Nuclear Fission

1. Size and organization of European Scientific Effort

An indication of the European coordinated Scientific Effort developed in addition to the national efforts can be obtained from the size of the SNETP and the Nuclear part of the EERA. The EERA Joint Programme on Nuclear Materials is composed today by 26 organizations from 13 European Countries (198 persons years are committed). Regarding the SNETP, Sustainable Nuclear Industrial Initiative, an overall number of 116 organizations are today members of the SNETP. The typologies of the members are: industry, research, academia, technical safety organizations, non-governmental organizations and national representatives. Among the three pillars of the SNETP, ESNII (the European Sustainable Nuclear Industrial Initiative), official SET-Plan EII focused on the science and technologies for fast neutron reactors and associated closed fuel cycle, is composed by 24 organizations (12 from industry and 12 from RTD organizations). NUGENIA, the second pillar focused on Gen II and III reactors, is composed today by more than 80 members. The third pillar, NC2I, the initiative on nuclear co-generation, is composed by 16 organizations. In addition there are two other informal technological platforms, IGD-TP, dedicated to the R&D and validation of the technologies for the geological disposal of radioactive waste, and MELODI, for health effects of ionizing radiations and other radio-protection topics. Furthermore, the Nuclear Energy Agency coordinates the OECD nuclear R&D efforts, and the International Atomic Energy Agency the nuclear R&D in the United Nations framework, both with large contributions from European research institutions

2. Strategic Research Agenda

The Vision report, issued in 2009, prepared the launch of the SNETP. The Platform then issued the first Strategic Research Agenda in 2009, followed by the Deployment Strategy in 2009. The ESNII Concept Paper, was issued in October 2010. The SRA was updated in 2013 with the Strategic Research and Innovation Agenda. NUGENIA has also published a more detailed Strategic Research Agenda for the GEN II and III R&D topics. There are also an IGD-TP Strategic Research Agenda and a MELODI draft Strategic Research Agenda.

2.1 Key objectives in SRAs

Safety of operation of present GEN II and III reactor and associated fuel cycle installations, allowing maintaining or increasing the contribution to electricity generation with low CO2 and GHG emissions. Development and demonstration of fast reactors, critical or subcritical, with closed fuel cycles to enhance sustainability, by increasing energy value of natural resources and minimizing the ultimate nuclear wastes. Development and demonstration of the feasibility of industrial applications using direct nuclear heat in cogeneration with electricity. Demonstration of the safe long-term radioactive waste geological disposal feasibility. Clarifying low radioactive doses effects on people and other radio-protection issues

2.2 Main challenges in SRAs

- Evaluation of the safety margins of present reactors in normal and beyond design base conditions, particularly: limitations of high power/burn-up fuels; long term utilization of materials (metallic, polymers and concrete) under irradiation, temperature and other conditions at present reactors; behavior of the reactor under severe accident conditions.

- Demonstration of fast reactor systems with significant power (>50MW), including development and validation of fuels and materials for the prototypes for different reactor coolants. Development of advance fuels for advance reactors (fast reactors and others) and fully closed fuel cycles including partitioning and transmutation. Development of reprocessing technologies for present and future fuels compatible with the fuels and fuel cycles of advanced reactor concepts using fully closed fuel cycle.

- With regard to the renewal of Large Experimental Research Reactors, the SRA mentions that Europe can only hold on to its leadership in the field of reactor technology if it maintains its efforts towards the realization of a European Research Infrastructure Area. The irradiation capacity for R&D and production of medical isotopes should be based on three pillars: Jules Horowitz Reactor (RJH) at Cadarache in France, MYRRHA at Mol in Belgium, and PALLAS at Petten in The Netherlands .

- Conditioning of high level radioactive waste and characterization of their behavior at long-term in the conditions of deep geological repositories.

3. Existing Research Infrastructures

The Nuclear Energy Agency, NEA, of the OECD has prepared and maintains a database on Research and test facilities database (RTFDB), http://www.oecd-nea.org/rtfdb . A summary of the status, needs and recommendations were issued in 2009 in the report "Research and Test Facilities Required in Nuclear Science and Technology", NEA, OECD 2009, NEA 6293, available from the NEA web.

