ESNII

European Sustainable Nuclear Industrial Initiative

Implementation Plan 2010-12

A contribution to the EU Low Carbon Energy Policy:

Demonstration Programme for Fast Neutron Reactors

This document has been prepared by the ESNII Task Force
established within the Sustainable Nuclear Energy Technology Platform.

Contact: secretariat@snetp.eu

Table of contents

1. Objectives of this plan

The threats to the Earth's climate have never been so strong, while worldwide energy needs are still expected to increase significantly. In order to address these future needs, the development of non-CO2 emitting sources of energy, in a sustainable way, is required.

Nuclear energy is clean and competitive and is thus part of the solution for the coming years and decades. Cross-cutting R&D should address the short and long term challenges of nuclear energy technologies.

The short term issue is to maintain the competitiveness in fission technology and to provide long term solutions for high level waste management

In the long term, in view of the rising demand for electricity, the question of uranium resources will be raised. The deployment of fast neutron reactors (FNR), with closed fuel cycles, has the potential of multiplying, by a factor of 50 to 100, the energy output from a given amount of uranium, while improving the management of high level radioactive waste through the transmutation of minor actinides

The European Sustainable Nuclear Industrial Initiative has the prime objective to develop a nuclear technology which will make the use of nuclear energy more sustainable through more efficient use of uranium resources through recycling of Plutonium and by the reduction of the radio toxicity and of the potential impact of the ultimate radioactive wastes. The development of these technologies will achieve the SET Plan objectives for nuclear energy and also will give to the European Industry a leading role.

As described in the ESNII Concept Paper, three Generation IV reactor concepts, namely, the Sodium Fast Reactor (SFR), the Lead cooled Fast Reactor (LFR) and the Gas cooled Fast Reactor (GFR) are being considered in Europe. Of these three, SFR is considered to be the reference technology with both LFR and GFR being considered as longer-term alternative technologies. The Concept Paper includes the identification of supporting R&D and testing facilities for which the specifications shall be defined during this time period.

The initiative will gather most of the European R&D capabilities in fast breeder reactors and the industrial capability which are committed to succeed. The Concept Paper has presented the broad picture with the identification of key milestones at which decisions will be taken for the next phase of the design and of the construction of the SFR demonstrator and the assessment on the alternative technology – GFR or LFR – before launching the next development, design and construction phases.

This Implementation Plan is focussed on the period 2010-2012, 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

Technology breakthroughs and innovations are still needed for all Generation IV 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 Generation IV.

The required R&D activities for all three fast neutron reactor concepts (Sodium, Lead and Gas fast reactors) 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)

The objectives of the ESNII-1 Task are to promote, develop and construct a prototype sodium cooled fast reactor 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 2010-2012:

ESNII 1.1 Innovation

In order to attain GENIV criteria which are necessary for the acceptance of a new sodium cooled fast reactor, significant progress needs to be made in the following areas, leading to key R&D programs:

- Robustness of the safety demonstration, in particular by prevention and mitigation of severe accidents, including those linked to sodium;
- Economic competitiveness, covering investment and operational costs, reliability and availability;
- Meeting operator's needs: Ease of maintenance, in-service inspection, occupational safety, limited sensitivity to human factors;
- Capability to reduce the long-term burden of ultimate radioactive waste for geological disposal by recycling and transmutation of actinides extracted from spent nuclear fuel.

Investigating innovative paths allowing significant progress in domains such as safety, economy, in-service inspection and actinides incineration calls for a close collaboration between R&D organisations, industry, utilities and safety experts.

Past R&D, engineering and construction experience, together with operating and licensing experience of past European SFR (DFR, KNKII, Rapsodie, PEC, PFR, Phenix, SNR300, Superphenix), represents a huge asset for Europe, which was 10 years ago the undisputed leader in this domain, with the European Fast Reactor (EFR) project.

