the technical capability to launch the ALLEGRO gas cooled demonstrator.

Based on the ADRIANA project, a number of supporting facilities for the different systems and technologies have been identified. The realisation and operation of these supporting facilities, in particular a fast reactor MOX production line, will be of primary importance to reach the aforementioned objectives.

Raising the financial resources to carry out the ESNII projects and to build the different facilities will be a key factor of success. In this respect, international collaboration through GIF and bilateral or multi-lateral frameworks will be sought to optimise resources. In the next years, project financing capabilities may modify the ESNII part of this Strategic Research & Innovation Agenda

This Implementation Plan is focussed on the period 2013-2015, with a more accurate description of the R&D tasks and with a deeper integration of national programmes and the EURATOM framework programme. This plan will highlight also the additional support from public finance which is required to mitigate the developmental risk.

2. Detailed action plan

Further work and innovations are still needed for all ESNII reactor concepts to achieve safety and security standards anticipated at the time of their deployment, to minimise the wastes quantity and toxicity, and to enhance proliferation resistance, as well as to improve economic competitiveness especially with a high availability factor. To be successful, these challenges need a more integrated approach to R&D within Europe, which goes beyond today’s Euratom framework programmes and takes advantage of wider international cooperations, in particular with other nations involved in the development of the innovative nuclear reactors.

The required R&D activities for the three fast neutron reactor concepts (ASTRID, MYRRHA, ALFRED and ALLEGRO) are described in the following section, together with their challenges and milestones. Priority activities are identified as:

- Primary system design simplification,
- Innovative heat exchangers and power conversion systems,
- Advanced instrumentation, in-service inspection systems,
- Enhanced safety,
- Partitioning and transmutation,
- Innovative fuels (incl. minor actinide-bearing) and core performance,
- Improved materials.

This implementation plan will focus on the main activities that are required to provide the results on which the future decisions can be based

2.1. ESNII-1 (SFR) - ASTRID project (Advanced Sodium Technical Reactor for Industrial Demonstration)

The objectives of the ESNII-1 Task are to promote, develop and construct an integrated technology demonstrator of a sodium-cooled fast reactor (SFR) coupled to the grid, ASTRID (Advanced Sodium Technological Reactor for Industrial Demonstration), with start of operation in the 2020's.

2.1.1. Priority actions for 2013-2015

Status of the work, innovation, and description of the main activities during the Conceptual Design phase

The main goals of the next three years work is related to the Conceptual Design phase of ASTRID with engineering partners, and the pursuit of R&D in support to the integrated technology demonstrator.

The 2010-2012 period (*Preconceptual Design Phase*) achieved end of 2012 was marked by:

- the development of partnerships that cover all the engineering batches, for the period until Basic Design phase, with:
  - AREVA-NP, for nuclear island, nuclear auxiliaries and I&C,
  - EDF, as support to the owner and contribution to R&D,
  - ALSTOM for power conversion systems,
  - BOUYGUES for civil engineering,
  - COMEX NUCLEAIRE for innovative studies in robotics and mechanics,
  - TOSHIBA for development of large electromagnetic pumps,
  - JACOBS for infrastructures and joint site facilities,
  - ROLLS-ROYCE for research and technologies development on sodium gas exchangers and fuel handling,
  - ASTRIUM for the reliability, maintainability and availability analysis,
- the confirmation of some innovations; the Table 1 summarized these.

Table 1. Innovative options for ASTRID deriving from R&D and feedback of experience

Feedback of previous SFR	R&D directions	ASTRID Orientations
Core reactivity Issue of sodium void coefficient → Safety	Optimization of core design to improve natural behavior in case of abnormal transients Exploration of heterogeneous cores	CFV core (patented in 2010): innovative approach, very low or negative overall sodium void coefficient. Better natural behavior of the core, for instance in case of loss of cooling (e.g. due to loss of supply power).
Sodium-water reaction → Safety - Availability	Limitation of total released energy in case of sodium-water reaction Limitation of wastage propagation Replacement of water by another fluid	Modular steam generators Steam generators with sodium in tubes Gas energy conversion system (nitrogen in place of steam/water)
Sodium fire → Safety	Innovation on sodium leak detection systems R&D on sodium aerosols	Improvement of detection (patent on a detection system integrated in the heat insulation) Close containment (limitation of available oxygen, inert gas)
Severe accidents	Core catcher	Core catcher. Several locations are under study

→ Safety	R&D on corium and sodium-corium interaction	(in-vessel, ex-vessel or between the two vessels).
Decay heat removal → Safety	Reactor vessel auxiliary cooling system (extrapolability)	Combination of proofed DHR systems, RVACS
In-Service Inspection and Repair → Safety – Availability		Simplification of primary system design ISI&R is taken into account from design on New techniques : acoustic detection, LIBS, CRDS Signal processing TUSHT (ultrasound, high temperature), high temperature fission chambers, optical fibers, flow meters for subassemblies Remote handling for inspection or repair Under sodium-viewing

The first very important milestone was met at the end of 2012 (June 2006 French Act on wastes management), by:

- the ending of ASTRID pre-conceptual design studies, with a synthesis included in the "Report on the status of R&D studies on separation & transmutation and on new generation reactors" sent to French authorities at the end of 2012,
- the Safety Orientations File for ASTRID, submitted to the French Safety Authority in June 2012. A formal examination of this report will be made by the French Nuclear Safety Authorities in June 2013.

CEA obtained a green light to start *Conceptual Design phase* on the period 2013-2014/2015, and about 550 persons are involved in 2013 in the ASTRID design and the R&D in support.

The main objectives of the Conceptual Design phase are:

- to confirm identified innovative options;
- to provide R&D results in support to the design activities, and in support to the safety case;
- to expand the industrial and international collaboration around ASTRID;
- to converge on complicated options, as:
  - energy conversion system,
  - architecture of the reactor pit in relationship the design of the reactor vessel cooling system and the location of core catcher,
  - confinement;
- to drive an optimization of the design in order to reduce costs;
- to prepare the Safety Options File that will be issued in 2015;
- to prepare next phases (basic design, construction).

Accordingly a lot of R&D is required in support to the Conceptual Design phase and the Safety Options File. A selection of examples of R&D is given in the next paragraphs.

