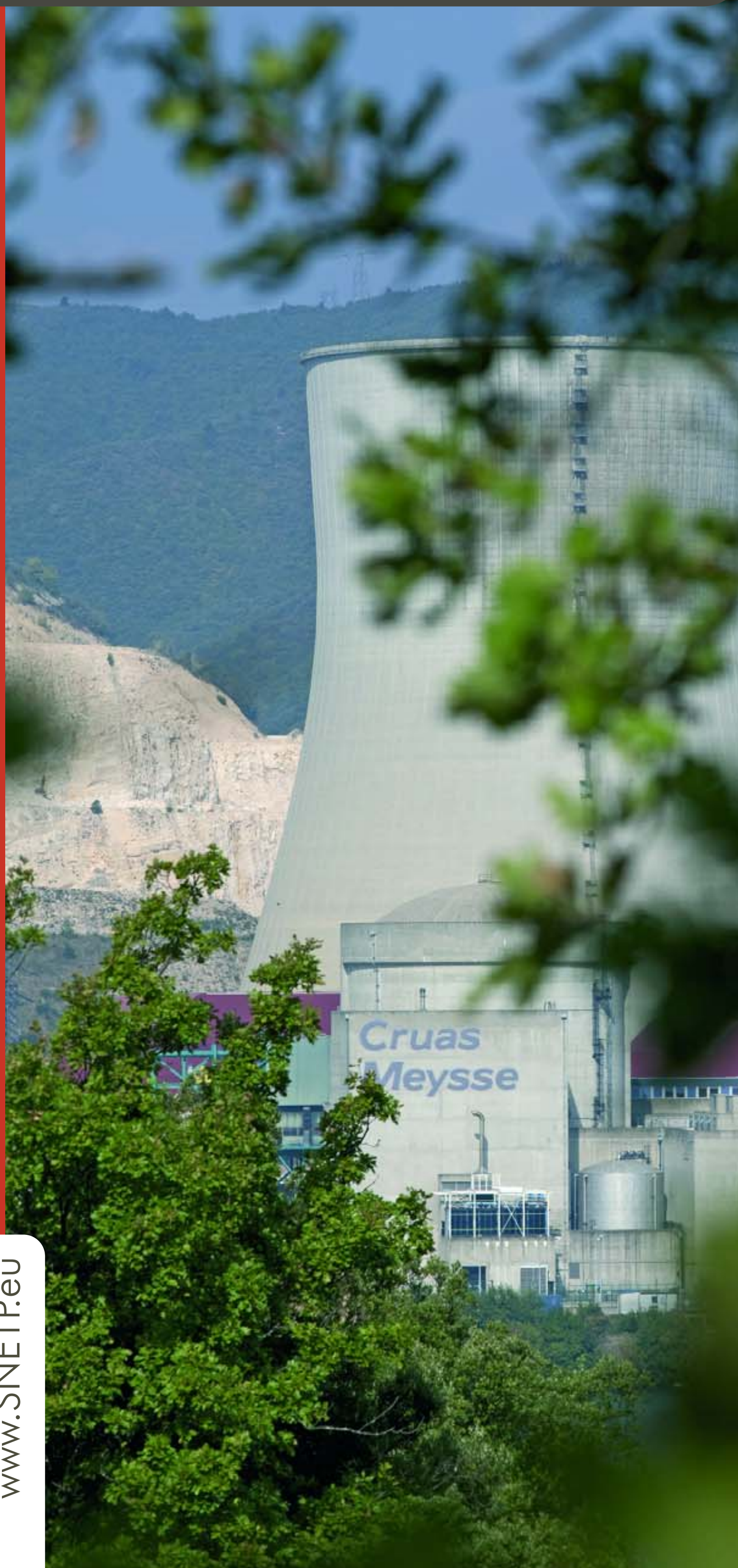
SNETP
Sustainable Nuclear Energy Technology Platform

Deployment Strategy

May 2010



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Cover illustration: Exterior view of the Cruas-Meysse nuclear power plant (Courtesy of EDF Médiathèque, illustrator Fabrice Arfaras)

Major nuclear research-orientated organisations and nuclear industry stakeholders have formulated a common vision of the role of nuclear energy in Europe's energy mix, its contribution to the security and competitiveness of energy supply, as well as to the reduction of greenhouse gas emissions.

Then, they have launched the Sustainable Nuclear Energy Technology Platform (SNETP) with the aim of integrating and developing R&D capabilities to maintain the safety and competitiveness of today's technologies, to develop a new generation of more sustainable reactor technologies and develop new industrial applications of nuclear power.

The anticipated research topics up to 2050 are described in the Platform's Strategic Research Agenda (SRA), released in 2009.

This Deployment Strategy document follows on from the SRA, identifying the key actions necessary to implement it. Like the SRA, the Deployment Strategy document is the outcome of many stakeholders involved in SNETP representing industry, research organisations, technical safety organisations and academia. I would like to express my gratitude to all of them.

Olivier Marchand,
Chairman of
the Deployment Strategy
Working Group

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Foreword

Launched in September 2007, the Sustainable Nuclear Energy Technology Platform (SNETP) now gathers more than 80 organisations (utilities, vendors, technology providers, technical safety organisations, research organisations, universities, consultancy companies and non governmental organisations) from 20 European countries. SNETP published its Strategic Research Agenda in June 2009 presenting the main R&D topics at short, medium and long-term.

In the same time, the European Commission published the Strategic Energy Technology Plan (SET Plan) in which the role played by nuclear energy in limiting greenhouse-gas emissions and in contributing to Europe's security of supply is clearly recognised.

The Deployment Strategy document identifies the key actions necessary to implement the SRA and the funding requirements in order to allow the Long-Term Operation of the current fleet, to support the deployment of the new generation of Light Water Reactors, to prepare the next generation of Fast Neutron Reactors and to develop non-electric applications of nuclear energy, thereby limiting Europe greenhouse-gas emissions and contributing to Europe's security of energy supply.

SNETP is now ready to transform a shared vision into reality by defining priority actions and coordinating activities on each of the three technology pillars, thus contributing to European energy policy.

Bernd Güthoff
E.ON Kernkraft GmbH
Vice-Chairman
of the Sustainable Nuclear Energy Technology Platform

Key messages

The Sustainable Nuclear Energy Technology Platform (SNETP) was launched on September 21, 2007. Major nuclear research-oriented organisations and nuclear industry stakeholders have endorsed the goals of the platform expressed in the Vision Report. Following this launch, the first edition of the Strategic Research Agenda (SRA) of SNETP has been published in May 2009[1].

The Deployment Strategy aims at identifying the key actions necessary to implement the SRA, overcome the technical and non-technical barriers, deliver its results, and communicate its benefits and impact to decision makers and the general public.

Ten key objectives are identified to allow the Long-Term Operation (LTO) of the current fleet (Gen II), to support the deployment of new technology (Gen III), to prepare the next generation (Gen IV) and to develop non-electric applications of nuclear energy, thereby significantly reducing CO_2 emissions.

1. Nuclear energy is crucial to achieve the goals stated in the EU's "Energy Policy for Europe".

- It is the main provider of low carbon energy in Europe's energy mix today.
- It improves security of supply by providing electricity on a massive scale at stable prices, thus bringing a competitive edge to European industry.
- Electricity demand is likely to increase in the future, as industrial processes and means of transportation switch from fossil fuels towards decarbonised energy.
- The share of nuclear energy in Europe's energy mix must increase or at least be maintained.

2. Europe needs to keep its current reactor fleet operating with high levels of safety and competitiveness.

- European energy policy must support LTO of existing Light Water Reactors (LWR), while maintaining or ensuring a high safety level.
- To support an objective of at least 60 years of operation of existing plants, priority actions must be undertaken to achieve harmonisation of LTO justification methodologies, preventing and managing effects of ageing, and performance improvement.
- These R&D actions will also support the new type of plants which are already being deployed (Gen III) or that will be deployed from 2040 onwards (Gen IV).

3. Development must be maintained to continuously improve the competitiveness and safety margins of the new designs of LWR (Gen III).

- The new Gen III LWRs are now being built in Europe and are likely to be operated throughout the 21st century as the main nuclear reactor technology for electricity generation. These first Gen III reactors already benefit from important design safety improvements.
- Improving Gen III reactor sustainability requires innovative core design to maximise uranium utilisation. Emphasis should also be given to waste minimisation with consideration of the overall fuel cycle.
- To promote the construction of new reactors across Europe, efforts should be devoted to supporting internationally harmonised methodologies for meeting licensing requirements. A larger reliance on the European standardisation system should be encouraged.

1 - The Vision Report and the SRA are available for download at www.snetp.eu

In the period 2010-2020, the total R&D investments for Gen II and III are estimated to be EUR2009 5 billion. By avoiding duplication of R&D investments and reducing fragmentation of effort, SNETP should enable at least a 20% cost saving.

4. To ensure the long-term sustainability of nuclear energy, Gen IV Fast Neutron Reactors should be available for deployment by 2040 or even earlier. Therefore an ambitious yet realistic R&D and demonstration programme is to be put in place.