On the basis of this asset, the priority work programme 2010-2012 includes investigations and developments on following main technical tracks:

<u>Core and fuel:</u>

- Develop an innovating core design allowing to reduce drastically or to exclude the risks of energetic accidents. Examples are low over-reactivity core concepts, or carbide cores (for the long term);
- Develop and irradiate innovative non-swelling cladding (manufactured with Oxyde Dispersion Strengthened steels), allowing to decrease the sodium content in the core, and to increase the fuel Burn-Up potential;
- Develop and validate innovative safety features, aiming to strengthen the lines of defence (objective: three, diversified) against core fusion risks, such as passive anti-reactivity insertion devices or advanced core controls systems;

- Develop 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:

- Define and validate advanced methods for minimising sodium leaks, detecting them in a totally reliable way, and mitigating the consequences of sodium fires so as to avoid any chemical consequences at the site boundary;
- Develop 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;
- Develop and validate mitigation provisions and simulation methods concerning defence-in-depth situations, such as core fusion (core catcher design), aircraft crash, very large earthquakes.

Reactor and systems design:

- Conceive an adapted reactor design and in-sodium telemetry or non-destructive examination techniques enabling efficient and practicable in-service inspection campaigns;
- Develop and test advanced cost-efficient steam generators concepts in order to improve the global thermal efficiency of the plant. This may involve developing 9Cr ferritic steels for nuclear use;
- Develop efficient fuel and components handling systems that allow availability objectives to be reached by reducing fuel and components replacement durations.
- Develop an advanced instrumentation and control system, adapted to sodium fast reactors challenges (sodium leak detection, individual subassembly temperature and leak control…).

ESNII 1.2 Prototype conception, licensing and construction

Based on the R&D as defined above, and in order to confirm the improvements obtained, it is necessary to design and construct a prototype. The ASTRID prototype (as for Advanced Sodium Technological Reactor for Industrial Demonstration) is seen as an industrial prototype prior to the first-of-a-kind, meaning that extrapolability of the technical options and of the safety demonstration is of outmost importance. The reactor will also provide irradiation capacities in very representative conditions (for example minor actinides bearing fuels). 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. The refurbishment of existing testing facilities and the construction of new tools for components testing is a part of the program as well.

ASTRID shall be coupled to the grid with an electrical power of about 600 MW. It shall integrate operational feedback of past and current reactors. It is seen as a full Generation IV prototype reactor. 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.

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 policy decisions.

- First design choices need to be made in 2010 in order to launch the pre-conceptual design phase, and start first discussions on orientation for the safety with the safety authority.
- The pre-conceptual design will developed until end of 2012 in order to get a sounder cost estimation for ASTRID and select among the open options the more serious ones for the following conceptual design phase.
- In parallel, an important R&D effort will have to focus on priority topics for the pre-conceptual design. This R&D will need to develop and operate a lot of small facilities. Important topics are the validation of innovative primary circuits internals favouring both the safety and in service inspection and repair, improving the instrumentation (safety and operability), and validating features of improved conversion energy systems minimizing the sodium risks, …
- The development plan for the large technological facilities needed for ASTRID components qualification will be issued in 2010 and the refurbishing or the renewal of the facilities will have to start as soon as possible (facilities for scale 1 qualification for systems such as handling machines, control rod mechanisms, heat exchangers, subassemblies dynamic behaviour, …)
- Launch in 2011 of a severe accident program in support of the safety dermonstration. This program could involved the use of international large facilities
- Pre-conceptual design of the fuel facility will have also to be done in parallel.
- Innovations proposed and assessed by 2012 through the pre-conceptual design will be the basis for a decision to enter the next phase of the project or to postpone it of some years to wait for additional results or confirmations.