<u>Core and Fuel:</u>

- confirmation of CFV (core with low sodium worth void effect) core behavior for prevention but also for mitigation,
- definition of complementary safety system(s) to enhance margins in addition to the natural behavior of the core,
- complement and improvement of material laws for core materials, including the post irradiation expertise of experimental subassemblies irradiated in Phénix,
- pursuit of the development of innovative non-swelling cladding (manufactured with Oxyde Dispersion Strenghtened steels), including the preparation of irradiation,

- development of a core design enabling the most efficient use of depleted or reprocessed Uranium, through in-situ plutonium production and consumption, and the recycle of minor actinides;

Safety:

- pursuit of the validation of innovative technologies and methods for minimizing sodium leaks, improving the detection performance and reliability, and the development of mitigation options for avoiding any chemical consequences at the site boundary,
- pursuit of the development of advanced sodium-water reaction detection and secondary loop designs enabling the containment of any sodium-water reaction accident without giving rise to consequences on the plant,
- pursuit of the development and the validation of an advanced instrumentation and control system of the core,
- pursuit of the development and the validation of mitigation provisions and simulation methods concerning defence-in-depth situations, such as core fusion (including the core catcher design), aircraft crash, very large earthquakes;

Reactor and systems design:

- pursuit of the primary circuit conception for increasing the performance of in-sodium telemetry or non-destructive examination techniques enabling efficient and practicable in-service inspection campaigns,
- pursuit of the development of robotics, under sodium-viewing and repair devices,
- pursuit of the development and the test of advanced cost-efficient steam generators concepts in order to improve the global thermal efficiency of the plant,
- pursuit of the development and the test of a gas energy conversion system, that should permit to eliminate the sodium-water risk reaction,
- pursuit of the development of efficient fuel and components handling systems that allow availability objectives to be reached by reducing fuel and components replacement durations,
- pursuit of the structure materials R&D in support to justification of lifetime of structures and components.

Another important R&D axis is too to continue:

- the verification and the validation of codes that will be used during the Basic Design phase and the Preliminary Safety File, with an important effort for severe accident codes,
- the upgrading or the building of experimental facilities in support to the verification and the validation of codes and for the qualification of ASTRID options and systems, as for instance the qualification for systems such as handling machines, control rod mechanisms, heat exchangers, subassemblies dynamic behavior, …).

Due to the large amount of R&D, another objective of the 2013-2015 period is to organize European and international R&D in support of ASTRID.

Finally it has to be pointed out the need to enhance education and training activities in the field of SFR technologies in order to provide the future specialists needed to build and operate the installation. Several tracks are studied:

- the opportunities from international cooperation with current SFR operators,
- an increase of the activities of Sodium and Liquid Metal School in relationship with ENEN (European Nuclear Education Network).

Prototype conception, licensing and construction

The ASTRID program has to also include the facility to manufacture the fuel for the reactor, of limited capacity from 5-10 tons heavy metal per year.

ASTRID shall be coupled to the grid with an electrical power of about 600 MW. Its design integrates operational feedback of past and current reactors. It is seen as a full Generation IV integrated technology demonstrator. Its safety level shall be at least as good as current Generation III reactors, with strong improvements on core and sodium-related issues. After a learning period, the reactor shall have a high load factor (e.g. more than 80%). The reactor shall provide capability for demonstration of transmutation of minor actinides, at larger scale than previously done in Phénix. The investment costs of the prototype shall be kept to the lowest possible, with technical options compatible with later deployment on a commercial facility.

Contribution of the Euratom collaborative projects

European R&D projects, under the 6th and 7th EURATOM Work programme, have definitely brought some added value to enhance cooperation among the countries with some key expertise in the field of sodium fast reactors and foster networking among available infrastructures. One should mention some important past projects that provide major achievements:

- EISOFAR: this project named "*Roadmap for a European Innovative SOdium cooled FAst Reactor – EISOFAR*"was launched in the framework of the 6th FP. This project was aiming at identifying, organizing and implementing a significant part of the needed R&D effort;
- ADRIANA: this very valuable project was aiming at defining a roadmap for the needs of infrastructures for the R&D in support to ESNII, and its results feed into new proposals for projects and international cooperations.

On-going projects are bringing R&D results that are valuable for assessing relevancy and viability of innovations considered for ASTRID prototype and future SFR. One should mention:

- CP-ESFR: this four years large *Collaborative Project on European Sodium Fast Reactor (CP ESFR* - 2009-2012, with an extension partly on 2013) undertaken in the framework of the 7th FP was a key component of the European Sustainable Nuclear Energy Technology Platform (SNE TP) and its Strategic Research Agenda (SRA) for SFRs. This project brought an important contribution with respect to the structuration of a R&D network on SFRs, the identification or confirmation of some promising innovations (e.g. Decay Heat Removal system, mitigation devices in case of severe accidents, etc.), the exchange of views on SFR safety standards, benchmark studies on simulation tools (PIRT analysis) and expression of R&D needs, and some developments of methods dealing with severe accidents, seismic studies etc.;
- Valuable results from the European FP7 projects on materials (GETMAT and MATTER) and their link to the joint Program Nuclear Material;
- SARGEN-IV (2 years program started in 2012): proposal for a harmonized European methodology for the safety assessment of innovative reactors with fast neutron spectrum to be built in Europe;
- SILER, cross-cutting project dedicated to seismic studies and development of adequate protection measures;
- THINS, cross-cutting project related to thermal-hydraulic issues, and validation of thermal-hydraulic codes;
- ANDES, cross-cutting project for improving accuracy and validation of nuclear data and models.

All these projects are the basis for a network of over 30 European partners.
We also hope for the outcome of very strategic future projects such as:

- MATISSE (Materials innovation for safe and sustainable nuclear energy):

This project proposal is structured in 5 work-packages:
  - modeling activities,
  - R&D on SiC-SiC ceramic material,
  - ODS innovative cladding,
  - activities in support to ESNII (creep fatigue of austenitic and martensitic steels, functional coatings and modified surface layer, fuel cladding interaction, environmental assisted degradation of materials in liquid metals),
  - coordination and support action to enforce the integration of the research program through the definition of a legal entity.

- ESNII +:

This project proposal is based upon two main components:
  - Roadmapping and structuring of ESNII, that will help to structure European R&D activities,
  - Cross-cutting R&D activities, with a proposal of a first list of R&D work-packages on core safety, fuel safety, seismic studies, instrumentation for safety.

2.1.2. Budget for 2013-2015:

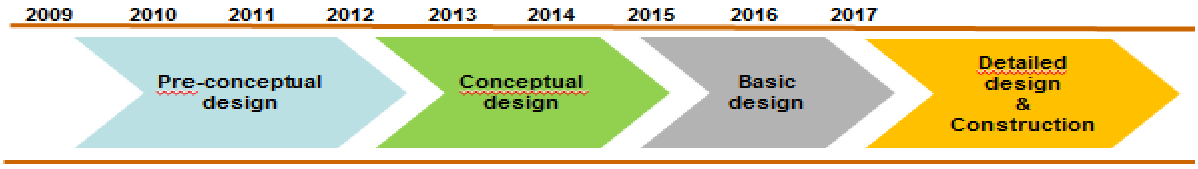
In 2010, the finance law put into place a multiannual budget for the ASTRID program (Advanced Sodium Technological Reactor for Industrial Demonstration) and an agreement was signed between CEA and the French Government awarding 650 M€ to CEA to conduct the ASTRID R&D and design studies, including the development of associated R&D facilities (see table below).

