

## **ESFRI**

European Strategic Forum for Research Infrastructure  
Physical Sciences and Engineering Working Group

### Up-date of the ESFRI Road Map

#### PSE RWG Report

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## **Introduction**

This is the Report of the Physical Sciences and Engineering Roadmap Working Group (PSE RWG, or in short PSE) to ESFRI. The PSE was appointed by ESFRI based on nominations from the member states and the PSE members represent a mixture of scientific expertise combined with science management and science policy experience.

This report recommends new or upgraded Pan European Research Infrastructures (RI's), to be included in the up-date of the ESFRI Roadmap for European Research Infrastructures and also contains an evaluation of the progress of the projects of the ESFRI roadmap 2006 in the field of the PSE group.

The PSE has considered and assessed the progress of 15 projects included in the first edition of the ESFRI Road Map. In addition the PSE has assessed 19 new or proposed RI's submitted by the ESFRI delegation and assigned to the PSE by the ESFRI Executive board. The PSE has been consulted with other working groups on projects on the borders between the areas covered by the working groups. The infrastructures under consideration span very different types, lifetimes and costs, from large, single site laboratories based on a specific large equipment or facility, to distributed facilities and network of national facilities.

The PSE divided itself into 3 sub-panels for the evaluation of both the current project on the ESFRI Road Map and the new proposals in the different fields: (1) energy research; (2) materials research and general purpose facilities; and (3) astronomy, astrophysics, nuclear and particle physics. The sub-panels were also asked to develop an overall strategic view of the landscape, based on existing indications and opinions within the involved scientific communities. Some fields are well covered by individual Roadmaps, and/or strategy documents that have been published by international institutions, e.g. Particle Physics (by the CERN Council) and Space (by the European Space Agency).

The sub-panels have operated on the basis of terms of reference aimed at ensuring that the members acted in their personal capacity, and taking care that conflicts of interest were declared and dealt with.

The 34 projects were assessed in detail by the sub-panels and the assessments were combined and integrated by the PSE as a whole into an overall view coherent with a strategy-led approach to European policy-making. The scope has been to help ESFRI to choose those proposals which are deemed strategically most important and mature for inclusion on the second edition of the ESFRI Roadmap. An important task was to fill thematic gaps of the ESFRI roadmap 2006.

An interim status of the work by the PSE was presented to ESFRI at its meeting March 6-7, 2008. Based on this report, the ESFRI asked the PSE to engage in a dialogue with the groups behind the new proposals in the energy field and the relevant directorate of the European Commission in an effort to further develop the most promising proposals. This resulted in resubmissions of four energy RI proposals which were subsequently assessed by the sub-panel and the PSE. The results of the new assessments were presented to ESFRI at the meeting of June.

The work of the PSE has required a difficult balance between merits of the scientific need and excellence, pan-European nature and added value, and strategic and societal relevance combined with the realities of budget constraints and science policy priorities in the member states.

The results are presented and summarized in three areas of research: (1) Energy research (2) Materials Sciences and Engineering, and (3) Astronomy, Astrophysics, Nuclear and Particle Physics.

## 1. Summary

Table 1 gives an overview on the assessment of the individual proposals, whether they are recommended by the PSE to be included in the updated road map or whether they will be mentioned in the descriptions of the technology roadmaps of the three sub-panels. The RIs have further been classified according to their scale as global, European unique RIs, Distributed RIs or RI networks and RIs of national relevance. Some of proposal concerned in addition to the PSE also the fields of one or more other ESFRI RWG's. This is referred to in the table as well.

The PSE recommends that the following new projects are included in the up-dated ESFRI Road Map list:

RU 07: Cherenkov Telescope Array (CTA)  
RU 19: European high Magnetic Field Laboratory (EMFL)  
RU 29: European Carbon Dioxide Capture and Storage Laboratory Infrastructure (ECCSEL)  
RU 38: European Incoherent Scatter Radar System (EISCAT)

The PSE has transferred the assessment of the RU 08 to the RWG ENV.

The PSE was asked to pay particular attention to projects in the field of energy. It found that the following projects have both scientific and strategic merit, but they do not yet meet all of the criteria for inclusion in the ESFRI Road Map list:

RU 03: Multipurpose Hybrid Reactor for High Tech Applications (MYHRRA)  
RU 34: European Renewable Energy Infrastructure – Solar (TEREI-SOLAR)  
RU 36: European Centre for Turbulence and Wind Energy (Windscanner)

The remaining projects were found not to meet the criteria for inclusion in the ESFRI Road Map list.

The second major task of the PSE was the assessment of the progress of the projects of the ESFRI roadmap 2006. The table gives an overview on the findings of the group. The group suggests to introduce an additional category for projects that already been progressed beyond ESFRI. These are the projects where construction has already been decided or started. The table also gives the classification according to the scale of the RI.

The PSE RWG finds very gratifying that all of the projects on the present ESFRI Road Map assigned to the PSE have made reasonable progress and recommends that they are included in the up-dated Road Map list. The following projects have advanced to or are very near to entering the construction phase based on national commitments or international agreements. These six projects are:

PSE 14: ESRF Up-grade  
PSE 16: FAIR  
PSE 18: ILL Up-grade  
PSE 20: JHR  
PSE 23: SPIRAL 2  
PSE 24: XFEL

The PSE has noted the CERN Council strategy for the development of infrastructure in the field of particle physics, but has not assesses any of the proposed projects.

No.	Title	Other RWGs involved	Recommendation		Scale of the RI			
			Road Map	Landscape	Global	European unique distributed	National	
RU03	MYRRHA			x		x		x
RU07	CTA		x			x		
RU08	3MERL	ENV + PSE	(x)				x	
RU12	FHS			(x)				x
RU13	ATRA			(x)				x
RU14	L-SURF			(x)				x
RU17	CECAM	eIWG + BMS, ENV, PSE, SSH						
RU19	EMFL		x				x	
RU20	CYCLOPE			(x)				x
RU21	DAFNE					x		x
RU26	LVR-HALE			(x)				x
RU27	NFFA			(x)			x	x
RU29	ECCSEL	ENV + PSE	x				x	x
RU31	Software services	eIWG + BMS, ENV, PSE, SSH						
RU33	IPURE	eIWG + BMS, ENV, PSE, SSH						
RU34	TEREI			x			x	x
RU36	Wind-Scanner (turbulence)	PSE + ENV		x		x		x
RU37	MAX-IV			x				x
RU38	EISCAT	PSE + ENV	x				x	
RU39	PRIN-CE			(x)				
RU40	DYNAMO							x

Table 1: Summary of the assessments of the new project proposals for the ESFRI Road Map from physical sci and engineering sciences

Table 2: Summary of the assessments of the existing project on the ESFRI Road Map list.

No.	Title	Progress	Recommendation		Scale of the RI			National
			Approved launched	Road Map	Global	European unique	distrib.	
PSE12	E-ELT	ESO decided to fund prep. project		x		x		
PSE13	HIPER	Delays		x		x		
PSE14	ESRF-UP	ESRF Council agenda next	x	x		x		
PSE15	ESS	Site discussions in ESFRI		x		x		
PSE16	FAIR	Int. negotiations ongoing	x	x		x		
PSE17	IFMIF	Int. negotiations ongoing		x	x			
PSE18	ILL	First stage on Board agenda	x	x		x		
PSE19	IRUVXFL	Scope Change in partner facility		x			x	
PSE20	JHR	Construction started 2007	x	x				x
PSE21	Km3Net	Communities coalesced		x		x		
PSE22	SKA	Global discussions ongoing		x	x			
PSE23	SPIRAL2	First construct. stage funded	x	x		x		x
PSE24	X-FEL	Int. owned company will be formed soon	x	x		x		
PSE31	PRINS	Moderate progress		x			x	
PSE36	ELI	Int. R&D effort		x		x		

## 2. Methodology

### 2.1 Setting up the PSE, collecting the proposals and developing the criteria and procedures

The PSE Roadmap Working Group has been (re-)appointed during 2007. The composition of PSE has been decided by ESFRI, and is listed in Annex I. The members of PSE are both Science Policy experts and Country Representatives having a scientific background, and act as a preparatory sub committee of ESFRI, therefore integrating science policy and technical aspects. The ESFRI Working Groups operate according to the Terms of Reference and Procedures (Annex II). Tasks of the PSE as of all the other groups was to elaborate a comprehensive overview on the research infrastructure related aspects and challenges of their field, to assess the progress the projects on the ESFRI list 2006 and to assess the new proposals that have been submitted to ESFRI for this update.

The new proposals were collected by ESFRI through the national delegations, and forwarded to PSE for analysis in the beginning of December 2007. These proposals are listed in the Annex III. The proposals were documented by a standard format "fiche", which was used as basis for the assessments together with publicly available material in form of reports and web-pages including material used for the first edition of the ESFRI road map.

For the assessment of the progress of the project on the ESFRI roadmap 2006 the coordinators of the projects have submitted actualized project fiches for analyses by the PSE. PSE members from the European Commissions Services also gave regular oral reports on the progress in the negotiations of contracts concerning Preparatory Phase projects concerning the RI's on the ESFRI Road Map 2006 selected for support from FP7.

According to the ESFRI guidelines the PSE and the sub-panels followed a stage-gate procedure in the analysis and assessments of the proposals. First, the assignments of the individual proposals to a given RWG were discussed amongst the chairs of the RWG and the ESFRI Executive Board. Secondly, the PSE assigned the proposals to the three different sub-panels. The PSE established a common evaluation form (Annex 4) for the analysis and assessments of the development for the projects already included in the ESFRI Road Map and for the new proposals. Those projects that have been included as emerging in the ESFRI Road Map 2006 had to be resubmitted via the ESFRI EB and thus had to follow the same procedure as new proposals. There were two resubmitted emerging proposals for consideration of the PSE. Additionally 17 new proposals had been assessed by the PSE.