- Fast Neutron Reactors (FNR) can multiply by a factor 50 to 100 the energy production from a given amount of natural uranium compared to current reactors. Most of the necessary technology has been proven at the experimental or demonstrator level, but not yet commercially deployed.
- SNETP places a high priority on the development of Gen IV FNRs, amongst which are the Sodium-cooled Fast Reactor (SFR) as a proven concept and the Lead- or Gas-cooled Fast Reactor (LFR, GFR) as alternative, longer-term technologies.

5. Speeding up the development of the Fast Neutron Reactor: a European Industrial Initiative

- FNRs benefit from feedback from past operating experience, but the present safety, operational and economic standards require new designs.
- To accelerate their development and deployment in the frame of the EU's Strategic Energy Technology Plan ("SET-Plan"), SNETP will launch the European Sustainable Nuclear Industrial Initiative ("ESNII") in 2010. This programme includes the construction of an SFR Gen IV prototype and a demonstrator of alternative technology (LFR or GFR).

6. As non-electric energy consumption, presently widely addressed by fossil fuel burning, is responsible for the majority of CO_2 emissions, SNETP also places a high priority on a rapid development of non-electric applications of nuclear energy for reducing CO_2 emissions, in line with the SET-Plan target.

- The coupling of a nuclear reactor with industrial process heat applications is a challenging innovation that requires a large-scale demonstration for proving the technical feasibility of such a coupled system, its operability under industrial conditions, acceptability for licensing and economic competitiveness.
- SNETP plans to launch a further joint industrial initiative, between the nuclear industry (vendors and operators) and energy-intensive industries, for carrying out such a demonstration by 2020.

The FNR and cogeneration prototypes or demonstrators are key projects and SNETP recommends that Member States and the European Union strongly support the corresponding Industrial Initiatives.

7. The European Industrial Initiatives need co-investment from private and public sources.

- Estimates suggest that the costs might range from EUR2009 8 to 10 billions for ESNII and about 3.5 billions for the cogeneration initiative. These costs are justified by a return from future revenues. However, these costs are subject to uncertainties and there are investment risks.
- Therefore, the coordination and funding of R&D programmes for the development of Gen IV and cogeneration systems at European level must be improved, combining EU, national and private initiatives.
- To this end, SNETP will interact with the European Commission, the SET-Plan governance bodies and the European Energy Research Alliance ("EERA").

European funding requirements for this FNR and cogeneration R&D effort are estimated at EUR2009 11.5 - 13.5 billions in the 2010-2020 period, which could be significantly reduced in case of international partnerships. The share of the cost is estimated at 80% from the public sector (national and/or EU) and 20% from industry.

8. To preserve its technological and industrial leadership, the European nuclear sector must increase the level of cooperation and reduce fragmentation of efforts.

- Further harmonisation of licensing processes, standardisation of design evaluation tools, coordinated R&D between all stakeholders as well as education and training of the existing workforce are needed.
- Moreover, advances in technology will coincide with changes in the workforce. There is a need to accelerate the development of a skills pipeline between university and industry to attract talented young people.
- Europe needs an appropriate network of nuclear R&D infrastructures, covering all aspects of the safe long-term use of power plants and the development of new, safe, competitive and sustainable reactor technologies.

9. Improving nuclear fission R&D coordination at EU level

- To reduce fragmentation of efforts, the most important topics in the SRA have to be identified and then funding and research activities concentrated on the most critical issues. This process of identification will be achieved in 2010.
- An "Implementation" document will be elaborated in 2010 to describe how research will be organised in order to share R&D capabilities and competences and ensure the leverage of necessary resources.
- SNETP will then organise, with its working groups, efficient execution of the implementation plan amongst its members.

10. In the longer term, the Sustainable Nuclear Energy Technology Platform aims to play a leading role in:

- coordinating and implementing research, development and demonstration initiatives,
- providing strategic guidance to the EU in the definition of nuclear fission related objectives in future Framework Programmes,
- coordinating efforts with EU institutions and Member States willing to engage in the further development of fission energy, as well as with non-EU countries via a mutual benefit approach,
- promoting actions in the fields of education, training, knowledge management, communication and dissemination.

1. Introduction

1.1 A sustainable contribution to EU energy policy

Nuclear power is the most abundant European source of carbon-free electricity and is an important element in combating climate change and minimising Europe's dependence on imported energy sources. Approximately 1/3 of the EU's electricity, and 2/3 of its low-carbon energy, is produced by nuclear power, representing a non-emission of almost 900 million tons CO_2 per year. Without nuclear energy, the European Union's target to reduce CO_2 emissions by 20% by 2020 and 60-80% by 2050 (compared to 1990 levels) is not achievable.

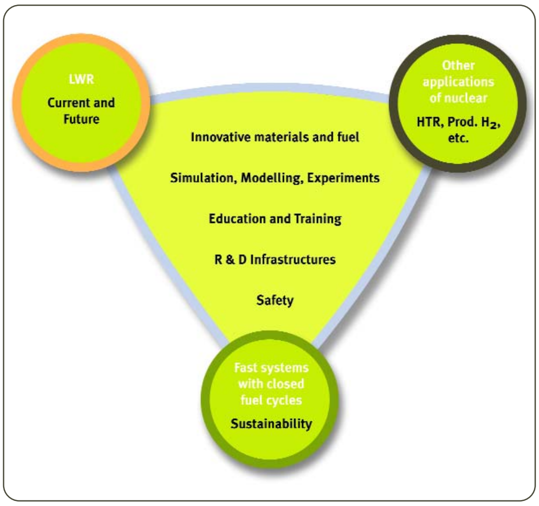


Fig. 1: The SNETP vision

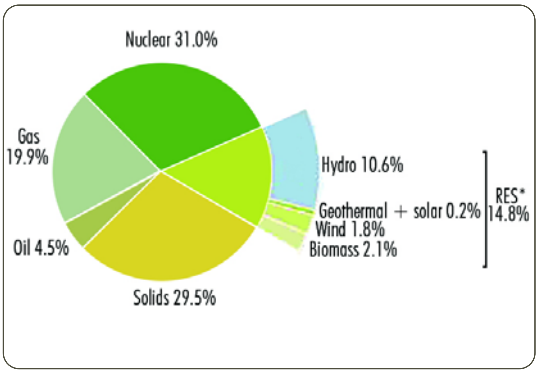


Fig. 2: Electricity generation shares in EU-25 in 2004[2] (*RES: renewable energy sources) [Source: Eurostat]

> Nuclear energy is the most important low-carbon technology in Europe's energy mix

Nuclear generation improves security of supply by providing electricity on a massive scale at stable prices, thus bringing a competitive edge to European industry. In addition, since the price of uranium is only a small part of overall generating costs, fluctuations in the uranium price have only a marginal effect on the cost of nuclear electricity.

The current fleet is primarily dedicated to base-load electricity generation. However, electricity demand is likely to increase in the future, as many industrial processes and means of transport switch from fossil fuels to decarbonised energy sources. Moreover, new non-electric applications of nuclear energy should be able to demonstrate that nuclear CO_2-free heat can substitute fossil fuel burning for the industrial process heat market, which is already very large today, and which will grow further if the markets for alternative fuels (oil from tar sand and oil shale, synthetic fuel and hydrogen) develop.

Nuclear safety is the top priority. The European Union has an outstanding nuclear safety record; however research must continue in order to maintain this high level of safety. Furthermore, advances in nuclear technology offer the prospect of significant improvements in efficiency and use of resources, whilst ensuring even higher safety standards and decreasing waste, compared to current designs.

The European nuclear sector is characterised by cutting-edge technology and provides highly skilled employment for several hundred

2 - Nuclear Illustrative Programme (PINC), COM(2006) 844, published in Jan 2007, and Annexes 1 and 2, SEC(2006) 1717 and SEC(2006) 1718

thousand people. To maintain the excellent safety record both now and in the future requires skilled people and well-equipped nuclear research facilities. The availability of these resources is a crucial prerequisite no matter what the future holds for the nuclear power sector.

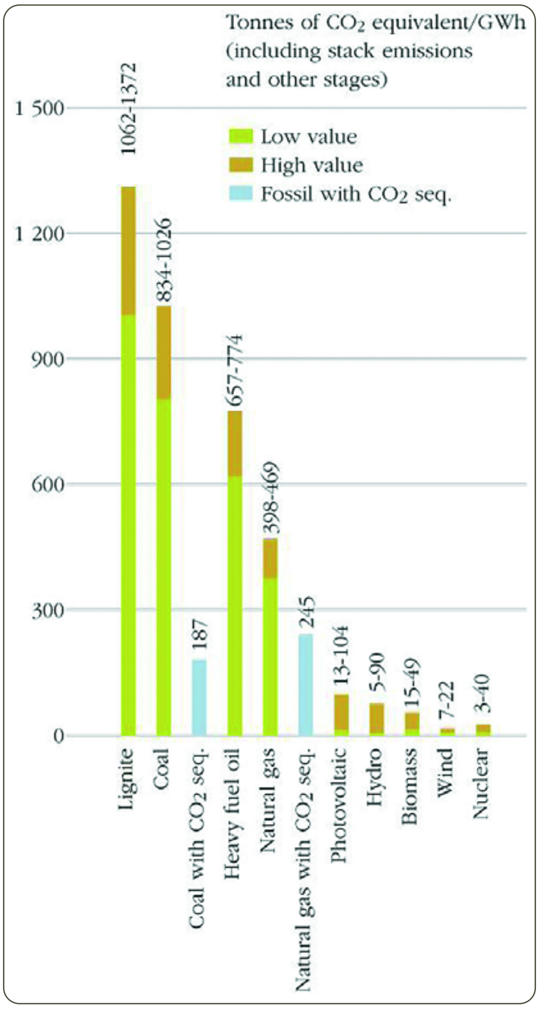


Fig. 3: Greenhouse gas emissions (in tonnes of CO_2-equivalent) per GWh for different electricity production means

1.2 The Sustainable Nuclear Energy Technology Platform

Technology platforms bring together a broad spectrum of stakeholders to formulate and implement common research agendas in strategic areas which could have significant impact on Europe's competitiveness and sustainability objectives.