Also the International Atomic Energy Agency, IAEA, maintains a Research Reactor Database at http://nucleus.iaea.org/RRDB/RR/ReactorSearch.aspx?rf=1 . IAEA List of Nuclear Fuel Cycle Facilities http://infcis.iaea.org/NFCIS/Facilities.cshtml and IAEA main Databases are available at http://www.iaea.org/OurWork/ST/NE/Main/databases.html

A recent comprehensive view of existing R&D infrastructures and needs for the ESNII reactor technologies has been prepared by the ADRIANA project (FP7 Coordination and Support Action). ADRIANA web link (http://adriana.ujv.cz) and its final report (ftp://ftp.cordis.europa.eu/pub/fp7/euratom-fission/docs/adriana-final-report_en.pdf).

The latest project are also updating the list of infrastructures ESNII+ (Gen-IV), NUGENIA+ (Gen II-III), TALISMAN (Fuel Chemistry and hot laboratories) and THINS (Thermal-hydraulics).

3.1 Field supported by existing Research Infrastructures

Experimental reactors are used to support many important fields of research and industry in Europe: safety, lifetime management and operation optimization of current nuclear power plants, development of new types of reactors with improved resources use and fuel cycle management, medical applications, material development for fusion reactors…

At the moment, the European Research Area for Experimental Reactors is based on the following pillars: BR2, HFR and OSIRIS. Taking into account the needs of nuclear industry, the strategic importance of future Generation IV reactors developments, the advanced fuel cycle and the public health stakes, a European policy must include a mid-term roadmap encompassing:

- A high performance material testing reactor
- A flexible fast spectrum irradiation research facility
- A research reactor as main European producer for medical isotopes.

As described in the Strategic Research Agenda of SNETP, Europe can only hold on to its leadership in the field of reactor technology if it maintains its efforts towards the realization of a European Research Area on experimental reactors based on three pillars:

- Jules Horowitz Reactor (RJH) at Cadarache in France, of which the construction has been started in March 2007. RJH will be addressing the needs for industrial applications for Generation II & III in terms of structural materials and fuel performance improvement as well as some generic Gen IV research. RJH will also contribute to the supply of radioisotopes for medical applications.

- MYRRHA at Mol in Belgium, a flexible multi-purpose fast spectrum irradiation facility, operating as a sub-critical (accelerator driven) system, and as a critical reactor for material and fuel developments for Generation IV and fusion reactors and in a back-up role for radioisotopes production. Operation as an accelerator driven system allows responding to the need of demonstrating the ADS concept and the efficient transmutation of high level nuclear waste (Minor Actinides). The MYRRHA fast research facility will also be able to serve as the European Technology Pilot Plant for the lead cooled fast neutron reactors development, and thereby contribute to the objectives of developing an alternative to the sodium fast reactor.

- PALLAS, a thermal spectrum facility, in The Netherlands, having an agreement in principle of the Dutch government for licensing and presently under design for serving the main objective of securing the radioisotopes production for medical application for Europe and will also contribute to support the industrial needs for technological development.

There are also few very large infrastructures for advance fuel development, including the JRC laboratories at Karlsruhe and the ATALANTE (CEA/Marcoule). These facilities however show some limitations that could make them inadequate for the development of fuels for the anticipated new reactor designs.

The fuel reprocessing is also the objective of significant research infrastructures at JRC laboratories, at ITU in Karlsruhe and the ATALANTE (CEA/Marcoule). New developments however are needed to validate new reprocessing concepts: like partitioning, grouped extraction of radioactive isotopes, new technologies like piro-metallurgic techniques, etc.

There are also a few laboratories, having hot cells, able to manipulate and make measurements with heavily irradiated/activated structural materials or fuel pins. The HOTLAB network has built a network coordinating these laboratories.