Programme ASTRID	2010-2012	2013-2014	2015-2017	Total
Réacteur prototype ASTRID				
Avant-projet sommaire - Phase 1 (AVP1)	75,0			**75,0**
Avant-projet sommaire - Phase 2 (AVP2)		52,0		**52,0**
Avant-projet détaillé (APD)			210,0	**210,0**
Installations technologiques de qualification des composants d'ASTRID - Réalisation/Rénovation				
Grandes installations	59,0	82,8		**141,8**
Petites installations expérimentales	37,8	34,0		**71,8**
Maquette critique de qualification du cœur d'ASTRID (MASURCA)				
Rénovation	5,3	11,6	23,1	**40,0**
Fabrication de combustible spécifique			10,0	**10,0**
Atelier de fabrication des combustibles d'ASTRID (AFC)				
Avant-projet sommaire (APS)	6,0			**6,0**
Avant-projet détaillé (APD)		20,0		**20,0**
Programme spécifique sur accidents graves	13,5	9,0		**22,5**
Atelier de fabrication d'assemblages chargés en actinides mineurs (ALFA)				
Études de faisabilité	1,5	1,0		**2,5**
TOTAL (millions d'euros)	**198,1**	**210,4**	**243,1**	**651,6**

Contributions to R&D in support to ASTRID project are also provided by EC projects, particularly CP-ESFR (*Collaborative Project on European Sodium Fast Reactor (CP ESFR - 2009-2012)*) with a budget of about 11.3 M€, half funded by EC. Next section explains the added value of these projects.

The schedule associated to the ASTRID prototype is very ambitious and will be adapted in the course of the project, following R&D results and polical decisions. First choices have been made in 2010 in order to launch the pre-conceptual and the conceptual design, and to start first discussions with the safety authorities. The first phase of the conceptual design was completed in time at the end of 2012 together with the submission to the French Government of a report on the status of R&D studies on separation & transmutation and on new generation reactors. The second phase of the conceptual design was launched at the beginning of 2013 for a duration of 2 to 3 years. This phase will be followed by the basic and detailed design. The objective is to put the reactor into operation around 2025.

Figure 1: schedule of ASTRID project



The ASTRID program also includes the facility to manufacture the fuel for the reactor, of limited capacity from 5 to 10 tons heavy metal per year. The refurbishment of existing testing facilities and the construction of new tools is part of the program as well.

2.1.3. EU added value

The ESNII programme on sodium-cooled fast reactors will allow Europe to develop its expertise and a reactor concept of the fourth generation, adapted to European needs and safety requirements.

For the SFR integrated technology demonstrator ASTRID, integration of European R&D which has been initiated with the CP-ESFR partners but open to others, is of high interest as a boost of the necessary innovation. Incentive European funding is also of utmost importance, allowing the development risk to be shared between public funding parties and industry.

2.1.4. Risk

This is a standard process for complex technology to design and construct the demonstrator prior full industrial implementation to decrease potential operational and investment risk. Since the process integrates very innovative features, risks are to be expected on the schedule side.

As far as the funding is concerned, there are always risks of lack of financial means, due to the highly innovative endeavor and the long term industrial application of SFR (2040). Political and social acceptance is also to be considered and needs to be addressed through proper explanation and communication. On the technical side, there is however no show stopper and there is good confidence that with enough resources and time, the targeted improvements will be achieved.

The 2010-2012 period has reduced some risks, as:

- an increased confidence on some major innovations considered in ASTRID, as for instance CFV core, gas energy conversion system, ISI&R, etc., due to the progress in the R&D and preliminary qualification program provided by involved engineerings that do not show any show-stopper at the current stage of the project (preconceptual design phase);

- the development of industrial partnerships that cover all the engineering batches, for the period until Basic Design phase.

The main risk during the next phases is to postpone the decision for the ASTRID prototype construction and so to delay the availability of the SFR system.

2.2. ESNII-2 (Fast spectrum research reactor) - MYRRHA Project (Multipurpose Hybrid Research Reactor for High-tech Applications)

The first objective of MYRRHA is to establish a multipurpose research facility serving as a flexible fast spectrum irradiation tool in support of the technology development (in particular for material, components and fuel irradiation tests) of the three fast reactor systems (SFR, LFR and GFR). Also, MYRRHA will offer a wide range of interesting irradiation conditions for fusion material research. As a multipurpose research facility MYRRHA was taken up in the high priority list of ESFRI. MYRRHA will be conceived as an Accelerator Driven System, able to work in critical and subcritical mode.

The combination of Partitioning and Transmutation (P&T) and dedicated burner technologies such as ADS is proposed needed to relax the constraints on the geological disposal Hence, since ADS represent a possible major component in the P&T framework, the demonstration of the sub-critical dedicated burner option is needed. The MYRRHA project proposed by SCK•CEN responds to this need. The objectives of MYRRHA are the demonstration of the ADS concept at a reasonable power level on the one hand and, on the other hand, the proof of technical feasibility of transmutation of minor actinides..

As an ADS MYRRHA contain a proton accelerator of 600 MeV, 4 mA, a spallation target and a multiplying core with MOX fuel, cooled by liquid Lead-Bismuth Eutectic (LBE).

Since MYRRHA is based on the heavy liquid metal technology, it will strongly contribute to the development of lead fast reactor (LFR) technology. MYRRHA will play the role of European technology pilot plant (ETPP) in the roadmap for LFR.

The Belgian Federal Government decided on the 5th March 2010 to give its strong support and commitment to the MYRRHA project, involving a financial contribution of the Belgian Federal State at a level of 40% of the total project investment cost of M€ 960. A budget of M€ 60 has already been allocated by the Belgian Federal Government for the first phase of works (covering the period 2010-2014 for the Front End Engineering Design phase).

2.2.1. Priority actions for 2013-2015

Following the decision of the Belgian Government to support the MYRRHA-project, SCK•CEN has set up a project structure and team integrating the design and R&D efforts performed in several project of the 7th Framework Programme (FP7), such as CDT (Central Design Team), SEARCH (Safe ExploitAtion Related CHemistry for HLM reactors), MAX (MYRRHA Accelerator eXperiment), MAXSIMA (Methodology, Analysis and eXperiments for the "Safety In MYRRHA Assessment), THINS (Thermal-hydraulics of Innovative Nuclear Systems), FREYA (Fast Reactor Experiments for hYbrid Applications), LEADER (Lead-cooled European Advanced DEmonstration Reactor), SARGEN IV (Safety Assessment for Reactors of GENeration-IV), SILER (Seismic-Initiated events risk mitigation in LEad-cooled Reactors), MATTER (MATerials TEsting and Rules), GETMAT (Generation IV and transmutation materials), ANDES (Accurate Nuclear Data for Nuclear Energy Sustainability), and HELIMNET (HEavy Liquid Metal NETwork).

During the 2010-2014 FEED (Front End Engineering Design) period the following items are being accomplished:

- primary system, plant design and the associated R&D programme
- pre-licensing process

- setup of the MYRRHA International Consortium

SCK•CEN is responsible for the primary system, but all other systems, structures and components together with the plant lay-out are being subcontracted to an industrial consortium (called FEED-engineer) selected through a European public tender.

Part of the design work was performed in the FP7 project "Central Design Team" from April 2009 till September 2012.