The Sustainable Nuclear Energy Technology Platform (SNETP) is the European Technology Platform aimed at promoting the research, development and demonstration of European nuclear fission technologies, covering current and future nuclear systems, including safety research, fuel cycle, appropriate R&D infrastructure and human resources.

SNETP was launched on September 21, 2007 in Brussels. The Vision Report, endorsed by 35 major nuclear research-orientated organisations and nuclear industry stakeholders, was distributed at this event. Following the launch, the Governing Board set up three Working Groups to establish the first edition of the Strategic Research Agenda (SRA), the present Deployment Strategy (DS) and an action plan on Education, Training & Knowledge Management.

In addition, coordination of the European research effort in the specific field of geological disposal of radioactive waste is addressed by the “Implementing Geological Disposal of radioactive waste Technical Platform” (IGD-TP, see www.igdtp.eu), launched in November 2009.

2. Planning assumptions for SNETP

The Deployment Strategy is based upon a set of basic assumptions regarding key drivers such as the composition of the nuclear fleet and its evolution over the period 2020-2050, the new markets for nuclear energy, fuel resource, etc.

Basic assumptions are listed in following sections.

■ 2.1 Nuclear fleet for electricity generation

At the moment 438 nuclear reactors are in operation worldwide and contribute to low carbon electricity supply. Several worldwide prospective studies, such as "Energy policy scenarios to 2050" performed by the World Energy Council (2007) and the World Energy Outlook published by International Energy Agency (2009) respectively show that, even with optimistic assumptions on the possible contributions of the other energy sources by 2050 (maintaining current utilisation of oil and coal, doubling of gas, development of renewable energies up to 30%), the use of nuclear energy will continue to be necessary.

The ratio of 30% of nuclear in the EU electricity generation mix is at least maintained up to 2050, the rest being provided by other non CO_2 emitting sources

This leads to an anticipated installed global capacity of nuclear power of the order of 1500 GWe by 2050, which is about four times the current installed capacity (370 GWe).

According to the Second Strategic Energy Review issued in 2008 by the European Commission, the EU would need a net power capacity in 2020 which is about 150 or 180GWe higher than today. This means, for maintaining at least a constant ratio of 30% from nuclear, more than 50GWe of new nuclear capacity.

Nuclear power technology has evolved in three distinct design generations: the initial prototype reactors; the second generation of reactors that form the current fleet of operating power plants ('Gen II'); and an evolutionary third generation of reactors with enhanced safety and competitiveness under construction today in Europe (Finland and France) and in China ('Gen III').

Throughout the 21st century, it is foreseen that Light Water Reactors will be responsible for the majority of nuclear electricity production in Europe. In the period 2010-2050, the successful operation and management of Gen II LWRs beyond their originally foreseen lifetime will be vital to achieve security of electricity supply of in Europe. The new evolutionary designs of Gen III LWRs will be deployed over several decades and will represent a large part of the worldwide fleet throughout the latter part of the 21st century. As a result of feedback from experience and improvements through targeted R&D, Gen III reactors later deployed will evolve as compared with the first-of-a-kind reactors, in areas such as economic performance.

A fourth generation of reactors ('Gen IV') is now the subject of an increasing R&D effort. The objectives of Gen IV reactors are competitive performance, high safety standards, increased sustainability, nuclear waste reduction and proliferation resistance. At least one prototype is expected to start operation in Europe in the 2020's and Gen IV reactors could be available for commercial deployment from 2040 onwards.

At the horizon 2040, the nuclear fleet consists of a mix of technologies: Gen II, Gen III, and Gen IV prototypes.

The penetration of nuclear energy in the market of industrial non-electric applications is also possible. After an initial demonstration in the early 2020s, the industrial deployment of High Temperature Reactor (HTR) cogeneration systems could be initiated in the late 2020s to answer market needs for reduction of CO_2 emissions, well ahead of the deployment of Gen IV systems.

The nuclear industry continuously upgrades the performance of its reactor fleet, maintains high safety levels, and promotes Long Term Operation where technically possible and approved by the Nuclear Safety Authorities.

2.1.1 Maintaining the Long Term Operation of the existing fleet

To maintain the competitive advantage of nuclear generation and to reduce the need for new build, commercial operation of the existing fleet should be extended beyond original design lifetimes while benefiting from feedback from experience and increased operational knowledge. A high level of safety corresponding to strict international standards is ensured through periodic safety reassessments. Plant life extension to 60 years or more is anticipated, as is the case with other similar plants around the world (e.g. in the USA), and this process should be an important driver for R&D.

2.1.2 Improving and sustaining performance of the existing fleet

Plant life extension is backed by performance enhancement to guarantee a competitive advantage for nuclear generation. The plants operate with high availability and efficiency and at low production costs and ensure a high safety level.

Capacity upgrading continues to be undertaken at more than 25% of all NPPs; the EU wide average unit availability has steadily increased over the last 10 to 15 years. Over the same period, programmes on both capacity upgrading and increasing plant availability have resulted in over 5000 MWe of additional net power output in the EU-27.

Advanced technologies, innovative management procedures or plant organisation have the potential to lead to further improvements in plant operation, performance, equipment maintenance and reliability, staff training, and therefore production costs.

2.1.3 New build

New nuclear build is a key pillar to the successful deployment of nuclear energy, and involves both the construction of additional plants and the replacement of reactors to be decommissioned in the coming decades.

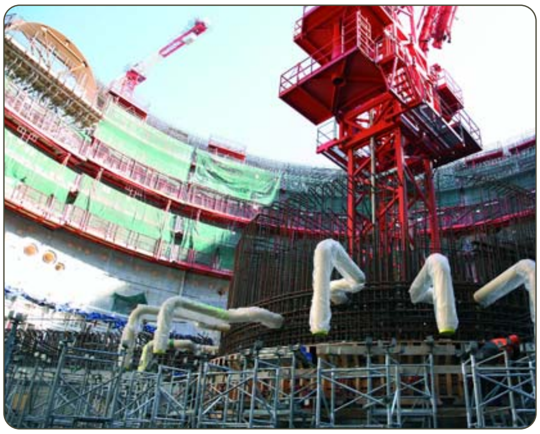


Fig. 4: Reactor building of the Flamanville 3 EPR construction site in March 2010 (Source EDF Médiathèque, illustrator Alexis Morin)

In Europe, new reactors will be built from now on. As of 2008, two European Pressurised Reactors (EPRs) are being built, in Finland and in France. Finland is also starting the approval procedure for the possible construction of two additional reactors and France has announced the construction of a second EPR. Other on-going new builds in the EU are the construction of two units in Bulgaria and the completion of the construction of two units in Slovakia. Furthermore, the United Kingdom, Poland, Italy and the three Baltic states are considering national options for new nuclear power plants.

The market for new construction is substantial since the current nuclear fleet capacity amounts to almost 135 GWe in Europe. Various factors add to the economic value of the new build market: economic benefit arising from low, stable nuclear generation costs; the industrial significance of a new project for national subcontractors; and the new jobs created for both the reactor construction and the subsequent services throughout the reactor's lifetime.

New generation reactors are the outcome of continuous technological development and learning processes from current reactors. Their design takes advantage of the operational experience that has been gathered until now. Safety is enhanced by innovative active and passive systems and by the design features preventing severe damage to the core. Efficiency is higher, fuel consumption is reduced, reliability

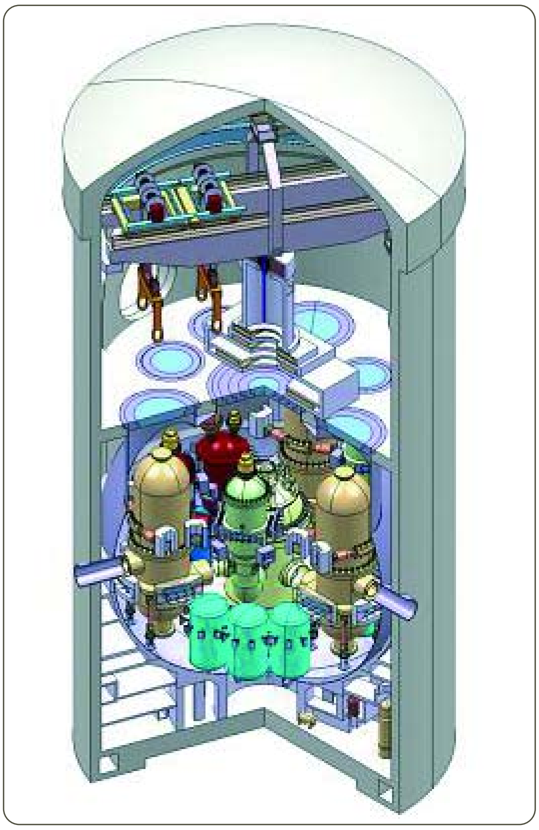


Fig. 5a: Lay-out of 1200 MWe GFR [Courtesy of CEA]