### 2.2 The assessment procedure and criteria

PSE decided at its first meeting in October (after the joint kick-off meeting September) to form three sub-panels for astrophysics, astronomy, nuclear and particle physics; materials and general purpose research facilities; and facilities for energy research. The proposals were divided between the sub-panels at the PSE meeting in December. The sub-panels have met in person and via telephone conferences and have in some cases, when necessary, also had meetings with the groups behind the proposals to clarify open questions. Sub-panels delivered progress reports at the meetings of the PSE in January and February. The assessment of the individual proposals was prepared by the sub-panels and finalized in discussions of the PSE. All decisions on the individual proposals were taken by the PSE whole group as a whole. A small number of proposals dealing with specialized aspects of engineering have been discussed directly within the PSE without the assessment having been prepared by one of the sub-panels.

The third step was an evaluation of the **scientific case**. Here the PSE has introduced additional criteria to distinguish between science driven projects and the development of technologies and products. These were subsequently endorsed by the ESFRI. Following the definitions in the Frascati Manual the PSE decided that ESFRI Road Map in the area of PSE should only include Research Infrastructures with significant elements of user driven investigations in basic, oriented basic and applied research. Research Infrastructures primarily for experimental developments are less within the scope of ESFRI. They can be included in the landscape descriptions but should not be included in the Road Map.

*Frascati Manual definitions:*

*Basic Research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of expected, current or future problems or possibilities.*

*Applied Research is also original investigations undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective*

*Experimental development is systematic work, drawing on knowledge gained from research and practical experience, that is directed to producing new material, products and devices; to installing new processes, systems and services; or to improving substantially those already produced or installed.*

The fourth step was an evaluation of the **European significance** using the following criteria:

- *project ensures open access to all interested researchers based on the quality of the user*
- *infrastructure is either new or proposing a major upgrade which is fully justified by quality and user needs*
- *proposal has true pan-European value and relevance*
- *interconnections and links between distributed facilities are seen to create synergy in an European infrastructure complex*
- *links to national "road maps" and other vision documents are available*
- *proposal should be considered in context of the overall landscapes with ranking and prioritization*

The final step consisted in an evaluation of the **maturity** of the project, taking into account technical, economic and management issues. Here the PSE was guided by the following definition of project phases:

- *Concept phase: Preliminary idea and concept.*
- *Conceptual design phase: Detailed scientific concept preliminary estimates for technical, feasibility and management aspects; preliminary cost estimate.*
- *Engineering design phase: Elaborated technical concept and feasibility study; reliable cost estimate; known partnerships.*
- *Detailed engineering design phase: Detailed technical concept required for construction, budgets and government decision,*
- *Preparation phase: Preparation of formal, legal, organizational, financial issues for agreement between partners.*
- *Construction and commissioning phase.*
- *Operation phase.*
- *Decommissioning phase.*

Not all projects follow this route literally and some of the phases may overlap, but these definitions can nevertheless still be used pictorially to assess the degree of maturity of a given project. The project also needs to be assessed with different weights for the different aspects relating to the scientific and technical maturity, the economic feasibility and the prospects for obtaining European wide support. A project should typically be in or near the equivalent of the detailed engineering phase preferably in the preparation phase to be judged mature.

In the end the PSE RWG arrived at unanimous conclusions and recommendations for this report. In the process care was taken to secure transparency by using the facilities for information sharing on the CIRCA web-site and to identify and deal with possible conflicts of interest.

### 2.3 Handling of the energy issue

The PSE RWG was asked to give special attention to projects within energy research. This was underscored by the approval of the new Strategic Energy Plan for Europe (SET-Plan) by the European Council in March 2008 with a specific request to ESFRI:

*- to improve and enlarge the Community's world-class knowledge base of energy researchers and research institutes ("capacity building"), including by reducing barriers to mobility, attracting world-class human capital, improving science education, and by asking the European Strategy Forum on Research Infrastructures (ESFRI) to identify the need for European research infrastructures in the field of energy technologies, such as renewable energy technologies;*

To meet the European energy and climate goals as well as to improve the industry competitiveness, increased efforts in R&D and energy technology innovation will be necessary. This will require stronger cohesion among the European research actors in energy but also much better performance in the commercialization of new technologies. For research infrastructures, this will mean that stronger industrial orientation would be beneficial, but also employing RI more effectively in the innovation chain, for example demonstration or pilot plants serving as RIs. Public-private partnership would be quite essential in realizing such innovation driven research infrastructures. Potential vehicles for this development are the Technology Platforms and the Joint Technology Initiatives.

On the other hand, meeting the Commission's challenging goals in renewable energy for the member states by 2020, or in average over 200% increase from the 2005 level, will require substantial increase in research budgets of renewable energy and carbon dioxide capture and storage, including major new research facilities. It would be highly relevant for the member states to coordinate their efforts, avoiding redundancy, and focusing on European wide larger RIs.

#### Energy proposals and assessments

The PSE reported its preliminary findings and recommendation to ESFRI at the meeting in March 2008 in Brdo, Slovenia. PSE had received five new proposals in the field of energy, and the preliminary conclusion were that none of these projects were mature enough to be recommend for the up-dated road map. The discussions at ESFRI lead to the conclusion that- due to the strategic importance of the European energy research agenda - ESFRI would invite the delegations and the institutions behind the energy related proposals to engage in a dialogue with the PSE RWG about the proposals and to allow submission of amended/renewed proposals for the up-date of the ESFRI Road Map. To prepare this process the projects were also discussed with representatives of the two Energy Research Directorates in DG Research of the European Commission and letters were send by the end of March to four of the project coordinators asking for up-dated proposals. The up-dated energy proposals were received on May 15. They were subsequently processed by the same procedure used for the other projects and the evaluation and recommendations were concluded at the PSE meeting at the end of May, 2008.

The present ESFRI list includes 3 nuclear energy based projects from the first call, 2 in fusion and 1 in fission. These address the needs of the nuclear communities both for Generation IV reactors and global fusion research community. One of these projects (Jules Horowitz Reactor) is now under construction and the other two (HIPER, high power laser facility; and IFMIF, materials testing facility) are candidates to be included in the up-dated road map. In the first round there were no projects from non-nuclear energy fields. In the second call of proposals by ESFRI (30 November 2007), five energy proposals were received, 1 on nuclear (MYRRHA, fast neutron accelerator driven system), 1 on magneto-hydrodynamics (DYNAMO), and 3 on non-nuclear energy (ECCSEL, carbon capture RI; TEREI, concentrated solar power RI; and Windscanner, turbulence and wind energy RI).

In the assessment process the PSE RWG and its sub-panels have employed the general ESFRI criteria (scientific, technical and financial criteria), and the strategic criteria arising from the EU policy side on energy and innovations. The work of the PSE RWG has required a difficult balance between merits of the scientific need and excellence, pan-European nature and added value, and strategic and societal relevance combined with the realities of budget constraints and science policy priorities in the member states.

The preliminary findings of the PSE RWG was that none of the new energy proposals were mature enough to meet the criteria to be included in the ESFRI Road Map up-date even though the sub-panels had recommend the 3 non-nuclear energy RI's. The PSE RWG found that two projects (RU\_34 TEREI and RU\_36 Turbulence, now Windscanner) were suitable for a 'fast track' maturing procedure. This was reported in the interim status report of the PSE RWG to the ESFRI meeting March 6-7, 2008.

Based on this report, the ESFRI asked the PSE to engage in a dialogue with the groups behind the new proposals in the energy field and the relevant directorate of the European Commission in an effort to further develop the most promising proposals.

These subsequent consultations resulted in resubmissions of four of the energy RI proposals by May 15 (TEREI, ECCSEL, MYRRHA and Windscanner). These were then assessed by the energy sub-panel in a telephone conference on May 19, discussed in a telephone conference on May 26 with officials from the two energy directorates within DG RTD, and finally assessed by the PSE RWG on May 30. It should be noted that only two members from the PSE-energy sub-panels were present at this discussion. Furthermore, the chair and the Spanish delegate had declared conflict of interest and were not present during the final discussions of the energy projects.

The revised proposals were evaluated positively within the PSE Energy sub-panel and seen very positively by the two directorates on Energy and on Nuclear Energy. All projects were seen to deal with issues of high European relevance, were found to be in line with the major strategies in the respective energy fields and were found to be crucial for a further progress in their fields of research. Also, a stronger industrial opportunity to use research infrastructures in the field of energy would be beneficial. This could make RI more effectively involved in the innovation chain, for example in connection with demonstration or pilot plants also serving as RIs. This in turn could make public-private partnership more likely and effective in realizing such research infrastructures driven by science as well as innovation needs. Potential vehicles for this development are the Technology Platforms, the Joint Technology Initiatives and the new proposed Industrial Initiatives in the SET-Plan.

These final assessments of the energy proposals were reported to ESFRI at the meeting on June 13, 2008. Following a debate the PSE was asked to review the issue once again and it was recommended by the ESFRI executive board to solicit second opinions from experts in the field with knowledge of the ESFRI process. Second opinions were subsequently asked from professors Norbert Kroo, Yves Petroff and John V. Wood, and John Wood was asked to act as the convener. The three experts agree with the findings of PSE. They are concerned that ECCSEL does not involve several relevant partners and state that the recommendation to include it should emphasize the need to bring other groups in.

#### **2.4 Conclusions by the chair of PSE road map working group concerning the energy issue**

The four up-dated proposals were assessed positively by the energy PSE sub-panel and by the two directorates on Energy and on Nuclear Energy in the EC. The concepts and descriptions of three proposals in the field of non-nuclear energy (ECCSEL, TEREI-SOLAR, and WINDSCANNER) were significantly developed in the up-dated descriptions and European wide engagements were documented. The nuclear energy proposal (MYRRHA) also documented a broad European interest among its stake-holders.