For the design of MYRRHA, as much as possible, benefis have been taken from previous fast reactor programmes to ease and optimize the licensing process. The objective of MYRRHA is also to excel in safety by practically eliminating all Fukushima accident initiators by means of redundant and diversified fully passive decay heat removal systems. Special attention will also be given to design choices and measures for prevention and hence practical elimination of severe accident scenarios.

The main technological choices for the primary system were fixed in 2012 and in the period 2013-2015 the basic design of the MYRRHA primary system will be finalised.

In 2011, the public tendering procedure to appoint a FEED engineering contractor was initiated. The FEED contract contains all the necessary basic engineering for the balance of plant of MYRRHA in view of the preparation of several technical lots for the construction of MYRRHA and a reevaluation of the detailed costs for the same. Three consortia have been preselected in 2011 and the final ranking of the three consortia was done in December 2012. Awarding of the FEED contract will be done as soon as possible after the contract negociation process as to conduct the FEED works in the course of 2013-2015. This will result in an updated budget estimate for MYRRHA within a cost uncertainty of 25% and in the elaboration of the necessary documents in support of the pre-licensing process.

The major technological issues for the MYRRHA demonstrator are:

- lead-bismuth chemistry control and conditioning R&D programme;
- lead-bismuth component testing and thermo-hydraulics programme;
- lead-bismuth instrumentation programme;
- material qualification programme;
- driver fuel qualification programme;
- coupling technology of accelerator with subcritical core.
- high intensity proton accelerator performances and reliability programme.

An extensive MYRRHA R&D support programme was established in 2010-2011 to address the above mentioned challenges. This R&D programme is based on internal SCK•CEN efforts, complemented by European FP7 projects (SEARCH, MAX, FREYA, SILER, ..) and international R&D programmes.

Several LBE facilities are now under construction and are being put into operation in 2013:

- CRAFT-loop for corrosion experiments;
- RHAPTER-facility for reliability tests of moving mechanical components in LBE;
- MEXICO-loop for testing components for oxygen control methodologies;
- COMPLOT-loop for testing mechanical components such as safety rods, fuel assemblies and beam window;
- ESCAPE-facility for thermal-hydraulic tests in a scaled-down facility of MYRRHA;
- Heavy liquid metal lab for testing of Hg and Po behaviour;
- Ultrasonic LBE facility for validation of the US visualisation strategy.

The 2013-2015 period will thus be devoted to the commissioning of these LBE facilities and running the associated experimental programmes.

Experiments in support of the validation of the on-line reactivity monitoring and validation of neutronic codes will be done in the VENUS-facility in the framework of the FREYA-project over the period 2013-2015.

Together with international partners, SCK•CEN is implementing a specific accelerator R&D programme for achieving the high level of reliability needed for the accelerator. The FP7 MAX-project is complemented with actions based on bilateral agreements.

With the Federal Agency for Nuclear Control (FANC), a pre-licensing procedure has been agreed. This pre-licensing procedure contains a list of “focus points” to be examined in more detail in view of the preparation of the Design Options and Provision File (DOPF) to be submitted by SCK•CEN by mid 2014 to the FANC. Based on the analysis of the DOPF, FANC will issue an advice on the licensability of MYRRHA by end of 2014. During the period 2013-2015, safety studies will be conducted to support this pre-licensing process.

With regard to the MYRRHA consortium, several bilateral discussions with different countries within Europe and Asia have been carried out. First Letters Of Intent of participation have been obtained. The goal is to reach an overall consortium agreement by the end of 2014 based on a set of bilateral agreements reached with the different partners by mid 2014.

2.2.2. Budget for 2013-2015

The total capital expenditure to build MYRRHA amounts to 960 M€ over the period 2010-2023. MYRRHA development and R&D support programme is already part of the regular SCK•CEN work programme, with additional contributions from the Euratom FP7 and in-kind contributions of partners.

An additional endowment of M€ 60 has been received from the Belgian Federal Government for the period 2010-2014.

The budget for the period 2012-2014 is as follows:

Year	Belgium Federal government special endowment	supporting R&D budget (SCK•CEN & others)	Total required budget
2013	15,00	15,00	30,00
2014	18,00	22,00	40,00
2015	To be discussed	To be discussed	61,00
Total	>33,00	>37,00	131,00

2.2.3. EU added value

With MYRRHA, Europe will possess a flexible fast spectrum irradiation facility in support of technology development (in particular for material, components and fuel irradiation tests) for the three fast reactor systems (SFR, LFR and GFR). Furthemore, MYRRHA will offer a wide range of interesting irradiation conditions for fusion material research. Since MYRRHA is conceived as an Accelerator Driven System (ADS), it will be able to demonstrate the feasibility of ADS technology, thereby allowing the technical feasibility of one of the key components in the double strata strategy for high-level waste transmutation to be evaluated. Due to the fact that MYRRHA will be based on heavy liquid metal technology (namely lead-bismuth eutectic), it will fullfil the role of Lead Fast Reactor European Technology Pilot Plant (ETPP) as identified in the LFR roadmap. An associated R&D programme will accompany and support the development of MYRRHA.

In November 2010 MYRRHA was put onto the high-priority list of the European Strategy Forum for Research Infrastructures (ESFRI). MYRRHA is hence acknowledged as a key large research infrastructure for innovative research with societal relevance in and for Europe.

2.2.4. Risk

By the end of 2014, the following risks need to be minimized:

1) Technical risks at the level of the accelerator, spallation target and reactor system

2) Licensing risks by obtaining a positive advice from the regulatory on the licensability of MYRRHA

3) Financial risks by forming an international consortium

2.3. ESNII-3 (LFR) - ALFRED Project (Advanced Lead Fast Reactor European Demonstrator)

The ALFRED project deals with the LFR technology development through the design, construction and operation of an LFR demonstrator (ALFRED). ALFRED is an essential step to reach the technology maturity level for the industrial implementation of the European Lead cooled Fast Reactor (ELFR).

2.3.1. Priority actions for 2013-2015

The main goals of the next three years work is related to further developments foreseen for the LFR demonstrator ALFRED. Over the period 2013-2015 the activities will be mainly focused on the need to start the basic design of the Advanced LFR European Technology Demonstrator Reactor (ETDR, namely ALFRED) and support as well the site selection and the pre-licensing phase with the Safety Authority.

A continued exchange of information is expected to take place between ALFRED and MYRRHA projects, in order to exploit to the maximum possible extent the large synergies existing between the two projects.

Priority actions for the LFR Demonstrator (ALFRED)

ALFRED, in the role of LFR ETDR, has the aim to demonstrate the viability of the LFR technology for use in a future commercial power plant, in terms of economic, safe and reliable operation.

The near-term (2013-2015) activities for ALFRED will be focused on the following main objectives:

- Establishment of an International Consortium, aimed at defining priorities, promoting optimal cooperation and joint programming for the implementation of the initiative, through strategic management and governance, financial seeking and technical work.
- Completion of the Basic Design, by solving the open issues, identified during the conceptual design performed in the EU-FP7 LEADER project (Lead-cooled European Advanced Demonstration Reactor), through the support of National R&D programs on key topics.
- Identify the roadmap of the R&D experimental activities which are necessary to support the design, identify the materials, test and qualify the components and the main design choices
- Finalization of the Site selection process and related studies being the current reference location identified in the Romanian nuclear site of Mioveni.
- Support to the Pre-Licensing Phase through iteration with the Romanian Safety Authority, leading to a Preliminary Safety Assessment.