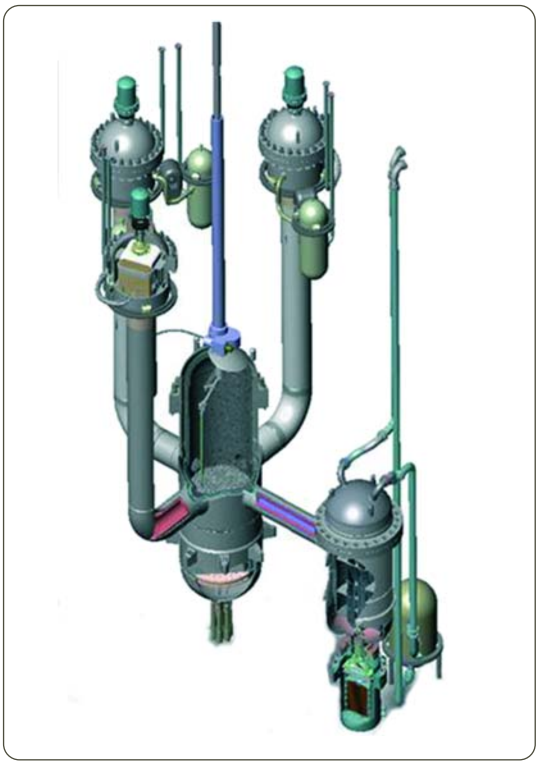
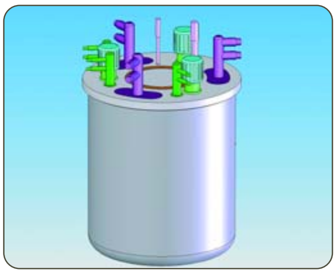


Fig. 5b: Lay-out of 50-100 MWth Experimental GFR (ALLEGRO) [Courtesy of CEA]

is significantly increased, waste is minimised and economics are improved.

However, like in every high-tech sector, new nuclear reactors will benefit from continuous developments and improvements as a result of technological progress. Research and innovation will therefore continue over the coming decades, especially regarding materials and assembly technology, fuel performance and utilisation, and advanced simulation; this will enable the emergence of an advanced generation of reactors. The Strategic Research Agenda presents a research strategy that takes full benefit from commonalities between current and future nuclear systems and creates scale economies, on basic research or research infrastructures. Research on new build therefore has considerable significance in view of the number of reactors to be built and its usefulness for future generation reactors.



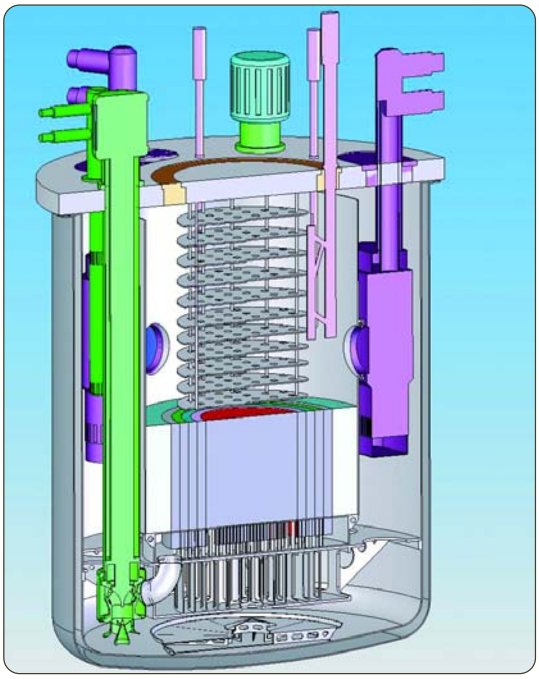


Fig. 6a: 1500 MWe Innovative SFR Pool Design [Courtesy of CEA]

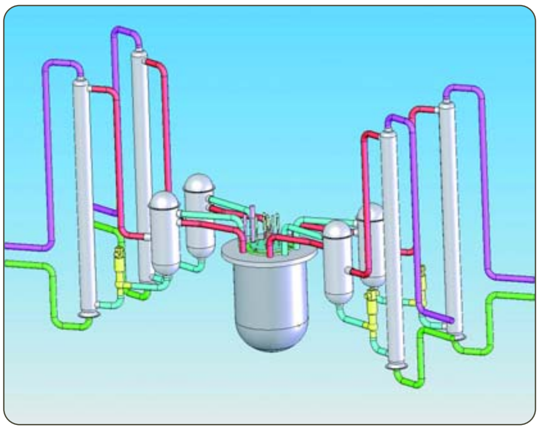


Fig. 6b: 1500 MWe Innovative SFR Loop Design [Courtesy of CEA]

Several international forums such as the Generation-IV International Forum[3] (GIF) launched by the US-Department of Energy (DOE) in 2000 and the International Project on Innovative Nuclear Reactor (INPRO) launched by the IAEA also in 2000, have identified a range of advanced reactor system technologies[4] that will enable nuclear energy to build on the success of current LWRs and deliver an important contribution to the world's primary energy needs in the longer term:

Gen IV fast reactors are scheduled to start commercial operation from 2040 onwards.

- **Fast neutron systems with a closed fuel cycle able to exploit the full energy potential of natural uranium (80-90% as opposed to slightly more than 1% with LWRs today) and to minimise the long-term radiotoxicity and decay heat of the ultimate waste for disposal,**
- **High or very high temperature nuclear systems for energy applications other than electricity production, such as hydrogen, synthetic transportation fuels, and process heat for industry (cf. §2.2).**

Gen IV fast reactor systems can therefore multiply by a factor 50 to 100 energy production from a given amount of uranium fuel, as compared to current reactors. Another potential benefit would be a reduction in the quantity of long-lived nuclear waste as a result of the ability to burn minor actinides, thereby expanding the capacity of geological repositories through the reduction in long-term heat load.

The sustainability of nuclear energy depends on the optimal use of natural resources.

Therefore, in a mid-term perspective, Gen IV fast reactors could deliver safe, more resource-efficient and more competitive nuclear energy.

Most of the Gen IV fast reactor systems have been proven at experimental level, but not yet deployed at commercial scale. A number of questions regarding specific safety topics, development and integration of systems and components, scale-up of technology, policy and regulation, public acceptance, operating performance and costs are yet to be resolved.

3 - The fully ratified GIF members are Canada, China, Euratom, France, Japan, Russia, South Africa, South Korea, Switzerland and the United States of America.

4 - In GIF, six reactor systems have been selected for further development:
- GFR Gas-cooled Fast Reactor
- LFR Lead-cooled Fast Reactor
- MSR Molten Salt Reactor
- SFR Sodium-cooled Fast Reactor
- SCWR Supercritical Water-cooled Reactor
- VHTR Very High Temperature Reactor

2.2 New Markets (Heat, Hydrogen, Desalination)

Nuclear reactors are sources of heat, which could be used to deliver heat or steam to energy-intensive industrial processes, such as (petro)chemicals, steelmaking, hydrogen production, or seawater desalination - processes which today rely on burning fossil fuels. However, the connection of a nuclear energy source to neighbouring industrial plants has yet to be convincingly demonstrated.

Nuclear reactors are capable of providing heat at a wide range of temperatures, which covers the requirements of most non-electric applications. There are still significant issues to be resolved before commercial deployment of nuclear fission in the non-electric energy market is possible: adapting the nuclear heat source to end-user requirements, developing appropriate coupling technologies between the reactor and the applications, and possibly adapting the applications to the specific capacity of the nuclear reactor. Furthermore, for successful market penetration, prior demonstration is critical, which may require public support.

At the same time, safety issues related to possible interactions between industries (nuclear and conventional) must be considered.

High Temperature Reactors (HTRs) are a promising technology, with significant experience of test reactors and industrial prototypes in several countries. With existing materials and fuel technologies they could provide heat up to a temperature of 750°C, sufficient for a large range of industrial applications. The development of advanced materials and fuel could extend the range to very high temperatures (VHTR).

Even though nuclear energy has the clear potential to develop non-electric applications, market characteristics need to be thoroughly evaluated: market size, competitiveness of nuclear energy in these markets, etc.

In Europe, opportunities may arise when large industrial platforms (e.g. refineries, ammonia production, and steel plants) commit to nuclear alternatives. At the time of writing, potential end users have begun considering HTR systems for site energy supply as part of CO_2 reduction strategies and energy cost stability.