The majority of the PSE panel finds that only ECCSEL meets the ESFRI criteria of scientific merit, technical and financial maturity, and European added value to be recommended as a candidate for the ESFRI Road Map

Update. This view is supported by the second opinions from the outside experts. Summarizing the conclusions of PSE and the results of this second consultation process the chair concludes that only ECCSEL is recommended for the road map.

However, the chair also finds that this road map list cannot be the whole answer to the request by the European Council and ministers:

*“.. to identify the need for European research infrastructures in the field of energy technologies, such as renewable energy technologies.*

The proposals received by ESFRI in the field of renewable energy were found to be relevant to the respective communities, by the PSE energy sub-panel as well as by the two directorates on Energy and on Nuclear Energy that have been consulted. They represent strategic rather than basic research oriented facilities which have been evaluated to be of high quality and relevance in their fields.

As a conclusion the chair recommends that in addition to the road map a specific statement is issued by the ESFRI, which includes the energy proposals in the road map and the renewable energy proposals (TEREI-SOLAR and WINDSCANNER) as a response to the request by the council of ministers.

## **2.5 Lessons learned during the PSE RWG process.**

The following issues have emerged during the evaluation process for the Road Map Up-date in the PSE RWG.

### Road Maps

Many scientific communities produce road maps showing the research infrastructures that are important for the future developments in their fields. These kinds of maps serve as the background for national maps. The first ESFRI Road Map has triggered more nations in Europe to produce such maps. The ongoing work in the OECD Global Science Forum shows that this is a global trend.

The scientific status and merits of a project should be coming from the road map efforts outside ESFRI. Ideally it is the transnational scientific communities that should make the assessments of the scientific scope and priority of a given project. The ESFRI RWG did not have broad enough expertise to make a detailed scientific assessment of the individual projects, but did have expertise to make a strategic assessment across fields and disciplines of projects that have been endorsed by the respective scientific communities.

Individual countries may decide to fully fund a project from their national budgets. Such national facilities are often made available to an international scientific community via merit based access procedure. Such national decisions should be applauded because they strengthen the research infrastructure in the European Research Area. They should be acknowledged by ESFRI in the landscape descriptions. There is no need for a process in ESFRI to realize such projects. Hence, they should not be on the list. The ESFRI PSE has a few examples of projects that are looking for an ESFRI stamp of approval. This should not be necessary.

### Role of ESFRI

ESFRI and the ESFRI road map should be instrumental those projects that need approval and contributions from several governments (national funding agencies/research councils) to obtain a “go-decision”. ESFRI should be the market place for exchanges and discussions that can lead to joint funding and operation of pertinent European Research Infrastructures.

Once a “go-decision” is reached or when dedicated parties have taken ownership of the process the project can be elevated to an ESFRI “success roster”. It should no longer be counted in the ESFRI list as such. The PSE

RWG has processed several projects that may be elevated to “success roster” either right away or in the coming months.

#### Networks and distributed infrastructures

There are many examples of networks of facilities/infrastructures both in the current Road Map list and the emerging projects as well as in the portfolio of new projects. These projects typically evolve with growing strength in the interaction between existing facilities in different countries or as a network of planned facilities. Some of the projects may make the transition from a Network to a Distributed Infrastructure which -in practice- act like one legal entity. The PSE RWG has discussed this issue and has concluded that networking alone does not merit inclusion in the ESFRI list. It typically does not need the attention at government level, and the EC has many schemes to promote networking at the European level. It is the credibility of the course towards a Distributed Infrastructure that should be criterion for inclusion in the list either as an emerging project or – if the transition to a Distributed Infrastructure is imminent – as is the case for a project on the list. A helpful question to ask is whether or not a collective “go-decision” is needed by two or more governments. Can the launch time be defined so that the project can move to the “success roster”? The PSE RWG has processed examples of both networks and emerging Distributed Infrastructures.

### **3 Landscapes of Physical Sciences and Engineering and Research Infrastructures**

The physical sciences and engineering cover a wide range of research areas and types of infrastructures. In the present context the main areas are: astronomy, astrophysics, nuclear and particle physics; materials science, energy research and engineering research. Research infrastructures (RIs) play an increasingly important role in the advancement of knowledge and technology in these areas. They are a key instrument in bringing together a wide diversity of stakeholders to look for solutions to many of the problems society is facing today. RIs offer unique research services to users from different countries, attract young people to science, and help to shape scientific communities. At the same time the new RI grow in size, complexity and resource requirements. A new large RI typically needs sponsoring from a consortium of nations. This has for a long time been recognized in the physical science and engineering communities. New knowledge and, by implication, innovation, can only emerge from high-quality and accessible RIs: for example, radiation sources, data banks, observatories for astronomy and astrophysics, systems of imaging or clean rooms for the study and development of new materials or nano-electronics are at the core of research and innovation processes. In the field of PSE the creation of such facilities depends heavily on international collaboration.

The development of the first ESFRI Road Map has shown that not all fields of research have developed the same degree of international cooperation concerning research infrastructures. This has led to the formation dedicated working groups for environmental sciences and e-science in the preparation of the second edition of the ESFRI Road Map. They were covered by the PSE in the first round. It has also meant that non-nuclear energy was given special attention both by ESFRI and by the PSE RWG. It is primarily nuclear energy research which is harvesting the benefits of international cooperation both within the European Research Area, ERA, and on the global scale with the Euratom fusion program as the prime example.

The landscapes of the different areas reflect this difference in tradition. In addition there are several international European research organizations like CERN, ESO, ILL, ESRF and EMBL in the areas covered by the PSE. These organizations have prominent roles in their respective fields and have developed their own road maps. This means that there are different kinds of fora for strategic planning and decision making that eventually lead to the construction of a new international research infrastructure. This has been discussed in the recent report of the ERA Expert Group:” Developing World-class Research Infrastructures for the European Research Area” (Directorate for Research, EUR 23320 EN 2008).

The discussion concerning the development of ERA also shows that the roles of the different actors involved in the creation of new research infrastructures are changing. The member states remain central in the development and financing of the infrastructures and the Community can and should play a catalysing and leveraging role by helping to ensure wider and more efficient access to, and use of, the infrastructures in the different Member States. The Community actions in the Framework Programs has also stimulated and coordinated development and networking of these infrastructures, and fostered the emergence and preparation of new ones. ESFRI is the Forum where these actors meet.

From the point of view of the scientific communities the process of development of new infrastructures has become more complex. On one hand there is a growing trend of increasing international collaboration at science community level and many international science communities are successful in their efforts to bring out consensus views on the needs for new facilities. This is helped and stimulated by the international scientific organizations like ESF, IUPAP and others. The descriptions of the individual landscapes in the following have drawn upon such work and the resulting reports. On the other hand the decision making process involves an increasing number of national governments and agencies, which has made the decision making process both cumbersome and slow. The work of ESFRI and the new edition of the Road Map is intended to reverse that trend.

The term 'research infrastructures' refers to facilities, resources and related services used by the scientific community to conduct top-level research in their respective fields, ranging from astronomy to nanotechnologies. Examples include singular large-scale research installations, databases, clean rooms, integrated arrays of national research installations, high-capacity/high speed communication networks, telescopes, synchrotrons and accelerators connected to networks of computing facilities. RIs may be 'single-sited' (a single resource at a single location), 'distributed' (a network of distributed resources), or even 'virtual' (the service is provided electronically). The PSE has found it useful to make distinction between:

- research infrastructures that are unique in the world and require collaborations on a global scale
- single-sited research infrastructures that are unique in Europe and require ERA type-collaborations
- distributed infrastructures with unique features and roles in ERA and with joint management
- national facilities with international users
- ERA-networks of national facilities

The PSE finds that ESFRI primarily has added value for the development of infrastructures in the first three categories.

Since the release of the first ESFRI Road Map there has been an increasing effort to establish similar tools for improving strategic decision making on both national level and on the international (OECD wide) level. Many governments around have prepared their own national road maps for research infrastructure. The OECD Global Science Forum has launched a study of road map practices. The comparison shows that it is very much the same large infrastructures in the fields of physical science and engineering that appear repeatedly in the different national road maps. This is illustrated in Table 1 which list the most frequent mentioned RIs in the area of physical sciences and engineering in the OECD survey of national road maps (Fontana, OECD, 2008).

This is encouraging and shows that the ESFRI Road Map has had a broad impact and have stimulated the international dialogue with the result that several of the large projects have moved closer to realization.

PSE	European XFEL	Hard X-ray Free Electron Laser in Hamburg
PSE	SKA	Square Kilometer Radiotelescope Array (in two phases)
PSE	ESS: The European Spallation Source	European Spallation Source for neutron spectroscopy
PSE	FAIR	Facility for Antiproton and Ion Research
PSE	ILC	International Linear Collider
PSE	ELT: The European Extremely Large Telescope	European Extremely Large optical telescope
PSE	IRUVX-FEL	Infrared to soft X-rays complementary Free Electron Lasers (in 5 users facilities)
PSE	LHC Upgrade	Large Hadron Collider and Upgrades
PSE	LIGO, VIRGO	Gravitational Wave Observatory (LIGO, VIRGO)
PSE	ESRF Upgrade	Upgrade of the European Synchrotron Radiation Facility (in 7 years)
PSE	ILL 20/20	Upgrade of European Neutron Spectroscopy Facility (in 2 phases)
PSE	KM3NET	Underwater Neutrino Observatory (in design phase)

Table 1: List of the most frequently mentioned research infrastructure projects in a OECD GSF initiated survey and comparison of national road maps for research infrastructures.

### 3.1 Landscape of research infrastructures for energy research

The threat of energy-induced climate change is great challenge that modern man-kind. Within half a century a reduction of 60 to 80 per cent of all green house gas emissions is needed, which is turn is not possible without massive introduction of sustainable energy technologies and systems on a global scale. Moreover, 80 per cent of global energy production is still based on fossil fuels, and the emerging economies rely increasingly on these. This makes reaching the goals even harder. Europe has decided to take the lead in showing the way to a sustainable energy future. But huge research and development efforts will be needed to create the necessary technology solutions for the energy needs ahead.