Contribution of the ESFR Euratom collaborative project:

Coherently with the SNETP Vision report, the schedule for this project fits with an industrial deployment of the SFR technology around 2040, with the preliminary deployment of a demonstrator by the 2020 years. The two mains steps which are identified are fully coherent with the above milestones : a first period of 2 years (2009 – 2010) the objective of which will be to assess and down select innovative options which will end selecting a consistent set of ESFR pre-conceptual designs; The following period (2011– 2012), will result in the endorsement of a set of consistent optimized options which could be implemented on a future SFR and contribute to the ASTRID pre-conceptual design. Work is organized in work-packages which address directly the priority R&D needs on topics relevant for the ASTRID development. In particular :

- WP 2 (core with an optimized designs) : improvement of core safety parameters, evaluation of minor actinide transmutation in the homogeneous and heterogeneous modes, advanced fuel options, …
- WP 3 (safety concept options and PR&PP) : safety options and principles, representative transient and accident scenarios studies, containment measures and core catcher design, modelling capabilities of accident scenarios

- WP 4 (innovative reactor architecture, components and Balance of Plant) : re-examination of primary circuit, innovative energy conversion systems, update of codes and standards.

This EU project involves about 25 participants among which a strong contribution of French organizations (CEA, AREVA, EDF and IRSN). Other important contributors are : the JRC, FZK, AMEC, ANSALDO, CESI, ENEA, NRG, PSI, Uni-K. The total budget is 11.5 M€ (EU contribution of about 5.8M€) for the four year duration of the project (2009-2013)

2.1.2. Budget for 2010-2012:

Provisional figures for the 2010-2012 period budgets are given below. These figures do not consider potential additional funding from future partners of the ASTRID program and suppose confirmation of other budgets sources. The two first lines are French contributions (including from industrial partners). The ASTRID design line includes the design studies for the fuel manufacturing facility and the development of facilities for scale-1 large components testing.

	2010	2011	2012
R&D	52 M€	54 M€	61 M€
ASTRID design	27 M€ (incl. 0.5 M€ for AFC 8 M€ for large loops)	57 M€ (incl. 5.5 M€ for AFC and 17 M€ for large loops)	79 M€ (incl. 34 M€ for large loops)
ESFR EURATOM	3 M€	3 M€	3 M€
Total	**82 M€**	**114 M€**	**143 M€**

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 demonstrator ASTRID, integration of European R&D which can be initiated with the 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. Risks

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 endeavour 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 necessary improvements will be achieved.

The 2010-2012 period is a critical one to put on right tracks the project with the necessary available innovations. The main risk during this period is to postpone the decision for the ASTRID prototype construction and so to delay the availability of the SFR system.

2.2. ESNII-2 (LFR)

The final objective of the LFR technology development initiative is the design, construction and operation of an innovative lead cooled fast reactor.

2.2.1. Priority actions for 2010-2012

The main goals of LFR technology development over the period 2010-2012 are:

- to finalise the design and obtain a license for the construction of the LFR European Technology Pilot Plan (ETTP, namely MYRRHA) with full operation by 2023;
- to finalise the conceptual design of the LFR Demonstrator (named ALFRED) taking advantage of the EU –FP7 LEADER project.

ESNII-2.1 LFR ETPP (MYRRHA)

MYRRHA (SCK•CEN, Mol, Belgium), a flexible fast neutron irradiation facility, conceived as an accelerator driven sub-critical system (ADS) able to work also in critical mode, will fulfil the roles of:

- LFR European Technology Pilot Plan (ETPP) for the LFR;
- Research and testing facility to support fast neutron reactor (FNR) development.

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).

The objectives for the LFR ETPP (MYRRHA) during the Front-End Engineering Design (FEED) phase are:
- to complete the FEED and the necessary support R&D-programme to respond to the remaining technical challenges;
- to obtain the construction permit and licenses from the Belgian authorities;
- to establish a solid basis for the project execution by setting up an international members consortium.

Part of the design work will be performed in the FP7 project "Central Design Team" from April 2009 till March 2012 and is based on the design and R&D work performed in FP6 EUROTRANS. By the end of 2010 all technological choices will be frozen. The R&D support programme will be based on internal SCK•CEN efforts complemented by European and international R&D programmes.