Process heat opportunities also exist in the large-scale production of hydrogen, required for

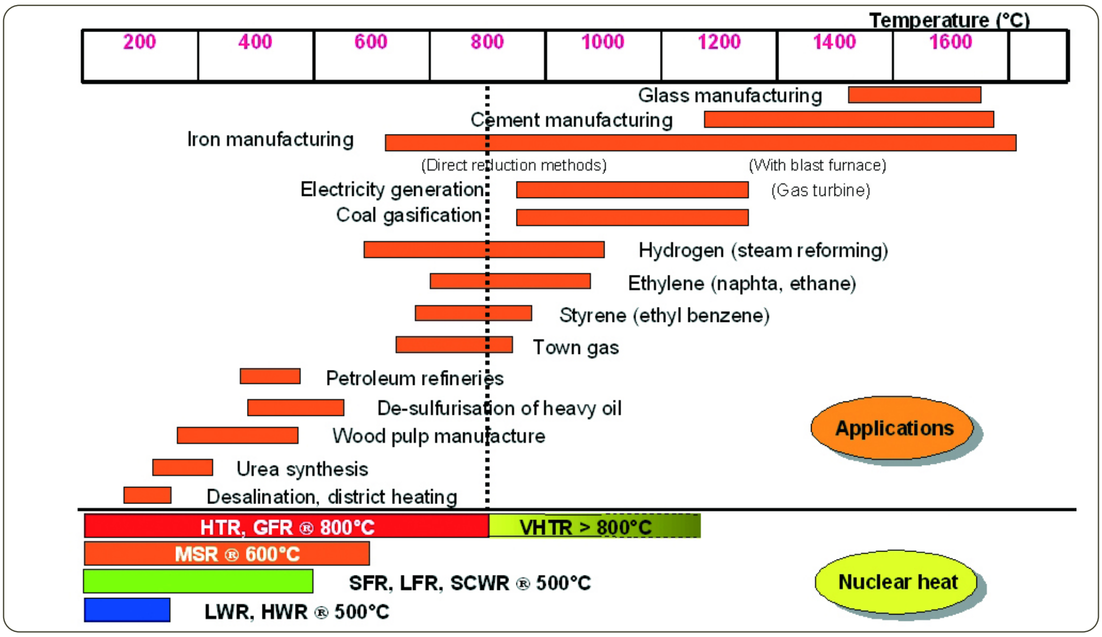


Fig. 7: Range of operating temperatures for heat intensive industrial processes (> 100 MW of heat needed in each plant) (Courtesy of Michelangelo Network FP5 project)

the synthesis of new liquid fuels by hydrogenation of high carbon content materials (coal, tars, residues) or for fuel cells for the transportation sector.

However, important commercial and socio-political acceptance issues are still to be overcome:

- resource-oriented issues: the degree of deployment of nuclear non-electricity production depends on the availability of capital investments,
- societal and legal issues: the use of nuclear energy for non-electricity applications will have to face the same issues as for electricity generation (safety, waste management).

■ 2.3 Fuel Resources, Security of Supply

At the end of 2008, 438 commercial reactors (corresponding to a worldwide installed capacity of 370 GWe) were in operation, requiring about 66 500 tonnes uranium per year. Natural uranium production provided about 60% of these requirements. The rest was coming from excess government and commercial inventories, down-blending of highly-enriched uranium (dismantling of nuclear warheads), re-enrichment of depleted uranium tails and spent fuel reprocessing.

By 2030, worldwide generating capacity is projected to reach 473 to 748 GWe[IAEA, nuclear energy review, 2009] Accordingly, world uranium requirements are projected to rise to between 95 000 and 120 000 tonnes uranium per year.

Uranium reserves are expected to last for several decades at an acceptable cost.

According to the latest joint report prepared by NEA and IAEA [OECD/NEA and IAEA, uranium 2007: Resources, Production and Demand, OECD, Paris (2008)], the total identified resources (reasonably assured and inferred) are estimated at 5.5 Million tonnes uranium in 2007. These resources are relatively well distributed (Canada and US: 14%, Kazakhstan: 15%, Russia: 10%, Australia: 23% and Africa: 18%).

The identified resources are sufficient to feed the expected world nuclear fleet in 2030 for around 50 years and to leave time to prepare the

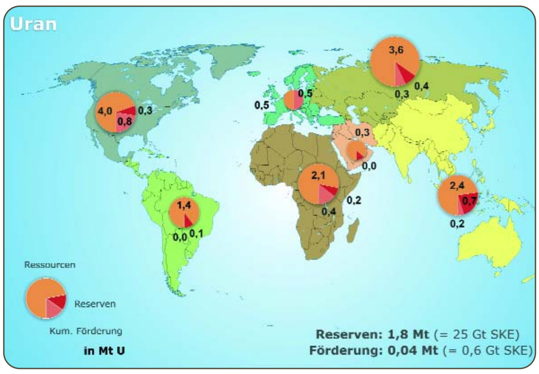


Fig. 8: Uranium resources, reserves and demand across the world (Copyright BGR, Hannover 2009)

deployment by 2050 of more fuel-efficient nuclear systems such as fast neutron reactors with a closed fuel cycle. Uranium reserves can be expected to grow with extended and improved uranium prospecting (in the NEA-IAEA report, the total undiscovered resources, prognosticated and speculative, were estimated at 10.5 million tonnes uranium).

However, the expected rapid rise in the demand of mined uranium will challenge the mining industry as never before.

Generation IV will extend energy recovery from uranium by a factor of 50 to 100, enabling the use of nuclear fission energy for centuries.

Thorium has the potential to complement uranium (worldwide reserve are 4 times those of uranium), but being only a fertile material, its use requires large neutron sources in order to produce usable fissile material. Significant R&D efforts would be necessary to achieve a complete fuel cycle and therefore thorium is not considered to be part of the deployment strategy at this stage. Nevertheless, some R&D efforts must be maintained so as to retain European proficiency in this area; this is detailed in a specific annex to the SNETP Strategic Research Agenda.

■ 2.4 Reprocessing, Spent Fuel Management and Disposal

Long-term storage technology is already available. Technical solutions exist for geological disposal, but need to be implemented (this relies on political decisions at national level; as of 2010, such decisions have been taken in Sweden, Finland and France). A specific Technology Platform (*Implementing Geological Disposal of radioactive waste Technology Platform*, www.igdtp.eu) was launched in November 2009. Interfaces between SNETP and IGD-TP must be established in order to complement knowledge and strategies in an efficient and effective way.

Spent fuel transportation casks are secure and qualified. Waste conditioning is industrially mature.

Reprocessing technology exists for LWR and enhances conservation of resources, though further R&D efforts are required for extension to Gen IV fast breeder reactors.

Transmutation of isotopes separated from nuclear waste (minor actinides and long-lived fission products) offers the potential option to further reduce the radiotoxicity and long-term decay heat of high-level radioactive waste destined for disposal. However, energy-related, economic and technical issues associated with this option need to be assessed in more detail.

Fig.9: The SFR facility for operational waste in Forsmark, Sweden (Source SKB, illustrator Curt-Robert Lindqvist)

■ 2.5 Decommissioning

Decommissioning techniques exist and benefit from feedback from previous decommissioning operations. These technologies allow the recycling of the bulk of the steel inventory, e.g. steam generators, piping and reactor vessel heads. Thus quantities for final disposal are significantly reduced.

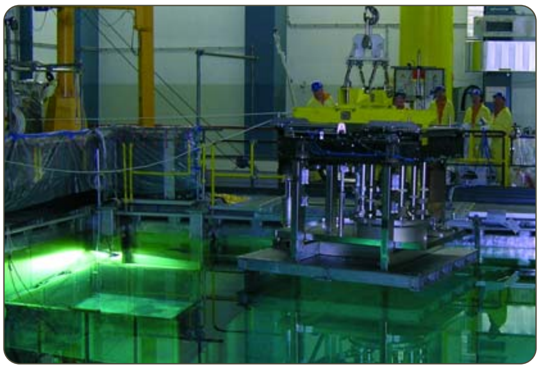


Fig. 10: Decommissioning in EON NPP Würgassen (Courtesy by E.ON)

■ 2.6 Climate change and external influences

Over the last decade, more and more compelling evidence points to the link between human activity and climate change. The Intergovernmental Panel on Climate Change (IPCC) has been the principal forum for synthesising this information and estimating impacts and trends. In this context, nuclear power is widely seen as one option to counter rising emissions of CO_2, considered to be largely responsible for global warming.

Nuclear energy is one solution to mitigate climate change (current EU CO_2 avoidance: 900 Mtonnes per year).

Existing and future nuclear assets have also to cope with the changing environment: plant efficiency has to be optimised while managing new constraints as a result of extreme weather events, such as exceptionally high temperatures, flooding or cooling water shortages and coastal erosion.

In particular, future plant designs must be able to deal with evolving external and internal threats. Stability of buildings, security measures and proliferation resistance need to be carefully assessed.

■ 2.7 Competences

The nuclear renaissance will create jobs but will demand that appropriate competences are available.

There is strong competition with other sectors to hire new recruits, but mobility between sectors should also be encouraged.

Increased investment in training facilities has been forthcoming, but more is needed.

■ 2.8 Harmonisation of technical safety requirements in the European Union

This issue, which extends to all aspects of nuclear technology from R&D to energy production, is more and more important, not only to ensure an appropriate and harmonised level of safety but also to facilitate the deployment of nuclear energy in the EU, based on standardised reactor designs. Moreover, it can contribute to maintaining or even increasing European industry's competitiveness through easier access to the EU market, by avoiding unnecessary or duplicated licensing costs.