#### 3.1.1 General and background

The ESFRI/PSE working group was given a special assignment to assess the opportunities for the development and use of research infrastructures (RI) within the field of energy, also in the light of global change and the need for an integrated European energy policy. The Strategic Energy Technology Plan (SET-plan) communication from November 2007 emphasizes the need for RI in the field of energy. This was confirmed by the European Council of Ministers in March 2008. Public and private energy R&D budgets in the EU have declined substantially in real terms since peaking in the 1980s. This has led to a clear under-investment in energy research capacities and infrastructures.

To meet the European energy and climate goals as well as to improve the industry competitiveness, increased efforts in R&D and energy technology innovation will be necessary. This will require stronger cohesion among the European research actors in energy but also much better performance in the commercialization of new

technologies. For research infrastructures, this will mean that stronger industrial orientation would be beneficial, but also employing RI more effectively in the innovation chain, for example demonstration or pilot plants serving as RIs. Public-private partnership would be quite essential in realizing such innovation driven research infrastructures. Potential vehicles for this development are the Technology Platforms and the Joint Technology Initiatives.

On the other hand, meeting the challenging goals in renewables for the member states by 2020, or in average over 200% increase from the 2005 level, will require substantial increase in research budgets of renewables and carbon capture as well, including major new research facilities. Foreseeing this development, ESFRI is in a position to help the member states in coordinating their efforts, avoiding redundancy, and focusing on European wide larger RIs instead of isolated facilities that may prove to be sub-critical in size.

The present ESFRI list includes 3 nuclear energy based projects from the first call, 2 in fusion and 1 in fission. These address the needs of the nuclear communities both for Generation IV reactors and global fusion research community. There were, however, no projects from non-nuclear energy fields. This can be easily explained by the historical development as in nuclear physics international collaboration around large research facilities has been very strong since the 1950's. Whereas in non-nuclear energy the research to a large extent has had a national focus. As a result the research efforts have been dispersed, and the research financing has been quite modest in view by the number of technologies covered. In the light of the above facts, it was decided in PSE to provide a thorough updating of the landscape of non-nuclear energy technologies. Possible nuclear-based RIs are much easier to identify due to their massive and centralized character and several are already running.

In the second call of proposals for ESFRI (30 November 2007), five suggestions arrived, 1 on nuclear, 1 on plasma, and 3 on non-nuclear energy.

In the following, the working group has provided an update of the landscape of energy research infrastructures. The main sources used has been written material in particular from the Commission's Communication "An energy policy for Europe", Commission's SET-plan from November 2007 and the hearings in 2007, earlier ESFRI hearings from 2005, and individual interviews of research organizations, industry representatives and officials. Important criteria employed in the assessments have been the general ESFRI criteria (scientific, technical and financial criteria), and the strategic criteria arising from the EU policy side on energy and innovations.

### **3.3.2 Update of energy RI**

The European policy goals for non-nuclear energy are challenging. The renewable energy contribution should be tripled up to 20% of primary energy, and the share of biofuels should rise to 10%, all by 2020. The recent Strategic Energy Technology plan strives for major technology breakthroughs, for example by 2020 in large-scale wind energy, biofuels, and carbon separation and storage, and in several other important areas such as fuel cells and hydrogen, solar cells, storage, etc. by 2050. On the 2050 scale, new nuclear technologies such as Generation IV and also fusion are perceived important. The Commission mentions different types of public-private-partnership models for realizing these visions – purely public efforts will not be adequate but strong industrial presence is necessary.

The RIs in energy should support this European vision. Considering the R&D demands in energy and the characteristics of the energy innovations and the energy systems, the definition of the a traditional RI is extended in the energy context also to pilot and demonstration plants. To be relevant for ESFRI such energy RIs should, however, have a clear scientific purpose, for example the pilot plants should be employed for more fundamental scientific work. To enhance European competitiveness, these kind of energy RIs should in parallel with the industrial needs and therefore co-financing schemes between public and private bodies is foreseen for such installations.

The working group found the following relevant technology themes in the energy field that could be relevant for ESFRI:

Non-nuclear energy: Wind, Biofuels, Photovoltaics, Smart Grids, Hydrogen and fuel cells, Zero emission power-plants, Concentrated solar, Renewable sources, Ocean and hydro, Solar thermal, Co-generation, Oil and gas, (no current ESFRI-projects).

Nuclear energy: Fission, Fusion

(current ESFRI-projects: HIPER High power laser RI for inertial fusion, IFMIF Materials RI for fusion energy reactors, JHR Materials research for fission energy reactors).

### 3.1.3 Need for research infrastructures

Photovoltaics: The PV field is growing fast or by 40% per annum with global turnover in the range of 20 billion €. Much of the research in the PV field is done in dedicated research institutes and by the industry itself. Single major RI needs in PV is difficult to identify as this technology is already commercially available and R&D needs are covered by different market actors. FP7 and the PV technology platform provide improved focus and cohesion into the R&D efforts on a European level. The possible investment in new PV R&D-infrastructure should preferably cover the different parts of the value chain, with interlinked centres to ensure continuity and cost-effectiveness. Possible RIs could be related to platforms for advanced manufacturing systems and base materials for solar cells and development of new promising concepts like 'Concentrating PV'. In addition a RI platform for information exchange and benchmarking of the various approaches to thin film photovoltaics would be valuable.

Wind energy is the fastest growing electricity production form representing close to 2% of world electricity and a business area of over 20 billion €. Present research infrastructures are inadequate to address research needs on large-scale wind turbines and systems. With the move towards up-scaling of turbine technologies, there is a crucial need to build research infrastructures that are able to demonstrate the latest technology developments at a relevant scale, for example multi-MW systems in offshore environment. Relevant RIs could be related new generation of technology components at a relevant scale, wind research facilities with necessary enabling technologies and power infrastructures such as grid integration and storage. The Commission's new goals for renewable energy use in Europe from 24 January 2008, will put much emphasis on wind energy – it is possible that wind power would provide up to 15-20% of all electricity in Europe by year 2020. This will put very strong pressure to develop larger and more reliable wind machines, often in wind regimes and heights where little experience is available. The influence of turbulence in particular on performance and durability is a highly critical factor. European research infrastructures in this area but addressing in parallel local conditions (e.g. magnitude of microturbulence) would be beneficial. Proposal RU36 European Centre for Turbulence and Wind Energy fits well into the RI landscape.

Biofuels for transport are highly strategic for Europe. There is a general debate on the effectiveness and sustainability of different biomass feedstock and biofuel conversion paths. So-called 2<sup>nd</sup> generation biofuels based often on lignocelluloses or waste are perceived as a benign solution and prerequisite for large-scale deployment of biofuels., the challenges are more acute. The R&D infrastructure for 2<sup>nd</sup> generation biofuels is not available yet. There is a crucial need to demonstrate the technology at a relevant industrial scale. Such pilot plants could serve more profound research on advanced biofuels. The R&D priority incl. RI is on the development of advanced conversion processes and bio-refineries, i.e. the integrated conversion plants for biofuels and bio-products. Also, advanced biomass gasification plant could be a relevant topic in this context.

Ocean and marine energy is a new field of renewable energy, though having a relatively large potential in some ocean-shore sides of Europe. One RI identified here would be a versatile European test capability including cabling and grid connection covering the different technology approaches for marine energy. Some kind of networking between different European research institutes to form a virtual RI could be one possible approach.

Solar thermal power based on concentrating collectors has received renewed interest world-wide with interesting utilization possibilities in southern latitudes. Concentrators can be used for steam, electricity, fuels and chemicals production. There is a clear need for a truly European large-scale facility incorporating different concentrator technologies and energy processes and being located in the sun-belt. Such an effort could bring together dispersed skills and groups for Europe together, even more globally (e.g. Russia, USA, Japan, Central Asia). The key features of the proposal RU34 European Renewable Energy Infrastructure addressed the central RI issues of the concentrated solar power in Europe.

Smart-grids: Going for large-shares of intermittent energy and distributed production means major challenges for electricity transmission. Present solutions have a limited carrying on capacity. Smart grids could be one technical solution. Here a full scale European grid research infrastructure incorporating flexible production, load and grid set-ups would be an important RI enhancing innovation in the field.

Fuel cells and hydrogen: The Commission recently launched the first energy Joint Technology Initiative (JTI) in fuel cells and hydrogen. The JTI should pave the way for a breakthrough of this technology on a long-term run. A lot of R&D in different technologies and by different actors are foreseen. At this stage, the RI needs in fuel cells and hydrogen seems to be related to EU test facilities for H<sub>2</sub> safety and security, standardization work but also to full scale demonstration type projects on H<sub>2</sub> infrastructure. Additionally, R&D efforts on hydrogen-from-renewables will be necessary if hydrogen were become an important energy vector in the future.

Zero-emission plants: Fossil fuels play an important role in power production and in the years to come. Climate change mitigation will necessitate carbon removal and storage (so-called CCS). Large scale experimental facilities to enable research on both CO<sub>2</sub> removal from flue gas and storage of CO<sub>2</sub> in geological formations will be essential to enable CCS. Taking the global dimension and European competitiveness aspects, creating necessary RI would be urgent. This would in turn pave the way for zero-emission power plants. An important point with CCS research infrastructure is an adequate size of the facility (closer to a demonstration plant) and that key stages of the CCS, namely flue gas – sequestration-storage are present in the facility. Taken the scale of RI needed, it is perceived that a few European joint facilities would be an effective approach covering the different variants of CCS. Proposal RU29 European Carbon Dioxide Capture and Storage Laboratory Infrastructure is well in line with needs.