By the end of 2012, a preliminary safety assessment report will be submitted to the Belgian Safety Authorities to obtain a first preliminary advice as foreseen in the licensing procedure.

ESNII-2.2 LFR Demonstrator (ALFRED)

The conceptual design of the LFR demonstrator will be performed in the EU-FP7 LEADER project (Lead-cooled European Advanced DEmonstration Reactor). Starting from the results achieved in the ELSY (European Lead-cooled System) project, the focus of the first part of the activities will be on the resolutions of the remaining issues to reach a new reactor configuration. With reference to this new reactor configuration of an industrial size LFR, the design of a low cost and fully representative scaled down LFR demonstrator of a suitable size – ALFRED - will be performed.

At the end of 2012, a conceptual design of the LFR Demonstrator will be available. The LEADER activities will respond to the following objectives:

- Define the main suitable characteristic and design guidelines;
- Identify components/technologies/materials already available in the short term to proceed in the near future to a detailed design followed by the construction phase;
- Evaluate safety aspects and perform a preliminary safety analysis;
- Minimise the cost of the demonstrator;
- Confirm that the newly developed and adopted materials, both structural materials and innovative fuel, are able to sustain high fast neutron fluxes and high temperatures.

In order to achieve these goals, following are the priority actions planned in Italy and Sweden with parallel support by German organizations:

- perform the conceptual design activities of a Demonstrator Reactor;
- to conduct the supporting R&D programme on:
  - LFR Decay Heat Removal System (DHR) in order to improve the LFR DHRs and develop solutions for the Demonstrator;
  - Qualification of the innovative design adopted for the Steam Generator;
  - Specific tests representative of Steam Generator Tube Rupture (SGTR) to investigate Pb-water interaction;
  - Test of the innovative materials for the LFR primary pump;
  - Development of oxygen and purification systems for large pools;
  - Qualification of cladding and coating materials for LFR fuel pin and subassembly thru material and processes development;
  - Qualification of simulation and modelling tools suitable for LFR design;
  - Design of a European Lead Cooled Training Reactor (ELECTRA) to address the education and training program through the development of a dedicated experimental facility;
  - Experiments/modelling of heavy liquid metal thermal hydraulics in the TALL loop to validate numerical modelling of HLM using dedicated experiments.
  - HLM technologies and cross cutting topics as materials and thermalhydraulics
  - Safety cases and design issues
  - Neutronics and fuel

2.2.2. Budget for 2010-2012:

LFR ETPP (MYRRHA)

The total capital expenditure to build MYRRHA amounts to 960 M€ (2009 value) over the period 2010-2023. MYRRHA development and R&D support programme is already part of the regular SCK•CEN work programme, with contributions from the Euratom framework programme, and in-kind contributions of partners.

The supplementary budget from the Belgian Federal government for the period 2010-2014 is 60 M€.

The required and allocated budget for the period 2010-2012 is presented below:

	2010	2011	2012
Required budget	11 M€	20 M€	23 M€

LFR Demonstrator (ALFRED)

The total budget (25.7 M€) dedicated in Europe to the development of the LFR technology in the 2010-2012 period can be divided between EU funded projects and national programmes as follows:

Projects	EC	National programs	Private programs
LEADER specific	3 M€	3 M€ (Member States)	
Italian R&D on LFR		6 M€ (IT)	
TRAsmutazione SCOrie (IT)		3 M€ (IT)	3 M€ Ansaldo, ENEA, Others (IT)
GENIUS (SE)		3.4 M€ (SE)	
P&T			0.6 SKB (SE) 0.1 KTH (SE)
German R&D on LFR		3.6 M€ (D)	

2.2.3. EU added value

LFR systems, as an 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.

LFR ETPP (MYRRHA)

For the development of the LFR technology, the LFR roadmap identifies the need for a European Technology Pilot Plant (ETPP). MYRRHA will fulfil this role.