The laboratories of HOTLAB are complemented with microscopy and metallographic laboratories able to analyse the samples prepared in the HOTLAB.

For nuclear data research and determination, in order to contribute to the safety and sustainability enhancement of the nuclear technologies, the CHANDA (following ERINDA, EUFRAT, ANDES and other previous project) project has put together a network of 20 laboratories with the capability to provide world class measurements. The network includes a few very large facilities like CERN, GANIL or GSI (FAIR) facilities for nuclear data and a group of very specialized laboratories that address specific measurement capabilities and methodologies. The whole set will be operated as a kind of large distributed research infrastructure

3.2 Opportunities for improved use of existing Research Infrastructures

The approach would first consist in a rationalization and an optimization of existing facilities before evaluating the needs for new facilities.

Distributed infrastructures may be of interest but attention must be paid to implement friendly access to the various facilities for experimentation and not to increase unduly the shipment of radioactive materials.

Maintenance and operation of relevant facilities should be be supported in order to keep them at their best technical level., with the objective to constitute networks of facilities. Access of scientists to these infrastructures should be made available and supported.

The construction of the JHR is in progress and is scheduled to be completed by the end of the decade. Research programs involving numerous partners are being elaborated.

Extension of the license of BR2 from 2016 till 2026 through a significant refurbishment programme will allow maintaining irradiation capacities in a transition period until new facilities from the ERAER come on-line.

The upgrade of the JRC-ITU capabilities for handling minor actinides will allow significantly progressing in the preparation of minor actinide bearing fuel for transmutation studies.

4. Areas of SRA with insufficient RI support

After the closure of Phenix in 2009, Europe has no longer any fast neutron spectrum irradiation facility. To develop the different fast reactor technologies mentioned in the ESNII concept paper, it is of paramount importance that Europe can perform its R&D programme in support of these technologies in its own fast spectrum irradiation research facilities

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, new prototypes and demonstrators will have to be built. In the SRIA, 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 promote the design, licensing, construction commissioning and operation, before 2025, of the Sodium Fast Reactor Prototype reactor called ASTRID and the flexible fast spectrum irradiation facility MYRRHA. In parallel to the realisation of ASTRID and MYRRHA, activities around the Lead Fast Reactor technology with the ALFRED demonstrator reactor and the Gas Fast Reactor technology with the ALLEGRO demonstrator reactor should be continued, taking into account their specific needs.

Additional facilities are needed to :

- work using significant amount of Americium and Curium for fuel fabrication and/or fuel reprocessing.
- analyze the behaviour of present and next generation reactors in accidental beyond design basis conditions.
- Investigate the behaviour of circuits containing liquid metal as proposed for fast reactor systems.

Implementing Geological Disposal and Waste Management

1. Size and organization of European Scientific Effort

The Implementing Geological Disposal Technology Platform (IGD-TP) was formally launched and its vision report published in November 2009. The work of IGD-TP is driven by ten waste management organizations and one governmental body that share a common vision:

- "By 2025, the first geological disposal facilities for spent fuel, high-level waste, and other long-lived radioactive waste will be operating safely in Europe" (Vision 2025).

2. Strategic Research Agenda

IGD-TP gathers around 80 participating organizations endorsing IGD-TP vision report and representing stakeholders such as waste management organizations (WMOs), industry, research institutes, research centers and academia. The Strategic Research Agenda (SRA) published in July 2011 identifies the main RD&D activities needing a coordinated effort at European level to reach the endorsed vision of 2025.

2.1 Key objectives in SRAs

Key objectives and IGD-TP's commitment is to:

- build confidence in the safety of geological disposal solutions among European citizens and decision-makers;
- encourage the establishment of waste management programmes that integrate geological disposal as the accepted option for the safe long-term management of long-lived and/or high-level waste;
- facilitate access to expertise and technology and maintain competences in the field of geological disposal for the benefit of Member States

The concept of engineered geologic disposal has been developed for the safe long-term management of long-lived radioactive waste. This involves emplacement of radioactive waste in deep geological repositories that contain and isolate the waste and, consequently, protect humans and the environment. A nuclear waste repository takes decades to develop and the best available technologies and engineering design are applied to achieve long-term safety. Throughout the development of a repository, the feasibility, safety and appropriateness of the proposed system must be proven to all stakeholders before a decision can be made and the development process can progress. There are several such decisions underpinned by safety reviews until the licensing of the final closure of a repository, and there is a commitment on all stakeholders to continuously improve the technical solutions in a virtuous process of optimisation.