In other renewable energy sources not covered above such as solar heating, solid-biomass, hydro power, speculative energy forms, etc. the group could not identify relevant single RI needs. Some kind of networking among R&D performers or test centres to form virtual networks could provide additionally, but their link to ESFRI is not fully clear.

The PSE recommends that a RI facility for solar thermal energy (solar heating and cooling) may be formed as a network with experimental and demonstration facilities placed in different climatic zones. These sites could be used for explorations of different building designs and solar technologies with participation from industries and academia.

Oil and gas: No major RI needs identified.

Co-generation: No major RI needs identified.

Fission and fusion: Nuclear energy has been subject for intensive collaboration for a long time and much of the science is actually done around large facilities, and The Euratom programs has to a large extend provided the strategic stewardship. The first ESFRI round included 3 projects in nuclear energy. It is foreseen that e.g. Generation IV nuclear reactor R&D may create new RI ideas in the coming years, e.g. test reactors, which could be captured by future ESFRI landscape updates. The fusion side is well covered by ITER and IFMIF facilities, these are closer linked to the EURATOM than to national research infrastructure questions. The JHR facility is important for reactor material research. Proposal MYRRHA, Multipurpose hYbrid Research Reactor for High-tech Applications represents accelerator driven reactor research. The proposal MHD Dynamo Platform related to plasma physics and magnetohydrodynamic phenomena fall aside present priority areas.

### **3.1.4 Summary of the assessments of the proposed energy research infrastructures:**

The detailed assessments are included in section 4.

ECCSEL: The proposal was not found fully matured in the first round, but based on the up-dated proposal and supporting documentation, and after extensive discussions the PSE RWG found that the ECCSEL proposal as the highest ranking of the energy proposals is a suitable candidate for the roadmap update.

TEREI-SOLAR: The reformulated proposal now focused on concentrated solar power; it deals with an upgrade of existing facilities located at Almeria in Spain. After extensive discussions and motivated by the wish to limit the number of proposals the PSE decided to maintain its recommendation as an emerging project.

WINDSCANNER: The revised project is deemed very relevant for further research and development in the field with links to the Wind Energy Technology Platform and the large FP6 project UPWIND. After extensive discussions and motivated by the wish to limit the number of proposals the PSE decided to maintain its recommendation as an emerging project.

MYRRHA: The proposal was in the first round recommended to be maintained as an “emerging” project. After extensive discussions in the second round the PSE RWG maintained its recommendation of MYRRHA as an emerging project pending the definition of the final specifications.

## **3.2 Landscape for Materials Research.**

The use and development of materials has been of enormous importance for the European civilisation and culture. In fact the different periods of our history is often named after the material used at the time, Stone Age, Bronze Age and Iron Age. The ongoing progress of information and communication technology is largely based on the development materials for transistors and lasers. Another important contribution in this field comes from the discovery of the Giant Magneto Resistant, which is the scientific breakthrough for which A. Fert and P. Grünberg were awarded the 2007 Nobel Prize in Physics and constitutes the basis for modern magnetic memories in our computers.

A most important trend in Materials Research today is the synthesis of materials and structures of materials with very small dimensions, which popularly called Nano Materials. This type of materials has already proven their value in applications from catalysers to electronic components and is also used in medical, mechanical and many other applications. Some people believe that future historians may say they call the present time the Nano Age to follow the time period mentioned above.

### **3.2.1. General considerations.**

The advanced research new materials need access to well equipped laboratories both for synthesis and characterization. Among the necessary infrastructures for Materials research is: Clean rooms for synthesis and processing; Synchrotron radiation sources; Free electron lasers; Neutron sources; High power laser laboratories; High magnetic field laboratories; and High resolution electron microscopes.

The complexity of Materials research is large both what concerns the different classes of materials as well as their applications and most important in this case the size and cost of the infrastructure. Infrastructures in Materials research may be divided in two main categories: (a) Exceptional European, and (b) Networks of unique competence. With Exceptional European installation are understood infrastructures, which due to their high costs only one can be build in Europe. Examples of laboratories in the first group are the X-ray Free Electron Laser and the European Spallation Source. To the second group belongs network various synthesis and characterization laboratories for materials, such as clean rooms, high magnetic fields and electron microscope installations.

The RI landscape for materials research can be described in three parts: (1) nanomaterials; (2) light sources; and (3) neutron sources. The Nanomaterial part encompasses network of synthesis and characterization laboratories, the Light sources are both network and Exceptional European installations and the Neutron sources are now Exceptional European Installations.

### **3.2.2. Nanomaterials.**

Nanotechnology is the manipulation or self-assembly of individual atoms, molecules, or molecular clusters into structures to create material and devices with new properties. As such it covers a very broad domain of applications which can be divided in following categories on which research is performed in many research infrastructures spread over Europe: nanomaterials; electronics and systems; fundamental research (chemistry and physics); analytical and diagnostics; engineering and fabrication; nanobiotechnology and energy.

There is no doubt that nano-science and technology is and will be one of the major research and development areas for the coming decade. Due to its very multidisciplinary nature, the question on research infrastructure needs is quite different from that of other fields. A broad range of often smaller but dedicated and complementary equipment is needed in one single site in order to be able to perform all processing and characterization steps needed. An overview of the future areas on nano-science and -technology was already given in the previous roadmap report and is still valid.

According to the recent (July 2007) report “European Nanotechnology Infrastructure and Networks” of the Nanoforum ([www.nanoforum.org](http://www.nanoforum.org)), a total of 303 research infrastructures dealing with nano-science and -technology can be identified in Europe. The centers are spread over 30 countries. 18 centers can be considered as major EU research infrastructures with large scale facilities (clean rooms and state of the art equipment) and annual budgets in the multi-million range. These large centers are concentrated in Belgium (1), France (6), Germany (3), Ireland (2), Switzerland (2) and United Kingdom (4). 102 centers are engaged in the field of nanomaterial research and fabrication. 58 international networks dealing with nanosciences exist in Europe.

The nanoforum report illustrates however that significant differences exist between countries. The centers in France for example have a focus on electronics and nanobiotechnology while Germany has an infrastructure covering all areas. Like the United Kingdom, Poland has a strong base in nanomaterials, electronics, fabrication and analysis.

Some countries have more limited facilities and no large scale centers. They would benefit from better information on the existing infrastructure and from easier access to these facilities. The report clearly shows that Europe has already a large number of research centers dealing with nano-sciences and -technologies.

To avoid unwanted duplication of large infrastructures and the high associated investments and running costs, it makes sense to put the leading centers in specific fields in network and to stimulate the access from other, smaller centers and research groups from all countries to this virtual paneuropean large infrastructure.

This is what is proposed in the already listed “Pan-European Research Infrastructure for Nano-Structures (PRINS)” project proposal which is focusing on existing large scale facilities dealing with ultimate silicon and heterogeneous integration and is grouped around CEA-LETI (France), FhG (Germany) and IMEC (Belgium). The three consortium partners are in the list of 18 major research infrastructures for nanoscience in Europe as identified in the Nanoforum report. This distributed (ultra)large scale facility will collaborate with the European nanoelectronics community through the strategic European Technology Platform “ENIAC”. The total cost of the PRINS project is estimated to be of the order of 3 B€ whereof a significant amount will be raised by industry in a public-private partnership.

The new ESFRI project proposals “Nanoscience Foundries and Fine Analysis (NFFA)” and “Pan European Research Infrastructures for Nano-Structures –an extension to central Europe (PRIN-CE)” can in some sense be considered as projects that fit well in the PRINS initiative.

NFFA covers a broad range of nanoscience areas and proposes a close linkage of nanoscience facilities with existing or planned large scale facilities for material analysis. Only one of the five partners of the NFFA consortium is a large research infrastructure (CMF in United Kingdom) as identified in the above mentioned list of 18 while the other partners can be considered as medium or small sized infrastructures. As commitments and budgetary aspects are not yet clear nor the relation with the PRINS project, NFFA should be considered as an emerging project. The proposal could be further developed in close connection with the PRINS consortium during the preparatory phase of the PRINS project.

PRIN-CE is very much a Polish national project with weak international involvement at the moment. The intention is to set up a large research facility for nanoscience research. In view of the large number of already existing facilities in Europe it would be good to explore synergies and complementarity during the preparatory phase of PRINS. At the moment the PRIN-CE proposal seems to be still in an immature phase.

EMFL is a network of high magnetic field laboratories. High magnetic field studies are an important characterisation in many areas of materials research. The EMFL proposal aims to create an integrated facility of four existing European high magnetic field laboratories (the Grenoble High Magnetic Field Laboratory (GHMFL), the Laboratoire National des Champs Magnétiques Pulsés (LNCMP) in Toulouse, the Hochfeld-Magnetlabor Dresden (HLD) and the High Field Magnet Laboratory (HFML) in Nijmegen).

Traditionally Europe has had a strong position for high magnetic field studies. At present, however, the state of the laboratories is in the USA. This proposal addresses this situation and aims to strengthen the European position. The laboratories involved in the proposal provide an excellent basis for a new network ESFRI network of high magnetic field laboratories. The PSE working group strongly recommends this proposal for further considerations within ESFRI.

### **3.2.3 Large Neutron Infrastructures in Europe**

It is widely acknowledged that neutron science is one of the scientific techniques in which Europe has clearly been world leading over the last 30 years. It is estimated that there are currently about 5000 European scientists using neutron scattering as part of their research programmes.