In the 2008 roadmap of the European Strategy Forum for Research Infrastructures (ESFRI), MYRRHA is listed as an emerging project and expected to become a confirmed project on the ESFRI list by the end of 2010. The MYRRHA facility is a research facility and a flexible irradiation tool with a fast spectrum in support of GEN IV reactors development; therefore MYRRHA will also complete the renewal of the European Research Area of Experimental reactors.

LFR Demonstrator (ALFRED)

Fostering the European efforts towards an LFR demonstrator and 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 LEADER Project 16 European industries and R&D organizations are grouped for the development of the LFR technology which can be considered as an essential part of EURATOM contribution to GIF and may be part of a fruitful exchange of information with non-European organizations.

The partners of the LEADER project are:
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), UJV (Czech Republic), UNIBO(Italy).

Additional support to LFR technology development is also provided by Italy, Sweden, Romania as well as by German organizations at the research centres of Dresden-Rossendorf, Jülich and Karlsruhe and at the corresponding universities.

2.2.4. Risks

The initiative is devoted to design activities 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 research centres following standardised procedures.

As a research facility, MYRRHA will interest primarily public research institutions working in the field of development of fast reactors, fusion material research and advanced fuel cycles.

2.3. ESNII-3 (GFR)

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 recyclying 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.

2.3.1. Priority actions for 2010-2012

ESNII-3.1 Support R&D program

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 cladding and fuel material studies
- Basic core material studies
- Development of cladding and fuel fabrication processes
- Fuel and fuel assembly development and irradiation testing
- Analysis of behaviour during fault conditions

Development 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)

Helium technology and components development

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

- Management of gas impurities;
- Development and qualification of heat insulation techniques;
- Construction and qualification of main specific components (helium bowers, 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).

ESNII-3.2 ALLEGRO: A GFR demonstrator

- Central European ALLEGRO Consortium (CZ, SK, H) 2010
- Enlarged European ALLEGRO Consortium 2012
- Feasibility studies 2010-12

Site selection and site permit

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 in two different countries. The parallel process will proceed according this time schedule:

- Selection of potential sites 2010
- Environmental Impact Assessment Reports for each site 2011
- Documentation for site permits 2012
- Closure of Environmental Impact Assessment process 2012

Conceptual and preliminary basic design and viability report (2010-2012)

The safety study must deliver in due time data for:

- ALLEGRO preparation and siting documentation (to demonstrate the GFR design feature),
- Requirements on test program for research and testing infrastructure
- Data required for global GFR feasibility study

ALLEGRO Safety studies are essentially the same as for GFR, but is dedicated to the ALLEGRO specific case and has thus a tighter schedule. This work will use the ALLEGRO Safety Options Report as input which is due at the end of the ALLEGRO conceptual phase. This work will consist of:

- Review of the exploratory and pre-conceptual studies
- Core studies.
- Mission & design consistency
- Safety analyses

The design activities and safety analyses must deliver in due time data for:

- ALLEGRO Environmental Impact Assessment Report 2010,
- Siting documentation 2011
- Preliminary Basic Design 2012
- Requirements on test program for research and testing infrastructure for ALLEGRO detailed design and safety report 2012

- Data required for ALLEGRO feasibility study 2012

ESNII 3.3 Future GFR plant prospects

Preparation and signature of Consortium Agreement on GFR + ALLEGRO development:

- Feasibility study 2011
- Financial study 2011
- Consortium Agreement 2012

GFR Design studies (Define a consistent, high-performance GFR Design)

The main goal is to define a consistent, high-performance GFR design. The GFR core should be at least self-sustaining in terms of the consumption and production of plutonium and should be capable of plutonium and minor actinide multi-recycling. The GFR system should have an adequate power density to meet requirements in term of plutonium inventory and breeding gain, economics and safety.

Alternative design features should also be identified and studied.