In addition, for Gen IV reactors, the joint development of codes and standards should provide a common European tool for capitalising on the knowledge gained from R&D on improved materials and advanced manufacturing processes.

3. Deployment Strategy for R&D

Nuclear fission energy is crucial to achieving the goals stated in the EU's "Energy Policy for Europe": reduced CO_2 emissions, security of supply, competitiveness and stable electricity prices.

Nuclear power generates one third of all the electricity consumed in the EU today, at the same time emitting very low quantities of greenhouse gases (cradle to grave analysis). Thanks to nuclear, the EU's total greenhouse gas emissions are reduced by some 14% a year – almost 900 million tonnes of CO_2, equivalent to that produced by all the private cars in Europe.

Therefore, nuclear power contributes significantly to helping the EU meet its current commitments under the international protocols and it offers options for sustainable energy supply into the future. Without nuclear, the European Union target to reduce CO_2 emissions by 20% by 2020 and 60-80% by 2050 is not reasonably achievable.

Nuclear fission energy is crucial to achieving the goals stated in the EU's "Energy Policy for Europe

Nuclear generation ensures a strong security of electricity supply and provides stable electricity prices, on a massive scale, bringing a competitive advantage to EU industry. In addition, since the price of uranium is only a small part of overall generating costs, fluctuations in the uranium price have only a marginal effect on the cost of nuclear electricity.

The current fleet is primarily dedicated to base-load electricity generation. However, electricity demand is likely to increase in the future, as many industrial processes or the transportation sector will switch from fossil-fuelled to de-carbonised energy. Moreover, new non-electric applications of nuclear energy should demonstrate that nuclear CO_2-free heat can substitute fossil fuel burning for the industrial process heat market, which is already very large today, and which will grow further if the market for alternative fuels (oil from tar sand and oil shale, synthetic fuel and hydrogen) develops.

Therefore, Europe must increase, or at least maintain, the share of nuclear energy in the energy mix.

However, for the period 2007-2011, the EU budget (Euratom FP7-indirect actions) for Community research activities in the field of nuclear fission and radiation protection is only EUR 287 million. Furthermore, a significant part of the funding necessary to carry out the R&D identified in the Strategic Research Agenda must come from the public sector.

3.1 Current nuclear fleet

Given the proven benefits of nuclear energy in terms of competitiveness and low CO_2 emissions, European energy policy must support the long-term operation of the existing plants, while maintaining a high safety level, managing the effects of ageing, and continuing efforts to optimise the utilisation of uranium resources through the development of innovative fuel strategies. The continued safe operation of existing Gen II nuclear power installations will provide diversity and security of energy supply in Europe whilst combating climate change.

Europe needs to keep its current reactor fleet (Gen II) operating with a high level of safety and competitiveness.

Nuclear power plants are complex technological systems and research into their operational safety is multi-faceted. It can involve tasks such as: plant life assessment and management, improved safety culture to minimise the risk of human or organisational error, advanced safety assessment methodologies, development and implementation of numerical simulation tools, instrumentation and control, and prevention and mitigation of severe accidents, plus associated activities to optimise knowledge management and maintain competence.

Gen II nuclear power plants are expected to operate well beyond their design lifetime (in most cases 40 years) resulting in superior economics. To support an objective of 60 years or more for existing LWR plants, priority R&D actions must be undertaken. The Strategic Research Agenda develops a list of key issues to be addressed, primarily:

- harmonisation of European Long-Term Operation justification methodologies, and also a more common technical basis to facilitate the licensing processes in Member States,
- prevention and managing the effects of ageing,
- improvement of performance: the interface between man, machine and organisation is also an important area for research[5],
- development and validation of multi-physics / multi-scale numerical simulation tools using High Performance Computing[5].

5 - Generic activities also concerning Gen III and IV

To further increase sustainability and competitiveness, actions will continue towards the more efficient utilisation of uranium and plutonium in LWRs.

These R&D actions and experience feedback will contribute to further improvements in design of the new generation of plants already being deployed (Gen III) or to be deployed from 2040 onwards (Gen IV).

3.2 Generation III Light Water Reactors

The new Gen III LWRs are now being built in Europe and are likely to be operated throughout the 21st century as the main nuclear reactor technology for electricity generation. These first Gen III reactors already benefit from important safety design improvements.

Development must be sustained to continuously improve the competitiveness and safety margins of the new technology of LWR (Gen III).

On the world market, about 12 vendors offer more than 14 Gen III designs: PWR, BWR and heavy water reactors (e.g. CANDU). Only some of these designs are likely to be exploited in Europe. European utilities have already shortlisted design specifications in the so-called "European Utility Requirements" and they cooperate in the joint assessment of designs proposed by vendors against these requirements. EPR, ABWR, AP1000 and KERENA have been examined and validated positively under this scheme by the utilities; the process is on-going for VVER-1000. Further candidates are the EU-APWR, ESBWR and ACR-1000.

Currently, there are some limiting factors for the construction of Gen III plants. Production capacity for reactor pressure vessels is limited to a few manufacturers worldwide. But in view of the expected worldwide growth of NPPs, some vendors have already announced the ramping up of their production capacities.

R&D activities can bring forward technology innovation for optimizing performance and economics (materials, assembly and fabrication of components) while maintaining a high safety level.

Fig. 11a: Artist's view of the Westinghouse AP1000 Reactor (Source Westinghouse Image Gallery)

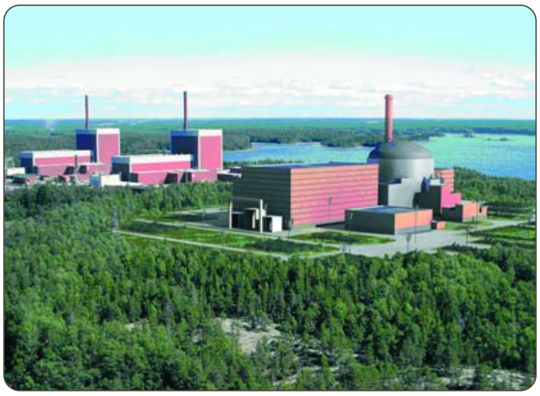


Fig. 11b: Artist's view of the Generation III EPR under construction in Olkiluoto, Finland

Improving the sustainability of Gen III reactors will require innovative core design to maximise uranium utilisation (increased reactor conversion ratio, high discharge burn-up with fuel enrichment above 5%…). Emphasis should be given also to waste optimisation with consideration given to the whole fuel cycle (advanced technology for fuel treatment / recycling / re-fabrication), while maintaining a high degree of safety and security.

To promote the construction of new reactors across Europe by bringing predictability to the licensing process, efforts should be devoted to involving European parties in the international harmonisation of methodologies related to licensing process requirements (design and safety evaluation, subcontractor certification, introduction of new fabrication and assembly technologies, transport of irradiated fuel / materials …). Towards this aim, a larger reliance on the European standardisation system should be encouraged. A harmonised safety approach (while still allowing for each Member State's specificities) will facilitate design licensing of standardised reactors and ensure more predictable reactor construction and operation timescales, while improving experience feedback.

Key R&D topics include:

- Improvement of systems, structures and component design, assembly and fabrication technologies to give better reliability, quality, performance optimisation and cost economics;
- Harmonisation of methodologies to assess the reliability of innovative systems and components (digital I&C, …);
- Harmonisation of methodologies for a new type of probabilistic safety assessment (earthquakes, …) and sharing of data;
- Upgraded Human System Interface, simplified operation of reactor systems;
- Environmental impact assessment: consideration of the adequacy of the cooling water source in the perspective of Climate Change[6];
- Fuel testing.

A strong R&D effort on innovative or even breakthrough technology should help maintain the competitiveness of LWR / Gen III reactors, in their role as the main nuclear reactors for the 21st century. This will encompass areas such as advanced materials and assembly technologies for nuclear components (including codes and standards issues), high conversion ratio reactors (higher than 5% enriched fuel) and harmonised safety culture (i.e. reactor operation, licensing process requirements…).

Throughout the 21st century, Light Water Reactors will be the main nuclear reactor technology for electricity generation

New infrastructures are likely to be required for the validation and assessment of the above-mentioned innovative technologies. A joint effort between R&D organisations, Technical Safety Organisations and industry will be needed to ensure efficient development.

3.3 Funding of R&D for Gen II/III

To estimate the R&D funding needs for Gen II and III reactors in the 2010-2020 period, the rationale is the following:

- Present R&D:
  - According to the IEA R&D statistics and to the EC/Joint Research Center report "R&D investment in the priority technologies of the European Strategic Energy Technology Plan, 2009", R&D investments in EU27 in nuclear technology amounted to EUR2009 400 million per year and are equally financed by the private and the public sector;
  - Today more than 95% of the R&D investments in Gen II and III come from private companies and national R&D programmes.
- Increasing needs: since several EU countries are considering building new reactors and/or extending the time of operation of existing ones, these R&D investments are likely to increase to about EUR2009 500 million per year by 2015[7];
- Benefits of working together:
  - SNETP will provide a better coordination of R&D programmes, avoid duplicate investments and reduce fragmentation of efforts. It is estimated that this will result in savings at least equal to the increasing needs above;

In the period 2010 – 2020, the total R&D investments for Gen II and III are estimated to be EUR2009 5 billion. Thanks to SNETP, this budget can be reduced to EUR2009 4 billion.