The main purpose of the near term phase is the reduction of uncertainties in construction and licensing. Within the LEADER project, the conceptual design of ALFRED has been focused on the identification of the main suitable characteristic and design guidelines for the facility leading to a scaled demonstrator fully representative of the industrial size reactor. The choice of components and technologies already available in the short term is of paramount importance, in order to proceed towards the basic design and pre-licensing phase in the near future.

Some R&D activities are already planned and prioritized in support of the next design and licensing steps, through the ongoing FPs funded by the EC, namely:

- Activities focused on the ALFRED design: assessment of the SGTR (LEADER), enhanced safety-by-design through a new concept of DHR preventing lead freezing (MAXSIMA), simulation of the critical core configuration (FREYA), cross-cutting aspects for enhanced safety through an improved core design, the reduction of uncertainties in fuel properties, protection measures from external events and the development of instrumentation and inspection tools;
- Activities in support of the LFR technology: identification of critical safety features, review of safety methodologies and related test application (SARGEN-IV), seismic studies and development of adequate protection measures (SILER), cross-cutting thermal-hydraulic issues (THINS), material selection for relevant reactor applications (MATTER, GETMAT), improved accuracy and validation of nuclear data and models (ANDES), studies on Fuel-Coolant interaction (SEARCH) and Innovative Fuel Development (SEARCH; MAXSIMA).

Moreover, the constitution of an International Consortium (planned for 2013 starting between Italian and Romanian organization and open to other interested European stakeholders) will reinforce the joint programming of the national research activities. In the frame of the more enlarged R&D roadmap, the short-term action plan will be focused on the following open issues:

- Scaled tests for the LFR Decay Heat Removal System (DHR) to demonstrate feasibility/reliability and validate the computational model;
- Qualification of the innovative design adopted for the Steam Generator;
- Assessment of the Steam Generator Tube Rupture (SGTR) behavior ;
- Conceptual design and related tests for Fuel Assembly (FA) spacer grids (prototype manufacturing, grid-to-rod fretting,…);
- Self-protecting structural materials through coolant chemistry control and corrosion inhibitors (controlled through purification systems for large pools) in thermal convective loops;
- Computational Fluid Dynamic analysis of FA flow blockage and lead freezing;
- Verification and validation of simulation and modeling tools suitable for LFR design;
- Safety cases and design issues in support of site selection and pre-licensing activities.
- Further investigations on core neutronics and fuel development

In order to meet the above listed R&D needs, the LFR demonstrator program will rely on the currently available European experimental facilities. In parallel, the International Consortium will evaluate alternative financial instruments (e.g. DG-REGIO Structural Funds) for the design, construction and operation of research facilities to support LFR technology studies (coolant physics-chemistry, corrosion/erosion phenomena, instrumentation/inspection and repair, thermal-hydraulic and heat transfer, structural material characterization in lead under irradiation at high dpa), as well as site selection and pre-licensing activities.

Finally it has to be pointed out the need to enhance education and training activities in the field of lead technologies in order to provide the future specialists needed to build and operate the installation. For this purpose the Institute for Nuclear Research (INR) is going to negotiate specific agreements with two universities in Romania on the educational programs for fast reactor lead technology. The activity includes cooperation with the advanced research centers (LFR community partners) and use of the EU ENEN framework for specific training activities.

2.3.2. Budget for 2013-2015

The total budget already allocated (close to 42 M€) dedicated in Europe to the development of the LFR technology in the 2013-2015 period is shown in the following table:

Projects	**EC**	**National Programs**	**Private Contribution**
LEADER	0.3		0.3
SILER	2.0		1.0
MAXSIMA	0.5		0.5
FREYA	0.4		0.3
MATTER	0.8		0.8
THINS	0.5		0.3
LFR - ITALY		18.0	
TRASCO - ITALY		3.0 *	1. *
ALFRED - ROMANIA		12.0	
ELECTRA - SWEDEN		1.0	
OTHERS		1.0 **	
41.9 M€	2.7 M€	35 M€	4.2 M€

* Expected approval 2013 ** Includes small contributions from EU countries

The above projected budget for the period 2013-2015 clearly indicates that the present investment level on the LFR technology are well below the threshold requested to obtain significant advances in the short term.

As an additional and essential source of funding, the accessibility to structural (cohesion) funds from DG-Regional is under consideration for the period 2014-2020. The amount to be requested is expected, if positively accepted, to raise substantially the available resources. Presently this is the only funding mechanism, so far identified, able to provide a substantial speed-up of the technology development.

As a consequence the main priority for the LFR development is the exploration of possible source for funding; in fact the first actions of the future consortium will be devoted to look for additional funding opportunities. The present limitation of available funding is considered to be the main cause of delay for the development of such technology in Europe, while outside Europe (e.g. Russia) the LFR technology is expected to reach a good level of maturity within 2020.

It is finally important to note that some activities for which funding is not yet available are considered critical for the timely evolution of the ALFRED project. The following table try to give a picture of the additional funding (in millions of euro) necessary for such activities in the period 2013-2015:

ACTIVITY	**2013**	**2014**	**2015**
ALFRED Basic Design	1	2	3
Exp. Investigation of critical Issues: Lead Chemistry	2	2	2
Lead Corrosion Inhibitors	2	2	2
Lead fuel interaction			5
Irradiation of selected materials		4	6
Scaled tests (passive systems)		2	1
Licensing : Pre-licensing	1	1	
PSAR			5
Site characterization		1	2
46 M€	6	14	26

2.3.3. EU added value

LFR systems, as a credible alternative fast reactor to SFR, are considered in the Gen-IV Technology Roadmap as a very promising technology, in particular for the mission of sustainability, actinide management and economics for electricity production. Although the main line of EU development is devoted to SFR, the LFR technology is considered the short term alternative to sodium coolant technology. As a consequence efforts should be dedicated to exploit as much as possible the advantage of this alternative technology and investigate the limits of possible industrial application.

Fostering the European efforts towards an LFR demonstrator and, in the long term, a prototype realization would be very beneficial. This will speed up the development of sustainable nuclear energy technologies and establish Europe as a leader in this field.

Within the European Framework Programs, a large number of research centers are supported by industrial partners interested in the LFR technology and its large-scale and near-term deployment. The collaboration on LFR technology is considered an essential part of Euratom contribution to GIF and may be part of a fruitful exchange of information with non-European organizations.

For instance, the partners involved in the LEADER project for the development of the ALFRED conceptual design include ANSALDO (Italy), AGH (Poland), CEA (France), CIRTEN (Italy), EA (Spain), ENEA (Italy), KIT (Germany), INR (Romania), JRC, KTH (Sweden), NRG (Netherland), PSI (Switzerland), SCK•CEN (Belgium), SRS (Italy), CV Rez(Czech Republic), UNIBO(Italy).