The design study must deliver in due time data for:

- ALLEGRO preparation and siting documentation, to demonstrate the GFR design features,
- Requirements on test program for research and testing infrastructure
- Data required for global GFR feasibility study

GFR Safety studies (Definition of a relevant safety approach for GFR)

The safety analysis for the GFR system is needed to establish a safety case for GFR and 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:

- ALLEGRO preparation and siting documentation, to demonstrate the GFR specific safety features,
- Requirements on test program for research and testing infrastructure
- Data required for global GFR feasibility study

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: AMEC Nuclear UK Ltd, Imperial College of London, Rolls-Royce Power Engineering and Nuclear National Laboratory Ltd in the UK, AREVA, Commissariat à l'énergie atomique and Institute de Radioprotection et de Sûreté Nucléaire in France, Inter universities consortium of Pisa, S.R.S. Servizi di Ricerche e Sviluppo, Ente per la Nuove Tecnologie, l'Energia e l'Ambiante and Ansaldo Nucleare in Italy, Empresarios Agrupados in Spain, Karlshrue Institute of Technology, Forschungszentrum Jülich and TUV Rheinland Industrie Service Gmbh in Germany, Institute of Transuranic Elements from Joint Research Centre in Belgium, Nuclear Research and Consultancy Group and Technical University of Delft in The Netherlands, Nuclear Research Institue in Chek Republic, Paul Scherrer Institute in Switzerland, Budapest Technical University BME and Atomic Energy Research Institute AEKI in Hungry.

Its total budget is 5.32 M€ on the period 2010-2012.

2.3.2. Budget for 2010-2012:

	Programme		2010	2011	2012
A.	The GFR system (Conceptual design and viability report for GFR system)	EC+MS	1.0 M€	1.0 M€	2 M€
		Private	0.3 M€	0,5 M€	1 M€
		Total	1.3 M€	1.3 M€	3 M€
B.	ALLEGRO: A GFR demonstrator	EC+MS	3.0 M€	6.0 M€	10 M€
		Private	0.2 M€	1.5 M€	4 M€
		Total	3.2 M€	7 M€	14 M€
C.	Support R&D programme	EC+MS	13 M€	15 M€	21 M€
		Private	0,1 M€	1 M€	2 M€
		Total	9.5 M€	16 M€	23 M€
	Total	EC+MS	13,4 M€	22 M€	33 M€
		Private	0,6 M€	3 M€	7 M€
		Total	17.6 M€	25 M€	40 M€

EC = European Commission; MS = Member State

2.3.3. 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. Of the four international partners working on GFR within Generation IV, three of these are European (France, Switzerland and Euratom). 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.

2.3.4. Risks

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.

2.4. ESNII-4 (Infrastructures)

Objectives of the Support Infrastructures:

- Design and construct the necessary irradiation tools and devices to test materials and fuels;
- Design and construct the necessary fuel fabrication workshops, dedicated to uranium-plutonium driver fuels, and to minor actinide bearing fuels;
- Design, construct or upgrade a consistent set of experimental facilities for component design, system development, code qualification and validation, that are essential to perform design and safety analyses of the demonstration programme of ESNII (see ESNII-1, ESNII-2 and ESNII-3), including zero-power reactors, hot cells, gas loops, liquid metal loops; MYRRHA is described separately.

2.4.1. Priority actions for 2010-2012

A first phase will consist in the definition of

- the existing facilities
- the requirements for their modification or upgrades
- the necessary additional new facilities

This phase is essentially implemented through the FP7 ADRIANA project (2010-11).

On this basis, a more precise financial estimate of the extra resources needed for new investments and to cover operation costs, will be possible, and specific projects will be launched in some of the member states.

2.4.2. Budget for 2010-2012

	2010	2011	2012
Assessment of existing and needed	1.4 M€		
Upgrades and new facilities (*)		10 M€	14 M€

(*) the AFC and large sodium loops are already included in section 2.1.2.

2.4.3. EU added value

Successful deployment of a demonstration FNR system whether it is SFR, LFR or GFR requires a comprehensive set of large and medium-sized research infrastructures including irradiation facilities, fuel cycle facilities and experimental facilities for reactor physics.