This success has been based on several factors:

- (i) A network of small and medium national sources, mainly multi-purpose reactors, which have made key contributions to scientific achievement, technical development and training of students and researchers, and to the growth and support of the scientific user community. These include the steady-state reactors BENSC in Berlin, Germany, FRG-1 in Geesthacht, Germany, FRM-II in Garching, Germany, LLB in Gif-sur-Yvette, France, BNC in Budapest, Hungary, RID in Delft, the Netherlands, JEEP-II in Kjeller, Norway, NPL-NRI in Řež, Czech Republic as well as the continuous spallation source SINQ in Villigen, Switzerland. Some sources were closed in recent years but this has been compensated for by new facilities such SINQ (1998) and FRM-II (2005). The second target station of the ISIS pulsed spallation source in the UK will be open for experiments in the autumn of 2008. The more recent sources were all purpose built for neutron science.
- (ii) The Institut Laue Langevin (Grenoble, France), acknowledged as the world leading facility for neutron science, is a very good example of successful collaboration between European countries. France and Germany made the initial agreement in 1968 and were followed soon after by the UK as the third associate member. Since 1987 the ILL has incorporated 9 more countries as new scientific members, making it a real European centre of excellence. It acts as the focal point of the European neutron community and is a centrepiece of the European Research Area. An ambitious modernisation programme was started in 1999. The ILL 20/20 Upgrade project to be implemented between 2007 and 2016 is part of the ESFRI Roadmap and will retain the leading-edge character of this facility.

- (iii) The operation of most European facilities, particularly the larger ones, has been primarily for the research programmes of external users (e.g. university researchers), with a culture of scientific excellence based on peer review.

Neutron scattering is one of the few scientific methods that have no 'small-scale' equivalent. Successful scientific exploitation of neutrons, as realised in Europe over the past 30 years, requires the maintenance of a number of sources providing for three key factors, viz. capability, capacity and variety. This should be the basis for the development of a strategy for neutron scattering in Europe over the coming decades.

During the 1990's attention was drawn to the fact that 2/3 of the existing neutron reactor sources would be approaching the end of their expected operating life between 2000 and 2020, and that steps should therefore be taken to provide for new capability. It was recommended that a 'next-generation' source should be built in each of the major world regions – America, Europe and Oceania. In the USA and Japan it was recognised that, as well as replacing capacity, there was a need to significantly improve capability.

Following a design study in the USA it was realised that a high-flux reactor source of significantly higher power than the ILL (50 MW) was not a realistic or cost effective option, so it is now generally accepted that all new high power sources will be based on spallation. Therefore it is questionable whether the 100-MW reactor PIK presently under construction in St. Petersburg, Russia will ever become a high-performance facility. The USA and Japan have, accordingly, made major investments, of order 1.5 billion euro each, in new, pulsed spallation sources. SNS in Oak Ridge, USA has become operational since 2006. J-SNS in Tokai, Japan will become operational soon. Conversely, the 1.5-MW pulsed reactor IBR-2 in Dubna, Russia is being reconstructed and will go into operation in 2010 with water moderator and in 2012 with a cryogenic moderator complex. This long-pulse facility may play a significant role until a powerful long-pulse spallation will be constructed in Europe.

ESS, the European Spallation Source, part of the ESFRI Roadmap should become the world's most powerful neutron source. The decision on the site of this 5-MW long-pulse source is due in 2008. Provided that its construction starts in 2010, the facility may become operational in 2017. This will ensure Europe's leading role in neutron scattering in the twenties. In the course of the work of the PSE the ESS project has been the subject of specific ESFRI initiatives. Three countries have announced their bids to host the ESS at specific sites and ESFRI has responded by forming a Working Group on ESS Siting in December 2007. The Working Group has established an international expert Site Evaluation Group SRG to conduct individual assessments of the proposed sites. The results will be presented to ESFRI at the meeting in September 2008.

### **3.2.4 Photon Sources:**

Photon Sources: Light photons are only one, but the most flexible, of the many complementary "probes" which can be used. They are needed over a large range of "colours", from the Far Infrared range up to the Hard X-Rays. Large related instruments are Synchrotrons, Integrated Laser Laboratories or High Power Lasers. They serve a broad community of users far beyond physics and material sciences. This is particularly true for synchrotron light sources. Biology and life sciences, environmental sciences as well as earth and universe ones and more recently archaeology and palaeontology are now their main users. High power lasers and Synchrotron light sources are also used to produce and study plasmas, e.g. the conditions for energy production by fusion, or to produce devices through lithography.

A technological breakthrough is now occurring with the Free Electron Lasers (FELs). They are capable not only of much higher brilliances than third generation synchrotron sources, but also of femtoseconds short time "flashes" opening the dynamic "filming" of atom related properties. Their new capabilities will allow the exploration of a new terra incognita by opening novel areas of research inaccessible with the third generation synchrotrons. Actually, the first exciting results in atomic and molecular physics are already coming out from the operation of the Flash soft X-ray facility in Hamburg. In this range of photon energies, Europe is well endowed

since several European national projects with different characteristics are presently in construction or in design. They have joined within the IRUVX-FEL consortium to develop R and D together and to coordinate their programs. In the hard x-ray domain, the size and cost of a FEL facility imply international collaborations at continental levels such as the international European XFEL facility. X-FEL aims at the measurement of the structures of clusters and single macromolecules with atomic definition, as well as at time resolved “atomic movies “. The project has moved on much in the past two years with the agreement of many European countries to join it. It is now close to start its construction. Its characteristics will make it the most powerful and the brightest X-FEL worldwide and should give Europe a dominant position in the field. It is thus vital that its construction moves on as quickly as possible.

In the field of *synchrotron light sources* where Europe has a long tradition of excellence with the ESRF leading the field worldwide, the landscape has evolved much in the last past years thanks to a continuous effort made by several EU countries. Three new bright medium energy facilities, SLS in Switzerland, Diamond in UK and Soleil in France are now in full or partial operation, while a fourth one, ALBA, is in construction in Spain. There are also new projects coming out like the innovative MAX IV one in Sweden, as well as suggestions for implementing new facilities in central Europe. This increase in the European capacity is a necessary answer to the ever-increasing demand of the still growing user community of more than 10,000 researchers. These new facilities are also complementary to a significant extent in terms of their experimental possibilities and scientific programs. In the field of hard X-rays, the rebuilding of a part of PETRA at Hamburg will provide a new low emittance high energy facility, Petra 3, which will significantly increase the European capacity. However, the International facility *ESRF* in Grenoble, which is one of the most successful European scientific initiatives, has to keep its position of leader for X-ray science worldwide. It is thus vital that its ambitious upgrade program, which is supported in the ESFRI Roadmap, be implemented soon and at the appropriate level.

The frontier of laser science is presently progressing at an extremely steep gradient in many different directions. New projects of extremely high power lasers are coming out opening new perspectives not only in basic research (ultra-relativistic intensity regime) but also as in applied areas (particle acceleration, development of efficient compact secondary sources of electron, ions and photons). Europe is in a good position in that competitive field with quite a few excellent institutes already working together within a I3 program and with the ambitious and innovative *ELI* project that gathers most of them. *ELI* aims at building the most powerful short pulse laser installation worldwide. The decision to build such a European facility is a necessity to maintain the European leadership in this very rapidly evolving domain. Important societal applications might greatly benefit from it (compact accelerators, hadron and radiation therapies, medical imaging, etc...).

### **3.3 Landscape of engineering research**

Engineering research typically has components of basic and applied research as well as experimental development. This means that many of the RI used for materials research also serves the engineering research communities. In other words many of the users at these facilities come from engineering departments at European universities and from industrial R&D departments. This is particularly true for the neutron beams and synchrotron radiation facilities. Engineering research communities are also heavily involved in the development of the RI's in PSE areas. New RI's take advantage of the latest advancements in technology and in many cases are key drivers for such advancements. The long string of spin-offs from RI-institutions like CERN is a testimony to that effect. Many of the ESA projects have an industrial engineering rationale as well as the scientific rationale.

The new proposals in the field of engineering research were related to aeronautical and aerospace research; safety research and fluid dynamics.

#### **3.4.1 Aeronautical and aerospace research**

Here the proposed LVR-HALE research platform is envisioned to be a flying laboratory capable to perform aeronautical research that meets requirements in terms of altitude, endurance and autonomous mission management. Its nominal performances are: 30 days endurance; 20 km altitude; fully autonomous flight; quasi-

geostationary flight. LVR-HALE will provide a flying platform for a wide range of applications and needs for research in aerodynamics, material technology, innovative structural concepts, innovative air transport system operational concepts. In addition auxiliary technologies can be tested such as on-board clean energy systems using fuel cells and photovoltaic cells, atmospheric pollution. LVR-HALE will also offer options for real-time monitoring of seismic areas, hydrograph monitoring, telecommunication services.

Another specialized flying test bed ACT/FHS. It is operated and owned by DLR and has been operational since the end of 2002. It is a European oriented flying test bed for innovative aeronautics technologies. The basic aircraft, an Eurocopter EC135, has been converted to fly-by-light helicopter with variable stability characteristics in order to allow research tasks to be performed in Flight dynamics, Flight systems, Flight guidance, Aerodynamics, measurement technologies and avionics. The ACT/FHS contributes to various initiatives such as FRIENDCOPTER, the smart rotorcraft, the quiet rotorcraft.

The DLR also develops an Advanced Testing Research Aircraft, ATRA. This aeroplane will be operational by the end of 2009. It will be unique in Europe because providing the widest scope of research possibilities in the area of flight testing, and it is oriented test innovative aeronautics technologies. The basic aircraft, an Airbus A320 -232, will be converted in order to allow research tasks to be performed in Flight systems, Flight guidance, Aerodynamics, Cabin research, measurement technologies and avionics. ATRA will give the European community of universities and Research establishments the possibility to test technologies on an industry standard aircraft.

### **3.4.2 Safety research**

The proposed L-SURF addresses the safety research needs from their increasing level of public mass transportation interconnections – especially underground - between different means of transportation (e.g. airport connected with rail and metro through a hub with a shopping mall included). The relevant boundary conditions of such spaces are limited access and therefore also provides limited escape routes as well as very special ventilation systems, resulting in safety risks in connection with dispersion of gases, spread of fire or distribution of Chemical, Biological, Radiological, and Nuclear material. The proposed L-SURF facility will offer flexibility of boundary conditions regarding the shape of cross sections, the ventilation of tubes and hubs, the surface properties – which is of importance for human behaviour – and the combination (like links and crosses) of different types of subsurface spaces. L-surF will also cover all environmental aspects being it waste air, waste water and solid waste.