Additional support to LFR technology development is also provided by Italy, Sweden, Romania as well as by German organizations at their research centers of Dresden-Rossendorf, Jülich and Karlsruhe and at the corresponding universities. In February 2012 Ansaldo Nucleare, ENEA, and the Romanian Institute for Nuclear Research (INR) signed an MoU, aimed at defining the steps and rules to be followed to form the International Consortium for ALFRED design and construction. Presently the baseline of the International Consortium are being established with the aim to reach an agreement of its establishment within 2013.

2.3.4. Risk

The foreseen initiatives are devoted to strategic, management, governance, financial and technical work and does not entail the construction of large experimental nuclear facilities. Experimental tests within the project will be carried out mainly at existing facilities and carried out by experts at laboratories locations in European research centers following standardized procedures.

The risks potentially mining the initiative in the near and long term are related mainly to financial aspects related to some specific technical aspects of the technology:

- Major research infrastructures and development of prototypes for reactors or fuel cycle technologies can be funded at EU level through private/public partnerships (PPP), involving national governments, regions, research organizations, industry, and the European Institutions. Research can be accomplished through coordinated national programs, but it must also be supported at EU level, especially for the short term issues, to give confidence to future private partners and to stimulate participation of Member States. In particular the Euratom Framework Program can play an important role, provided the funding for nuclear fission is substantially increased in the follow-up of the 7th Framework Program. The road map implementation should also take advantage of EU loans. The European Investment Bank has declared itself ready to help the financing of nuclear energy infrastructures, and the potential loans from this financial institution must be explored.
- The conceptual design of ALFRED is based on assumptions only partially supported by the current knowledge on LFR technology. The R&D programs are aimed at solving the main open issues which might impair the current reference design. In order to avoid setback at a too advanced stage of development, the key technical aspects are constantly monitored and traced. Entering the site selection and the pre-licensing phases is of great importance to identify in advance potential issues which might drive the technical choices. Unfortunately, the prioritization of research activities is impacted by the availability of resources, in terms of workforce, experimental facilities and funding. In particular, the LFR roadmap is based on a very tight schedule for the progressive up-scaling of facilities which has to be supported and oriented by design studies.

The set-up of an International Consortium focused on the prioritization of objectives, joint programming of research activities, identification of alternative financial instruments is considered a keystone in the LFR technology deployment and will play a fundamental role in the mitigation of the above risks.

2.4. ESNII-4 (GFR) - ALLEGRO Project

The Gas cooled Fast Reactor (GFR) is proposed as a longer term alternative to sodium cooled fast reactors SFR. As well as offering the advantages of improved inspection, simplified coolant handling and low void reactivity, the GFR offers the unique advantage of fulfilling two missions:

- To be a sustainable nuclear energy source through efficient use of the natural uranium resource and through the reduction of the amount and radiotoxicity of wastes through the recycling of minor actinides.
- To be able to deliver high temperature heat for industrial processes such as hydrogen production. As such, the GFR can be viewed as being a sustainable high temperature fast reactor for process heat utilization. In this respect the goal is to reduce the industrial consumption of fossil fuels to produce high temperature process heat.

For GFR to become an industrial reality, an intermediate objective is the design and construction of a small demonstration reactor. This reactor has been named ALLEGRO and its role, apart from being the world's first gas cooled fast reactor, is to demonstrate the GFR specific safety systems and to irradiate and qualify the innovative high temperature fuel required for GFR.

The safety of the GFR demonstrator ALLEGRO has been recently re-evaluated taking into account the experiences of the Fukushima accident. Currently a modified design is considered which increases the inertia of the system against complex accident sequences and includes accident management capabilities.

To fulfil the above goals five participants (institutes and companies) are currently involved in the project on the basis of a Memorandum of Understanding:
MTAEK Budapest (HU), ÚJV Řež, a.s. (CZ), VUJE a.s. (SK) and associated members CEA (F) with NCBJ Swierk (PL). A vision was accepted concerning the governance of the project that includes in the short term the establishing of the GFR Centre of Excellence. This GFR Centre of Excellence will cover four areas governed by the particular participants:

-safety concept and ALLEGRO design – VUJE a.s.
-helium technology – ÚJV Řež, a.s.
-fuel laboratory – MTAEK
-and industrial use of high temperature gas – NCBJ.

The activities of the GFR Centre of Excellence, coordinated with the ALLIANCE FP7 project, are expected to lead multi-govermental decisions on the establishing and siting of the ALLEGRO reactor in the CZ-HU-SK region. For the licensing, construction, operation and decommissioning of ALLEGRO, an international consortium will be established with the strong involvement of the industry. Financing aspects are prepared in the framework of the consortium.

2.4.1. Priority actions for 2013-2015

ESNII - ALLEGRO Support R&D program

Helium technology and components development

Building ALLEGRO will need to get a sufficient knowledge on technology using helium under pressure. This includes:

- Experimental verification of the DHR system using a dedicated integral He-loop (to be commissioned in 2015/2016 in CZ in the frame of the EU-funded project SUSEN);
- Management of gas impurities;
- Development and qualification of heat shielding and insulation techniques;
- Construction and qualification of main specific components (helium blowers, fuel subassembly, leak tightness of circuits, fits and valves, control rod mechanism, fuel handling system, …);
- Development of advanced instrumentation techniques in hot gas (optical 3D temperature measurements, etc).

Fuel Development

For continuous high power density and high temperature operation, dense fuels with good thermal conductivity are required. The R&D activities for the development of innovative fuels and fuel elements are as follows:

- Fuel and fuel assemblies modelling and design
- Basic fuel material studies
- Basic core material studies
- Development of clad and fuel fabrication processes
- Fuel & fuel assembly development and irradiation testing
- Analysis of behaviour during fault conditions

In this framework it is foreseen the development of the SiC-SiC_f cladding and carbide pellets by CEA. ALLEGRO and the Fuel Research Laboratory are aimed at serving for the irradiation and qualification of this fuel with a feedback to the designers.

What concerns the ALLEGRO first core MOX fuel a careful qualification procedure shall be executed because of the difference and also because of the lack of fuel behavior in a Helium cooled fast spectrum reactor. A part of this qualification program will be performed in MTA-EK planned new Fuel Research Laboratory in Hungary.

Development & validation of analysis tools and qualification

Computational tools are needed to design the system and to analyze operational transients (normal and abnormal) fall into five main areas:

- Core thermal-hydraulics
- Core neutronics
- System operation
- Fuel performance
- Other (materials performance, structural assessment, codes & standards etc)

ESNII - ALLEGRO Design & Safety

ALLEGRO Pre-conceptual design studies

The main goal is to identify, analyse end study alternative design features of the whole ALLEGRO demonstrator based on the original CEA concept from 2009. This concerns especially the innovative option proposed by CEA in 2010 (expansion turbine used for safety purpose in secondary circuit). The core characteristics (power density, plutonium inventory, breeding gain, minor actinide multi-recycling etc.) are expected to remain as proposed in 2009.