6 - As climate change could induce rise in river water temperature or sea level, which may somehow impact plant design

7 - However, the costs of the programmes are subject to uncertainties. They will be reviewed during the prioritisation process (cf. § 3.7.2) and updated regularly.

- By 2015, SNETP aims to play a leading role in managing these investments and to coordinate about 40% of them (about EUR2009 150 million per year);

- SNETP public / private partnerships:

The SNETP R&D programmes can be split into:

- R&D endorsed by industry (utilities and vendors). Primarily a responsibility of the industry, this part of R&D is mainly driven by their specific needs, and directly related to operational performance. The R&D organisations will provide their expertise and in specific cases some complementary investigations, but with a strict respect of confidentiality. This R&D is mostly based on private funding. The R&D deliverables benefit their owners;
- R&D shared between nuclear stakeholders and eligible for public-private partnerships (also includes topics addressed in Euratom Framework Programmes). The R&D deliverables tend to benefit the entire nuclear community.

SNETP will play a key role in coordinating R&D programmes on Light Water Reactors

Over the period 2010-2020, the total cost of the programmes implemented under the SNETP umbrella is estimated to be EUR2009 1.5 billion: i.e. 0.5 billion for the R&D endorsed by industry and EUR2009 1 billion for R&D open to public-private partnerships. Thus, assuming these are 50:50 partnerships, the share in overall costs will be 2/3 industry and 1/3 national and/or EU public sources.

3.4 Generation IV Fast Neutron Reactors

To ensure the long term sustainability of nuclear energy, the next Gen IV fast reactors should be available for deployment by 2040 or even earlier. Therefore an ambitious yet realistic R&D and demonstration programme is to be put into place, on the basis of an exhaustive review of the experience feedback drawn from the design, construction and operation of these types of reactors.

In order to provide a solution for long-term sustainability of nuclear energy, SNETP gives a high priority to the development of Fast Neutron Reactors (FNR), among which are the Sodium-cooled Fast Reactor (SFR) as a proven concept, and the Lead- or Gas-cooled Fast Reactor (LFR and GFR) as alternative longer-term technologies.

The SFR and LFR benefit from the feedback from past operating experience, but the present safety, operational and competitiveness standards require new designs. Such experience does not exist for the GFR. To achieve commercial availability of FNR technologies by 2040, it is vital to continue and accelerate R&D on key topics, primarily:

- primary system design simplification;
- improved materials and innovative fuels;
- improved safety (safety standards at least comparable to Gen III standards), particularly in terms of neutronics, risks associated with liquid metal, robustness against severe damage in the core and passive systems;
- innovative heat exchangers and power conversion systems;
- advanced instrumentation and in-service inspection capabilities;
- reduction of the plant costs;
- partitioning and recycling processes. The work in the area of partitioning and transmutation with innovative fuels and core performance and associated fuel cycle studies will lay the groundwork for assessment of future sustainable nuclear fuel cycle strategies, whether and to what extent it should involve transmutation and whether in a dedicated waste-burning Accelerator Driven System or in future Gen IV power plants.

R&D work on such 4th generation systems should be complemented by continuing R&D to further optimise the 3rd generation reactors that are anticipated to operate throughout the 21st century.

3.4.1 Speeding up the development of Fast Neutron Reactors: a European Industrial Initiative

To accelerate the development and the deployment of Gen IV FNRs, SNETP plans to launch a set of demonstration projects

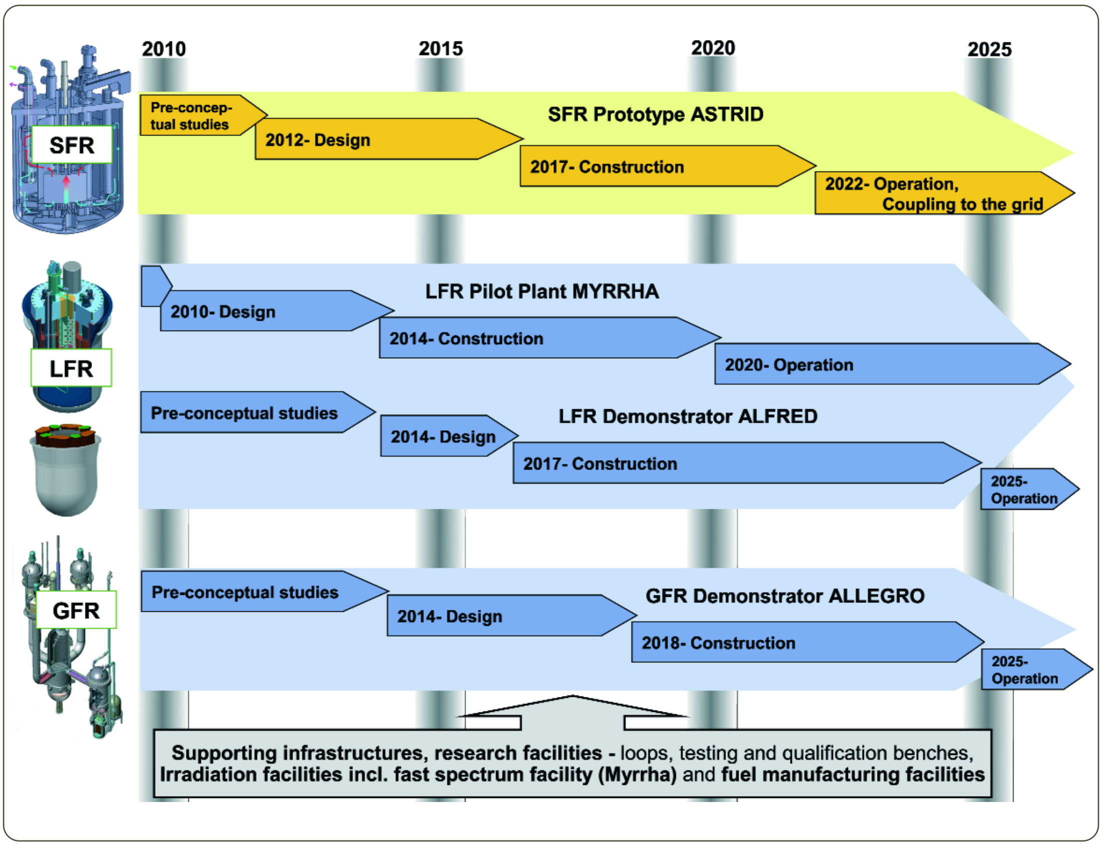


Fig. 12: The SET-Plan European Industrial Initiative dedicated to Gen IV FNRs

in the frame of a SET-Plan European Industrial Initiative.

Indeed, Gen IV FNRs are a promising technology, but demonstrators / prototypes are required before commercial deployment. In addition, their designs will take advantage of the operating experience of existing nuclear reactors. Considering that Gen IV systems are a revolutionary concept and the need for harmonisation and consensus, discussions on design criteria should involve all stakeholders: utilities, suppliers, design authorities and Technical Safety Organisations.

SNETP recommends that its member utilities should together list the criteria for designing safe, competitive, reliable and easy-to-operate Gen IV FNRs on the basis of their longstanding experience with operating nuclear reactors. In addition, the joint development of codes and standards would provide a common European tool for capitalising on the knowledge gained through R&D on improved materials and the advanced manufacturing processes required for these advanced reactors.

With this in mind, the European Industrial Initiative on FNR includes:

- the construction of an SFR prototype in France by 2020 (though open to the establishment of an international consortium), which is an essential step towards the industrialisation of this technology; and
- the construction of a demonstrator using alternative FNR technology (LFR or GFR).

Operation of the prototype and demonstrator would enable important experience to be acquired for the design and operation of industrial power plants using FNR technology, and is a key step towards industrial deployment.

The European Sustainable Nuclear Industrial Initiative is one of the six industrial initiatives being developed within the Community's SET Plan

In addition, the industrial initiative would include a fast spectrum irradiation facility and pilot fuel manufacturing and recycling facilities, as well as the necessary research infrastructure, including a further assessment of accelerator-driven systems for transmutation. Research must also continue on safety-related issues and validation of safety criteria.