### **3.4.3 Fluid dynamics**

The proposed CICLOPE is a new “single-site” RI created to develop high Reynolds number experimental facilities for detailed turbulence measurements. In combination with computational resources, the facility will provide a focus of activity for leading international researchers in the field of high Reynolds number turbulent flows. The main experimental apparatus, i.e. a large pipe flow facility (pipe diameter of the order of 1 meter and a length larger than 100 meters), is intended for at least ten years of basic research and has the potential for extensions with more direct impact on applications, such as the study of the effect of non-smooth walls or non-isothermal conditions, the evolution of various non-equilibrium flows, and of flows with some particulates. It is a national initiative aimed at an international user community.

The PSE has found that none of the proposals in the area of engineering research meets the science criteria based on the Frascati Manual definitions. Their main scopes are experimental developments and hence they fall outside the categories of the RI's to be included in the ESFRI Road Map.

## **3.3 Astrophysics, Astronomy, Particle, Nuclear, and Ionospheric Physics**

The subfields of Astronomy and Astrophysics, Nuclear Physics, Particle Physics, and Ionospheric Physics have a long tradition of coordination and international Institutions developing internationally agreed, designed and open-access projects, which ensure both a rational use of resources and the capability of long-term planning to

develop a coherent set of specialized roadmaps. In the case of Astronomy, Astrophysics, and Ionospheric Physics as well as in Astro-particle Physics, the issue of Space borne instruments is of obvious importance. One issue that has been brought to attention is the need of better coordination between Space and Ground long term planning of the needed infrastructures.

### 3.3.1 The proposed facilities and general considerations

The proposals to be submitted to ESFRI are the following (the dagger (†) indicates proposals that are new in this update – that were either classified embryonic/emerging in the previous roadmap or are new proposals; the asterisk (\*) indicates the RI where long term institutional commitments are still to be developed):

- **ELT**: Extremely Large Telescope
- \* **SKA**: Square Kilometer Array
- **KM3Net**: European deep sea neutrino telescope with a volume of at least one cubic kilometre
- † **CTA**: Cherenkov Telescope Array
- **FAIR**: Facility for Antiproton and Ion Research
- **SPIRAL II**: Système de Production d'Ions Radioactifs Accélérés en Ligne
- † **DAΦNE II**: Major upgrade of the Frascati e+e- Collider
- † **EISCAT-3D**: Next generation European Incoherent Scatter radar system

In the subfield of Nuclear Physics, the NUPPECC organization has been the main reference to converge towards a selection of proposals joining the criteria of Pan-European impact with the need of a small and significant set of major proposals. Some proposals by NUPPECC have been not included but the EWG recognizes their importance in the overall field, although they are of a size that can be easily realized within the existing resources of the Institutions operating in the field.

### 3.3.2 The overall landscape

In the exploration of the universe as a whole, of the objects in it and in a better understanding of the constituents of matter and their behaviour science has made enormous progress in the recent decades. But this progress has produced a lot of new fundamental questions which are today on the agenda of astrophysics, astroparticle physics, particle physics and nuclear physics. Now these research areas are in many ways interconnected. Examples are the search for dark matter or dark energy, the origin of mass or nuclear astrophysics. The exciting scientific perspectives and new technological developments have inspired the creativity of the scientists and led to a lot of proposals with a sound scientific and technical justification. Basic science has always been a driving force for the development of new technologies to improve the collection of information from the farthest distances and from the smallest dimensions of space. On the other hand new instruments have always led to new discoveries and new insight. But in the course of this development the facilities in fundamental physics and astronomy have become much larger, technically more complicated and very expensive. More than ever before it has become a necessity to join the intellectual and financial resources of many countries to realize these projects.

In **astronomy** outstanding discoveries in recent years have induced new fundamental problems. These include the nature of Dark Energy and Dark Matter, the emergence of the first stars and galaxies in the universe and their evolution, the description of gravity, and planet formation around other stars. To tackle these and other questions a new suite of instruments is required to provide data across the electromagnetic spectrum.

Current **ground-based optical astronomy** can use as largest instruments a set of 8-10 m telescopes, but it has become clear that the challenge of the new fundamental questions require still larger collecting area and larger

angular resolution. The **Extremely Large Telescope (ELT)** has been proposed as the follow-up project of the current generation of optical telescopes. With segmented mirrors and adaptive optics it seems possible to construct telescopes with diameters of up to 100 m. For many reasons there is now a concentration on 30-50 m class telescopes, which represent a natural scientific and technological step towards larger sizes.

The ELT will enormously deepen the knowledge in nearly all fields of astronomy, e.g. will help to investigate the formation of structure in the very young Universe and will allow studies of extra-solar planets in our galactic neighbourhood.

In **radio astronomy** there is consensus in the scientific community that the next generation telescope should be the **Square Kilometre Array (SKA)**. The SKA will have a collecting area of one million square metres distributed over a distance of at least 3000 km. This area will result in a 100 times higher sensitivity compared to existing facilities necessary to see the faint signals from the early universe. The radically new concept of an “electronic” telescope will allow very fast surveys. Thus it will be possible to tackle many important problems in cosmology and fundamental physics, e.g. tests of the theory of relativity or the formation and evolution of galaxies. The site for SKA is likely to be outside Europe.

Neutrino detectors have opened a new window for observations and a new field in astroparticle science, that of **neutrino astronomy**. The **Cubic Kilometre Neutrino Telescope (KM3Net)** will consist of thousands of optical sensors distributed in a volume of about one cubic kilometre in the depth of the Mediterranean Sea. The sensors detect the light which is produced in the water by charged particles originated from neutrinos and the earth. It is aimed to monitor the universe continuously – together with the ICECUBE neutrino detector currently under construction on the South Pole. It will search for distant sources like gamma ray bursters, supernovae or colliding stars.

In **gamma ray astronomy**, a **Cherenkov Telescope Array (CTA)** is proposed. There has been major progress in this field, where the HESS and MAGIC projects have observed a multitude of gamma ray sources both within the plane of our galaxy and outside our galaxy. The CTA will greatly extend the reach of these current projects and allow for further exciting scientific discoveries. The idea of CTA is now mature enough and the relevant research groups have coalesced into a coherent structure. The promise of this approach has also been noted in a recent ApPEC statement.

**Nuclear physics** has been revolutionized by the recent development of the ability to produce accelerated beams of radioactive nuclei. For the first time it will be possible to study reactions between the 6000 to 7000 nuclei we believe exist rather than the 300 stable ones that nature provides. Modern nuclear physics has two main aims. At the larger scale one wants to understand the limits of nuclear stability by producing exotic nuclei with vastly different numbers of neutrons and protons. At the smaller scale one wants to explore the substructure of the constituent neutrons and protons, for it is in the interaction of their constituent parts that the ultimate description of nuclei must lie.

There are two approaches to producing radioactive beams – the “In-Flight Fragmentation” and the “ISOL (isotope-separation on-line)” techniques. The In-Flight production technique is fast and can produce the shortest-lived radioactive nuclei, whereas the ISOL technique can provide more intense and better controlled beams for detailed studies. So both techniques are complementary.

The leading In-Flight facility will be the **Facility for Antiproton and Ion Research (FAIR)** planned as an international research centre in Darmstadt (D). The technical plan for the first stage and the legal documents will allow starting the centre in 2008. The central part of the facility are two superconducting synchrotrons which will deliver high intensity ion beams up to 35 GeV per nucleon for ions up to uranium and with secondary radioactive beams and antiprotons. FAIR will allow a broad spectrum of research programmes e.g. with cooled beams of antiprotons, for nucleus-nucleus collisions and for nuclear astrophysics investigations.

**SPIRAL-2** is a major expansion of the SPIRAL facility at GANIL in Caen (FR) which will help to maintain European leadership in ISOL development and is an essential step on the road to EURISOL. The technical challenges of the acceleration, targetry and experimental equipment will provide essential knowledge and

continuity. The **EURISOL** facility is intended to be the ultimate ISOL facility, for which a design study is under way, but the start of this facility is not expected before 2018, since formidable technical challenges have to be tackled. Therefore an intermediate step as SPIRAL 2 is required and essential.

**DAΦNE II** a high luminosity  $e+e$  – collider in the energy range between 1 and 2.4 GeV based at Frascati(I) has been proposed in Nuclear Physics. This facility will allow precision experiments in fundamental symmetry violations in the Kaon system, which are a probe of physics beyond the Standard Model. A program in Hypernuclear physics will also be carried out, which bridges the disciplines of High Energy and Nuclear Physics. In addition this collider will be the testbed for the development of beam handling techniques crucial to the operation of all future high luminosity colliding beam facilities.

**Particle physics** stands on the threshold of a new and exciting era of discovery. The next generation of experiments will explore new domains and probe the deep structure of space-time. European particle physics is founded on strong national institutes, universities and laboratories and the CERN Organization. The CERN Council created a Strategy Group which elaborated a Roadmap for the needs of the field, with the following major elements (reference):

- The Large Hadron Collider LHC at CERN will be the energy frontier machine for the foreseeable future and should fully exploit its physics potential. R&D has to be pursued now for a luminosity upgrade by around 2015.
- In order to be in the position to push the energy and luminosity frontier even further it is vital to strengthen the advanced accelerator R&D programme (CLIC technology, high performance magnets, high intensity neutrino facility).
- It is fundamental to complement the results of the LHC with measurements at a linear collider. In the energy range of 0.5 to 1 TeV, the ILC, based on superconducting technology, will provide a unique scientific opportunity at the precision frontier.”