The design study must deliver in due time data for:

- Requirements on test program for research and testing infrastructure
- Conceptual Safety Features Review File (CSFRF)
- Safety studies and siting documentation

ALLEGRO Safety studies

The safety analysis is needed for proving the viability of the ALLEGRO project from the safety point of view. This takes into account the post-Fukushima developments and the WENRA Safety Goals. It will be based upon the definition of a relevant safety approach for GFR. A combination of deterministic and probabilistic methods will be used to demonstrate that adequate provisions have been made and that the safety objectives have been met. Finally, severe accident studies will demonstrate that containment performance is satisfactory.

The safety studies must deliver in due time data for:

- Requirements on test program for research and testing infrastructure
- Conceptual Safety Features Review File (CSFRF)
- Pre-conceptual Design
- ALLEGRO feasibility study

ESNII – ALLEGRO Project governance, financing and siting & licensing issues

Creation of the Centrum of Excellence for the ALLEGRO project and signature of Consortium Agreement are assumed. A suitable legal structure of the ALLEGRO project is a condition for financing the project. A robust project framework will be established to ensure, under budget and on time, the schemes of work and funding the project:

- Establishment of a legal entity for the Centrum of Excellence of the ALLEGRO project
- Financial study
- Consortium Agreement
- Establishment of project framework and funding

Site selection & site permit, licensing issues

As to obtain the site permit is most risky (all three countries CZ, SK and H are prepared to do their best to get site permit) there should be parallel process for at least two sites. The parallel process will proceed in the following way:

- Selection of potential sites
- Environmental Impact Assessment Reports for each site
- GFR-related licensing requirements

EURATOM Project in support:

The GoFastR European Collaborative project gathers 22 partners from 10 member states on the priority activities in support to a European GFR.

Its total budget is 5.32 M€ on the period 2010-2013.

The ALLIANCE non-research activity "Preparation of ALLegro - Implementing Advanced Nuclear Fuel Cycle in Central Europe" gathers 9 partners from 6 member states.

Its total budget is 1.4 M€ (EC support is 0.85 M€) on the period 2013-2015.

2.4.2. Budget for 2013-2015

	Programme		2013	2014	2015
A.	ALLEGRO Support R&D program	EC+MS	2.0 M€	2.8 M€	4 M€
		Private	0.5 M€	0.7 M€	1 M€
		Total	2.5 M€	3.5 M€	5 M€
B.	ALLEGRO Design & Safety	EC+MS	1.5 M€	3 M€	3 M€
		Private	0.5 M€	1 M€	1 M€
		Total	2 M€	4 M€	4 M€
C.	ALLEGRO Project governance, financing and siting & licensing issues	EC+MS	0.4 M€	0.8 M€	1.6 M€
		Private	0.1 M€	0.2 M€	0.4 M€
		Total	0.5 M€	1 M€	2 M€
	Total	EC+MS	3.9 M€	6.6 M€	8.6 M€
		Private	1.1 M€	1.9 M€	2.4 M€
		Total	5 M€	8.5 M€	11 M€

EC = European Commission; MS = Member State

2.4.3. EU added value

Europe leads the world in gas reactor, high temperature reactor and fast reactor technologies. The GFR is an integration of all three of these technologies and presents an excellent opportunity for Europe to maintain its lead in these areas. The current international partners working on the GFR demonstrator are European (especially France, Czech Republic, Hungary, Slovakia and Poland). The GFR is technically very challenging, the benefits are great – GFR will be a reactor that can power the range of applications that, at the moment, are only in the domain of high temperature thermal reactors, in a future in which natural uranium is scarce. The GFR is an open-ended technology, the operating temperature is not limited by phase change or chemical decomposition of the coolant and the coolant is chemically inert. Irradiation channels and the Fuel Research laboratory ALLEGRO can be also used to test other Generation 4 fast reactor fuel types.

2.4.4. Risk

For final decision is absolutely necessary site permit. To comply with demonstration condition of GFR, the preliminary GFR basic design including safety concept must be available and to minimize the risk of unjustified design also preliminary assessment of fuel, design of key Helium technology and components and development of analysis tools and qualification.

3. Coherence with EERA

As recognized by the Strategic Research Agenda of the Sustainable Nuclear Energy Technology Platform, materials science and new materials development are key aspects for a further optimization of GenII and GenIII LWRs (e.g. with respect to plant lifetime extension) as well as for meeting GenIV nuclear systems objectives. In particular, the operating conditions envisaged for the innovative GENIV systems are rather demanding and will impact on the performance of the structural materials. Well targeted research activities are required to first develop adequate testing procedures and, subsequently, qualify accordingly the commercially available materials under the extreme conditions that can be encountered in the innovative concepts, as well as to develop and qualify new materials and coatings for longer term perspectives.

Taking into account that timely availability of such materials is a major challenge for the development of any GENIV systems, as far as nuclear fission is concerned the European Energy Research Alliance has decided to concentrate the effort on a Joint Programme devoted to R&D on structural nuclear materials. The Joint Programme is intended to address several classes of materials: ferritic-martensitic steels, austenitic steels, Nickel-based alloys, oxide dispersion strengthened alloys, non-ferrous high temperature materials (ceramics, composites, refractory alloys, etc.). For each of these classes, a number of transversal activities will be addressed: Screening, characterization, pre-normative R&D, development of models and relevant validation. For some classes (ODS steels and non-ferrous high temperature materials), also the development of new materials and of new fabrication routes will have to be considered.

As well known from past experience on GENII and GENIII reactors, full development and qualification of new nuclear materials to be deployed in commercial nuclear power plants is a long lasting activity which implies very demanding theoretical studies, experimental validation and industrial technologies. However, ESNII foresees the design and realization of demonstration plants and prototypes at the horizon of 2020.

- In order to be consistent with the ESNII and the overall Set Plan strategy, within EERA it has been decided to work out a short-to-medium term design-driven R&Dsub-programme aimed at supporting the design and construction of the ESNII prototypes and demonstrators. This sub-programme will mainly concern readily deployable materials, i.e. austenitic steels (extension to 60 years, swelling issues, coolant effect), ferritic-martensitic steels, Ni-based alloys, coatings and, last but not least, pre-normative research (i.e. mechanical tests procedures, procedures to assess liquid metal embrittlement, procedure for data quality validation, data handbook and data management platform).

- The other sub-programmes of the EERA JP are intended to address medium-to long term needs and are expected to achieve real breakthroughs also concerning the development of new materials (e.g. ODS steels, ceramics and composites and refractory materials) and of physics-based models describing the behavior of both new and conventional materials when subjected to reactor operation conditions.

The EERA Nuclear Materials community has also evaluated the overall effort which could be mobilized in Europe on this Joint Programme with a suitable and synergic coordination between the materials-oriented projects funded by the European Framework Programmes and the programmes domestically supported by the Member States. A first estimate indicates that about 200 person.year / year are already involved in R&D on innovative nuclear materials in Europe. This effort, together with the EERA instrument of the SET-plan, can put Europe at the forefront of this challenging topic worldwide. The R&D programme on materials for innovative nuclear systems established under the EERA will be shortly presented for formal approbation by the EERA Board.