2.4.4. Risks

Infrastructure unavailability will limit the verification and validation of the new design, operation reliability and safety. These support infrastructures are on the critical path for the whole demonstration programme.

3. Resources and financing instruments

ESNII Components	Resources and financing instruments (2010 – 12)
ESNII-1 Prototype SFR	The main resources are coming from French contributors: CEA, EDF, and AREVA. A small complement comes from the EU and European partners through participation to the Euratom FP7 project ESFR. Integration of European R&D will allow focusing supplementary resources, and partnerships will be developed with European and international stakeholders.
ESNII-2 Alternative technology LFR	The "FEED" phase of MYRRHA will be exclusively financed with public money. This period will be used to attract qualified partners, either public or private, as to join the International Members Consortium, before starting the construction phase (around 2016). The activity on the LFR Demonstrator is covered by EU funding to the LEADER project (50%) plus partners contribution (50%) and additional funding provided by Italy, Germany and Sweden as part of their national programmes as described in sub-section 2.2.2.
ESNII-3 Alternative technology GFR	Significant resources are coming from the French public funding. These are complemented by European R&D and Industrial partners through participation to the EU project GoFastR. In the longer term (post 2012), a major contribution will come from the host member states of the ALLEGRO reactor and associated support facilities. This may come from national funds and EU structural funds.
ESNII-4 Supporting infrastructures	The resources essentially come from the Member States where the facilities are established. In the longer term (post 2012), a major contribution may come from EU structural funds.

4. Monitoring

The Key Performance Indicators which are necessary to monitor the progress of ESNII are defined for each demonstration or prototype reactor in the ESNII Concept Paper.

Overarching Key Performance Indicators can be used to assess and monitor the ESNII:

- Levelized cost of electricity production by each of the considered systems,
- Capacity and availability offered by these systems.

Besides these generic indicators, specific Key Performance Indicators for ESNII can be grouped under the following headlines:

- Sustainability;
- Economical Performance;
- Availability and Robustness;
- Safety and Proliferation Resistance;
- Implementation Effectiveness: Compliance of specific projects with their planning (Design / License / Construction).

For the three years considered in this first edition of the Implementation Plan, we focus on this last indicator, with the main milestones for each of the three major technologies (SFR, LFR, GFR) and for the support infrastructures.

ESNII 1 – SFR ASTRID	ESNII 2 – LFR MYRRHA and ALFRED	ESNII 3 – GFR ALLEGRO
R&D innovation and pre conceptual studies		
2012: Consortia for funding, construction, operation. 2012: Assessment of innovations & design / GEN IV requirements.	2012: Establishment of MYRRHA International Members Consortium. 2013: ALFRED Consortium agreement, Site identification. 2013: Assessment of innovations & design for ALFRED with regards to GEN IV requirements.	2012: Confirmation of the feasibility. 2012: Assessment of innovations & design / GEN IV requirements.

R&D and testing facilities:

- End of 2011: shared identification of the needed supporting research, development and testing facilities for each of the components ESNII-1, ESNII-2 and ESNII-3 (ADRIANA FP7 project).
- End of 2012: Definition of an investment plan on the corresponding facilities taking into account opportunities from international cooperation.

Fuel manufacturing facilities:

- Definition of preferred advanced recycling flow sheet process at the pilot plant scale.

5. 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&D sub-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 behaviour 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 (2007-2011) – calls 2007, 2008 & 2009				
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 http://nuklear-server.ka.fzk.de/getmat/	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 http://www.fp7-fairfuels.eu/	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 http://gofastr.org/	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
ADRIANA – Advanced Reactor Initiative And Network Arrangement http://adriana.ujv.cz/	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
CDT – Central Design Team for a Fast-spectrum Transmutation Experimental Facility	Irradiation Facilities, Material Test Reactors, Partitioning & Transmutation	SCK.CEN (B) 18 partners (from 8 countries)	1/4/09 36 months	€4.0/€2.0

*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