Decision making requires practical demonstrations of key technical elements in order to demonstrate the robustness of the proposed design as well as to establish confidence. Underground research laboratories (URLs) play an important and multi-faceted role in these scientific assessments and demonstrations by providing a realistic environment for characterising and testing the selected technical approaches and materials. In areas such as demonstrating operational safety, acquiring geological information at a repository scale and in constructional and operational feasibility, only URLs can provide reliable *in situ* data. URLs can also provide tangible benefits in enhancing participation by the general scientific community and confidence amongst both technical and nontechnical stakeholders. The main purpose of URLs is to further the repository development process by facilitating research activities under an environment similar to the repository but with less disturbance to the actual repository.

2.2 Main challenges in SRAs

To that effect, Underground research laboratories are used to:

- develop the technology and methodology required for underground experimentation;
- provide data to understand the behaviour and assess the performance of the repository system and of their interactions;
- demonstrate the robustness of the design and to show the potential areas of optimisation of engineering components and processes;
- train personnel for safe operation of a future repository;
- build confidence with stakeholders for their understanding of the important processes governing repository performance.

3. Existing Research Infrastructures

Among the various types of URL, two broad categories can be distinguished:

- Generic URLs: Facilities that are developed for generic research and testing purposes at a site that will not be used for waste disposal, but provide information that may support disposal elsewhere.

Generic URLs are developed to gain general experience of site characterisation and underground construction techniques, model testing and verification of investigation and measurement techniques. They are not built in a specifically selected host rock formation with the intent to closely match a repository. Generic URLs are very useful at early stages of repository programmes. For instance, generic field investigations were carried out at the Switzerland Grimsel Test Site prior to the selection of a particular host geologic formation, whereas specific investigations were launched later in the Mont Terri road tunnel so as to study a clay formation that is being considered as a potential host rock elsewhere in Switzerland.

- Site-specific URLs: Facilities that are developed at a site that is considered as a potential site for waste disposal and may, indeed, be a precursor to or the initial stage of developing a repository at the site.

Site-specific URLs are often used for confirming the suitability of the potential geologic environment, guiding the site-specific layout and design of the repository, demonstrating the various technological operations under site-specific conditions, and allowing continuing R&D programme during the disposal operations.

Here below are European underground research laboratories in operation today :

- Äspö Hard Rock Laboratory, SE, www.skb.se/Templates/Standard____25506.aspx
- Grimsel Test Site, CH, www.grimsel.com/

- HADES underground laboratory, BE, www.sckcen.be/en/Our-Research/Research-facilities/HADES-Underground-laboratory
- Tournemire, FR, www.irsn.fr/EN/Pages/home.aspx
- Mont Terri Project, CH, www.mont-terri.ch/
- Olkiluoto Research Tunnel, FI, www.posiva.fi/en/research_development/onkalo
- ONKALO, http://www.posiva.fi/en/final_disposal/onkalo
- JOSEF Underground Research Centre, CZ

Each key research topic represents an area under which specific related for achieving RD&D results need to be achieved for implementing the Vision 2025:

1. Safety case,

2. Waste forms and their behaviour,

3. Technical feasibility and long-term performance of repository components,

4. Development strategy of the repository,

5. Safety of construction and operations,

6. Monitoring, and

7. Governance and Stakeholder involvement.

In addition, a number of Cross-Cutting Activities (CC) was defined:

- Dialogue with regulators,
- Competence maintenance, education and training,
- Knowledge management (incl. information preservation, memory keeping),
- Communication and other activities supporting information exchange.