APPENDIX 1

Overview of main Euratom FP6 & FP7 projects supporting Generation-IV Fast Reactors systems and/or ESNII

Euratom FP6 (2003-2006)				
Project acronym and title	**Key areas of R&D**	**Coordinating organisation & no of partners***	**Start date & duration**	**Total budget / EU contribution**
GCFR – Gas-Cooled Fast Reactor www.gcfr.org	Conceptual design, direct coolant cycles, transmutation, safety, …	NNC Ltd. (UK) 9 partners (from 7 countries)	01/03/05 48 months	€3.6M / €2.0M
ELSY – European Lead-Cooled System http://88.149.184.27/elsywww/	Core design, PA, main components & systems, system integration, safety, etc.	ANSALDO ENERGIA S.p.A. Nuclear (IT) 20 partners (from 12 countries)	01/09/06 36 months	€6.5M / €2.95M
EISOFAR – Roadmap for a European Innovative SFR	Support action – preparation of future activities/proposals	CEA (FR) 14 partners (from 9 countries)	Jan. 07 1 year	€500k / €250k
Euratom FP7 (2007-2012) – calls 2007, 2008, 2009, 2010, 2011 & 2012				
Project acronym and title	**Key areas of R&D**	**Coordinating organisation & no of partners***	**Start date & duration**	**Total budget / EU contribution**
GETMAT – Gen-IV and Transmutation Materials	Structural materials for core and primary components of Gen-IV and ADS	FZK (DE) 24 partners (from 11 countries)	1/2/08 60 months	€13.96M / €7.5M
ACSEPT – Actinide Recycling by Separation and Transmutation www.acsept.org	Advanced partitioning – chemical processes; aqueous & pyro	CEA (FR) 34 partners (from 14 countries)	1/3/08 48 months	€23.79M / €9.0M
F-BRIDGE – Basic Research for Innovative Fuel Design for GEN-IV systems www.f-bridge.eu	Basic research on Gen-IV fuel-cladding systems	CEA (FR) 20 partners (from 8 countries)	1/3/08 48 months	€10.2M / €5.5M
FAIRFUELS – Fabrication, Irradiation and Reprocessing of Fuels and targets for transmutation	Fuels an targets for partitioning, with close links to Gen-IV	NRG (NL) 11 partners (from 6 countries)	1/2/09 48 months	€7.7M / €3.0M

CP-ESFR – Collaborative Project on European Sodium Fast Reactor	Key viability & performance issues supporting development of a Gen-IV European SFR	CEA (FR) 26 partners (from 9 countries)	1/1/09 48 months	€11.5M / €5.8M
LEADER – Lead-cooled European Advanced Demonstration Reactor	Conceptual level of Lead Fast Reactor Industrial size plant and of a scaled demonstrator of the LFR technology.	ANSALDO (IT) 17 partners (from 11 countries)	early 2010 36 months	€5.7M / €3M
GoFastR – European Gas Cooled Fast Reactor	Demonstration of the viability of the GFR system & contributing to Generation-IV GFR research	AMEC (UK) 21 partners (from 10 countries)	early 2010 36 months	€5.32M / €3M
CDT – Central Design Team for a Fast-spectrum Transmutation Experimental Facility	Irradiation Facilities, Material Test Reactors, Partitioning & Transmutation	SCK.CEN (B) 20 partners (from 8 countries)	1/4/09 36 months	€4.0/€2.0
ADRIANA – Advanced Reactor Initiative And Network Arrangement	network facilitating construction and operation of research infrastructures in support of ESNII (coordination action)	UJV Rez (CZ) 15 partners (from 10 countries)	early 2010 18 months	€1.35M / €1M
ALLIANCE - Preparation of ALLegro - Implementing Advanced Nuclear Fuel Cycle in Central Europe	Preparatory phase of the ALLEGRO Project	MTAEK (HU) 9 partners (from 6 countries)	1/10/2012 36 months	€1.4 / €0.85
ASGAR – Advanced fuelS for Generation IV reActors ,Reprocessing and Dissolution	Cross-cutting studies innovative fuels to develop compatible techniques for dissolution, reprocessing and manufacturing of new nuclear fuels	CHALMERS (SE) 17 partners (from 10 countries)	01/01/2012 48 months	€9.6M / €5.8M CP-IP
MAX – MYRRHA Accelerator eXperiment, research and development programme	R&D activities in support of the implementation of the Strategic Research Agenda of SNETP - MYRRHA	CNRS (FR) 11 partners (from 6 countries)	36 months	€4.9M / €3M
FREYA – Fast Reactor Experiments for hYbrid Applications	R&D activities in support of the implementation of the Strategic Research Agenda of SNETP - MYRRHA	SCK-CEN (BE) 15 partners (from 10 countries)	48 months	€5.1M / €2.8M

JASMIN – Joint Advanced Severe Accidents Modelling and Integration for Na-cooled fast neutron reactors	To develop a new European code ASTEC-Na to capitalise SFR severe accident knowledge, with improved physical models to support the development of a Gen-IV European SFR	IRSN (FR) 9 partners (from 5 countries)	01/12/2011 - 48 months	€5.6M / €3.0M CP-FP
SEARCH – Safe Exploitation Related Chemistry for HLM reactors and Lead-cooled Advanced Fast Reactor	Investigating safe chemical behaviour of fuel and coolant in lead-cooled reactor and support of Myrrha LFR technology	SCK-CEN (BE) 12 partners (from 8 countries)	01/11/2011 - 36 months	€5.4M / 3.0M CP-FP
SARGEN-IV – Harmonized European methodology for the Safety Assessment of innovative GEN-IV reactors	Safety R&D assessment and methodologies in support to ESNII gathering European TSOs, designers, vendors and Research organisations	IRSN (FR) 22 partners (from 12 countries)	01/01/2012 - 24 months	€1.0M / 1.0M CSA-CA
MAXSIMA – Methodology, Analysis and eXperiments for the "Safety In MYRRHA Assessment"	To contribute to the "safety in MYRRHA" assessment to support the licensing of MYRRHA.	SCK-CEN (BE) 12 partners (from 8 countries)	01/11/2012 72 months	€10.9M / €5.5M CP

*only partners from EU MS and Euratom Associated Countries can normally receive EU funding

APPENDIX 2

Acronyms

ADS:	Accelerator Driven Systems
ALFRED:	Advanced Lead Fast Reactor European Demonstrator
AFC:	Atelier de Fabrication du Combustible (Fuel Fabrication Facility)
ASTRID:	Advance Sodium Technological Reactor for Industrial Demonstration
EERA:	European Energy Research Alliance
ETPP:	European Test Pilot Plant
GFR:	Gas cooled Fast neutron Reactor
GIF:	Generation IV International Forum
LFR:	Lead cooled Fast neutron Reactor
M€:	Million Euro
MWe:	Megawatt electrical power
MWth:	Megawatt thermal power
SFR:	Sodium cooled Fast neutron Reactor
SNETP:	Sustainable Nuclear Energy Technology Platform