**Ionospheric physics** studies the earth’s nearby space environment and its interaction with the solar radiation. As such it provides crucial input to the overall study of the Earth as a system and is of significance in the study of the Earth’s long term climate. **EISCAT 3D** an incoherent scatter system based in the northernmost parts of the European continent will allow for the first time the three dimensional real time mapping of the ionosphere and lead to a more complete and coherent view of the near earth space environment.

### 3.3.3 Particle Physics

Particle physics stands on the threshold of a new and exciting era. The next generation of experiments will explore new domains and probe the deep structure of space-time. Long-standing puzzles such as the origin of mass, the matter-antimatter asymmetry of the Universe and the mysterious dark matter and energy that permeate the cosmos will soon benefit from the insights that new measurements will bring.

The facilities in experimental particle physics are large and technically challenging. More than ever before it has become a necessity to join intellectual and financial resources to realise these projects. European particle physics is currently world leading, and has developed an efficient model for constructing and operating large research facilities, based on national institutes, a very large number of universities and laboratories, and the CERN Organisation.

Constructing such facilities requires focused R&D and technological innovation in a number of fields, covering from superconducting RF cavities and magnets, to new sensor technologies, advanced electronics and computing methods. The particle physics community has a strong tradition for efficiently developing and improving technologies, in collaboration with industrial partners, for use in new projects, often with significant applications outside the field of particle physics. Recent examples are light sources, GRID computing and medical applications for treatment and diagnosis. With very ambitious technical specifications for new projects, an international network of expertise throughout European research facilities and industries, a large participation of young researchers, engineers and students, particle physics has become a model for how large research facilities are planned, constructed and operated, and how large collaborative European and global research projects can be organized.

In 2006 the **CERN Council** created a Strategy Group that elaborated a Roadmap for the field. The follow-up of this strategy is done in regular European Strategy Sessions of the CERN Council. Currently the European particle physics community enters a particularly exciting period, where large facilities are operating collecting unique data, while in parallel extensive R&D is ongoing for new projects. This is reflected in the Roadmap, where the major scientific elements are:

- The Large Hadron Collider (LHC) at CERN now starting will be the energy frontier machine for the foreseeable future and it has the highest priority to fully exploit its physics potential. Depending on the nature of the discoveries made at the LHC, higher-statistics studies of these phenomena would naturally call for an increase in luminosity. This upgrade – referred to as Super-LHC – should increase the luminosity by a factor ten.
- It is vital to strengthen the advanced accelerator R&D programme in Europe, providing a strong technological basis for future projects in particle physics.
- It is fundamental to complement the results of the LHC with measurements at an electron-positron linear collider. Such a linear collider will provide a unique scientific opportunity at the precision and energy frontiers. This programme can be carried out by the International Linear Collider (ILC) or if multi-TeV energies are needed, a novel design called the Compact Linear Collider (CLIC) has the potential to deliver such energies. For essentially every new physics scenario involving particles in the linear collider energy range, detailed and very promising research programmes have been formulated. The linear collider studies are in the R&D and technical design phase, and also here LHC results will guide the way.
- Neutrino physics opens another exciting window to study physics beyond the standard model. Recent measurements of neutrino oscillations and masses, and the possibility of observing CP violation in this sector, point forward to the need of constructing more advanced neutrino facilities, and design studies are ongoing. Which route to take, depends on the result of accelerator R&D, and on results from experiments now starting.
- New initiatives and plans are being developed in the field of flavour physics where the Super-B facility near the INFN National Laboratory of Frascati is a possibility being pursued.
- Several important experiments take place and are planned in the overlap region between Particle and Astroparticle Physics, or between Particle and Nuclear Physics. Examples of such experiments can be found in Europe's four world-class deep underground laboratories: Boulby (UK), Canfranc (Spain), Gran Sasso (Italy) and Modane (France). These facilities study neutrinos – including in some cases long baseline experiments with accelerator neutrinos, and search for dark matter and for proton decays.

Common for several of the large future facilities mentioned above is that they are now in the preparation phase, and before definite construction programs can be launched, the scientific case has to be confirmed and elaborated with detailed measurements in ongoing projects, the technical solutions and designs have to be further developed and supported by rigorous R&D programmes, and the formal collaboration agreements and organisations prepared.

At the time of the next major update of the European Strategy for Particle Physics foreseen for 2011, these preparatory studies will be reaching conclusions, paving the way for new major construction projects.

## 4. Descriptions and assessments of the individual projects

### 4.1 Energy proposals

#### **RU 03 MYRRHA** (Multipurpose Hybrid Reactor for High-tech Applications).

MYRRHA is a plan for a European fast spectrum experimental facility able to demonstrate efficient transmutation and associated technology through a system working in a subcritical mode. The proposed facility combines both a fast neutron spectrum and a high flux level (up to  $3 \cdot 10^{15}$  n/cm<sup>2</sup>.s). The technical concept is based on employing a particle acceleration that generates high energy protons (350/600 MeV) which in turn create fast neutrons when colliding with a spallation target. For the accelerator, either a cyclotron or a linear accelerator system (LINAC) will be employed. The accelerator is coupled with a reactor core which consists of 30 wt% Pu-enriched MOX fuel pins. The spallation target module is located in the centre of the core. The whole installation is placed inside a reactor vessel including all equipment needed to operate the system. Rather than going for a critical reactor core, a subcritical level has been chosen with  $k_{\text{eff}} \sim 0.95$  to assure better safety. The thermal power is in the range of 50-80 MW<sub>th</sub>. The basic concept for producing fast neutrons is well-known.

The facility is intended to be used to demonstrate the applicability of partitioning and transmutation of long-lived fission products and actinides into less harmful elements. Another research aim is nuclear reactor research, in particular sodium, gas, and lead fast reactors. Fast neutrons can be used to a range of other applications as well for example production of radioisotopes or more fundamental physics research such as fusion physics.

The facility is proposed by SCK-CEN from Belgium. The detailed engineering and planning would take 4 years and the construction about the same time. The facility could be ready for operation around 2017 at earliest. The construction cost of the facility is 700 million € and for operation around 40 million €/year is needed.

MYRRHA is foreseen as a flagship facility for innovative research on radioactive waste management and Generation IV reactor systems, taking in particular advantage of the fast neutron spectrum. MYRRHA was not selected for the first ESFRI Roadmap 2006 as it was considered not sufficiently mature and it was then classified as 'emerging' project. The Strategic Research Agenda of the SNE-TP (Sustainable Nuclear Energy Technology Platform) has not yet concluded which Generation IV reactor systems and which actinide recycling technologies will be developed in the EU. Decisions on the technology paths to be chosen are expected in 2010 – 2012. New European nuclear facilities should follow these prioritizations.

MYRRHA has matured over the last two years and will be ready for detailed engineering design in 2009. The associated R&D projects have been supported by FP5 and FP6 and the EC RTD strategy for FP7. The project is supported by the research community in the Platform for Sustainable Nuclear Energy (PSNE), and the R&D efforts are part of the global GEN IV cooperation. It has official support from the Belgian government and institutions but need substantial funding contributions from other partners.

The only fast neutron facility in the EU is the French reactor PHOENIX, which will be closed down in 2014 and MYRRHA will then be the only EU installation in the field of fast neutron spectrum. The project requires a very high financial contribution but at present only the Belgian partner and consortium leader seems to be the only ones with indication of financial support to this project. Therefore it is strongly recommended that the implementation plan should be clearly improved on how the project will be financed. A plan for making the financial decisions for the construction should be worked out and the commitment of financing bodies should be clear. Also the European dimension should be worked out in a much stronger way. Open questions apart from the financing issues are strategic decisions on the final specifications for such a fast neutron facility. Currently such strategic decisions are foreseen in the 2010 -12 timeframe within the PSNE and GEN IV contexts

The proposal was in the first round recommended to be maintained as an "emerging" project. After extensive discussions in the second round the PSE RWG maintained its recommendation of MYRRHA as an emerging project pending the definition of the final specifications.

## **RU 29 ECCSEL** (European Carbon Dioxide Capture and Storage Laboratory Infrastructure)

Carbon dioxide capture and storage (CCS) is identified as a key technology for reducing emissions from fossil energy use in the future. The demand for it is globally large, but in particular in emerging economies. Europe lacks presently a large research infrastructure in this field.

The ECCSEL proposal combines three approaches to capture (pre and post combustion and  $O_2/CO_2$  -oxyfuel-recycle combustion capture) and three approaches to carbon storage (aquifers, depleted oil/gas fields, coal bed methane). The proposal includes upgrading existing national infrastructure into a European level. The research facility composes of distributed parts in partner countries with a core hub in Norway. This is a natural selection as Norway owns the best facilities in this field in Europe. All labs in the ESFRI proposal have been participating in the most important European research consortia.

The infrastructure in the proposal is unique world-wide and it is made open to European researchers through a joint management structure. The planned research infrastructure enables advanced level of research in post combustion absorption, new materials and processes, combustion facilities and storage facilities. These are all highly relevant to reduce the costs of CCS, improve the reliability of the various concepts and in particular to improve the knowledge of  $CO_2$  storage in aquifers and to develop qualification methods and mitigation strategies.

The ECCSEL addresses the following span of research capabilities:

- $CO_2$  concentration: 3-15% by volume
  - Capture rates: 0.1 – 200 kg/hr of  $CO_2$
  - Thermal capacity: 0.1 – 1000 kW (note MW's available for the industrial lab sites)
  - Impurities: 1-10000 ppm of various impurities ( $SO_2$ ,  $H_2S$ ,  $NO_x$ ..)
  - Pressure: 1-40 atm, from post C-conditions to high rated gas turbine conditions
  - Temperature: (-80..10- 1000  $^{\circ}C$  ;freeze out... post-C and pre-C conditions)
  - Fuel feed/exhaust: coal and gas exhaust
  - Hydrogen feed: equivalent to up to 500kW  $H_2$
- Oxygen feed: as required