These prototype and demonstrator reactors would not only establish a specific technology track but also act as multipurpose research infrastructures. In particular the GFR or LFR

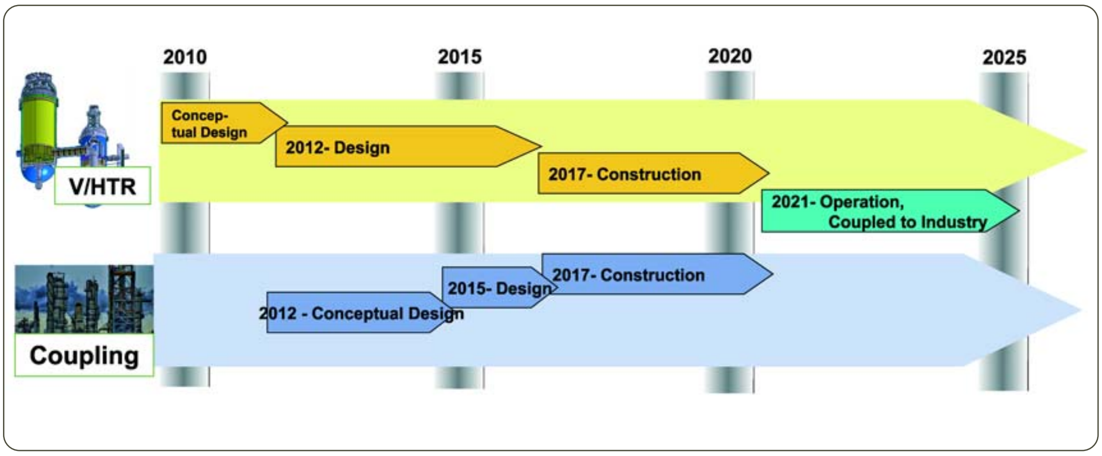


Fig. 13. Preliminary roadmap for cogeneration (Courtesy by HTR-TN)

8 - Formerly the HTR technology has been developed in Europe up to the operation of an industrial prototype (THTR). Since these past achievements, a new breakthrough occurred in HTR technology, with the development of the modular concept. Nevertheless, even if the viability of this concept has been validated for small test reactors, it has still to be demonstrated at industrial scale. Without excluding the possible use of other types of nuclear systems, the modular HTR has specific assets for a large and early deployment of nuclear co-generation of electricity and industrial process heat.

demonstrator could be an experimental platform to address innovative fuel development, including for the SFR prototype, for testing specific minor actinide-bearing fuel to demonstrate and optimise transmutation and also for addressing the development of high temperature applications for industrial end-users. These reactors would also provide facilities for experimental irradiations and minor actinide transmutation.

3.5 Non-electric applications of nuclear energy

SNETP also places a high priority on the rapid development of non-electric applications of nuclear energy in order to significantly reduce CO_2 emissions in line with EU policy objectives.

Non-electric energy is at present mostly produced by fossil fuel burning, giving rise to the majority of CO_2 emissions. Europe places a high priority on the rapid development of non-electric applications of nuclear energy, involving the demonstration in the short-term of cogeneration and the coupling of a nuclear power plant, e.g. High Temperature Reactor[8] (HTR) with an industrial process thereby significantly reducing emissions from as early as the 2020s.

SNETP places a high priority on the rapid development of non-electric applications of nuclear energy in order to significantly reduce CO_2 emissions.

Past achievements, as well as recent developments over the last ten years in Europe, suggest the potential for a fast track deployment of nuclear power for industrial process heat applications. However, in order to verify that the integration of all the different developments into an industrial system is feasible and to provide industrial process heat users with the evidence of licensing feasibility and compliance with industrial requirements (availability, reliability, flexibility, economic viability, absence of risks….), a demonstration of a real coupling between a nuclear heat source and actual process heat applications is necessary.

Such a demonstration will be possible only through a partnership between nuclear vendors and operators on the one hand, and end-user industries on the other hand. Such a partnership is presently initiated in FP7 by the EUROPAIRS project (nuclear industry + oil engineering companies, chemicals and fertilizer manufacturers, steel industry). Representatives of the regulators and of Technical Safety Organisations also participate in the project, in order to guide the developments by specifying requirements for licensing acceptability of the reactor and of its coupling with industrial applications.

On the basis of the technological assets from the historical legacy and recent developments, and of the partnership initiated by EUROPAIRS, SNETP recommends that the next step is to evaluate the establishment of the conceptual design for a cogeneration nuclear system coupled with industrial process heat applications, with necessary supporting R&D for the nuclear reactor, the application processes and the coupling system. An industrial initiative should be launched without delay to perform the next phases of design and construction of the demonstrator, which would allow start of operation in the early 2020s.

As the required power output is only modest, there will be no significant scaling up between the demonstrator and the commercial reactor. This demonstrator can therefore be considered a 'first-of-a-kind', preparing for rapid industrial deployment of "nuclear cogeneration", thus contributing to the SET-Plan objectives, expectedly before 2030.

Past and recent developments in Europe suggest the potential for a fast track deployment of nuclear power for industrial process heat applications.

In parallel to the development of the demonstrator, R&D on advanced materials and fuel should be continued to prepare for longer-term improvement of HTR performance. In addition, developments in the technology for coupling the nuclear reactor with process heat applications and feedback from operation of the cogeneration demonstrator will be of benefit for possible longer-term use of FNRs as a heat source for some process heat applications. It is therefore recommended to develop synergies between the HTR and Gen IV Fast Reactors systems, most particularly, but not exclusively, the GFR.

The FNR prototype and demonstrator and the cogeneration demonstrator are key projects for SNETP's research agenda. SNETP recommends that the Member States and the European Union strongly support the corresponding European Industrial Initiatives.

3.6 Funding of European Industrial Initiatives

A Memorandum of Understanding for the European Sustainable Nuclear Industrial Initiative (ESNII) is being established by some SNETP stakeholders for FNR development. Another Industrial Initiative, possibly with international partnership, is under preparation for "nuclear cogeneration" development. The parties to these two industrial initiatives will set up task forces to elaborate roadmaps in terms of design, planning, budget, intellectual and industrial property issues and to support the preparation of private-public and even international partnerships.

The European Industrial Initiatives need co-investment from private and public sources.

The European Industrial Initiatives will require significant investment: estimates suggest that the costs might range from EUR2009 8 to 10 billions for FNR and about 3.5 billions for the development of a nuclear cogeneration plant coupled with process heat applications. These costs for the European Union could be significantly reduced in case of international sharing of the developments. A large part of these costs could be repaid by a return from the future revenues generated by these technologies. However, the costs of the programme are subject to uncertainties (regulatory framework evolution, unrecoverable costs resulting from immature technology, learning curve effect).

Therefore, a better coordination and funding of R&D programmes at European level must be developed, combining EU (e.g. Framework Programme), national and private initiatives.

SNETP will interact with the European Commission, the Steering Group and the European Energy Research Alliance under the SET-Plan to reach this objective. The Communication from the EC on the funding of the SET-Plan proposes ways and means for the funding of low carbon energy technologies including nuclear fission. However, this will only come to fruition if all efforts, at national and EU level, are properly coordinated and focus on clear and agreed objectives. Public–private partnerships will also be necessary for technologies closer to the market.

The sharing of funding will depend on the part of the programme under consideration: for the SFR prototype (which is closer to commercialisation) participation of industry would be higher than for LFR or GFR demonstrators or testing facilities.

European funding needs for this R&D effort are estimated at EUR2009 11.5-13.5 Billions in the 2010-2020 period, which could be significantly reduced in case of international partnerships. The share of the cost is estimated at 80% from the public sector (national and/or EU) and 20% from industry (mostly vendors, utilities and end-users).

3.7 Nuclear R&D coordination and organisation

3.7.1. Increasing the level of cooperation and reducing fragmentation in Europe

For maximum effectiveness, a concerted approach at the EU level is required with continued cooperation between Member States and nuclear energy stakeholders. Significant efforts are required to maintain infrastructures, competences and know-how, and to continue long-term research activities, e.g. those supported in previous Community programmes.

European integration in the nuclear sector started with Euratom, the Framework Programmes and other European Commission initiatives or between private companies.

> To preserve its technological and industrial leadership, the European nuclear sector must increase the level of cooperation and reduce fragmentation of efforts

Operating at the European scale requires further harmonisation and standardisation of licensing processes, including codes and standards, improved coordinated R&D between all stakeholders (utilities, vendors, design authorities, research, Technical Safety Organisations), education and training of the existing workforce, etc.

Also, SNETP will strengthen information exchange and synergy with other European technology platforms with common R&D interests (e.g. hydrogen production).

In addition, the joint development of codes and standards should be a European shared tool in order to capitalise on knowledge gained in a European framework and to industrialise the results of R&D.

Basic research infrastructure and competence

Research infrastructures are key to a successful R&D programme as well as to education and training. They range from large, expensive laboratory complexes to high performance computing resources and modelling platforms. Experiments are critical to better understand nuclear phenomena and develop knowledge and are further used to validate models and qualify materials.

Fig. 15: INVAP-Isolux's economically most advantageous PALLAS design (copyright INVAP and NRG)

Fig. 14: Artist's view of the Jules Horowitz Reactor JRH (Courtesy of CEA)

Fig. 16: Overall design of 50-100 MWth MYRRHA/XT-ADS (Courtesy of SCK•CEN)

SNETP strongly recommends keeping adequate research infrastructures across the EU in order to support national nuclear research programmes and training of students or national operators.

Europe has built a very good quality research infrastructure since the beginning of its nuclear programmes but many experimental reactors are now ageing. They will require upgrading as well as replacement.

Support may cover design, refurbishment, construction and/or operation of key infrastructures. This could include material test facilities and training reactors. All are necessary to maintain high standards of technical achievement, innovation and safety in the European nuclear sector.

In order to make best use of infrastructures in Europe, research facilities should network to offer mutual services to one another. This represents an optimal use of competences and capabilities. Mobility of researchers and teachers must in consequence be supported as much as possible. Adequate support for the transporting and sharing of irradiated fuels and materials among irradiation and research facilities should be provided, including an effort to harmonise licence requirements and procedures.

Some very large multipurpose research infrastructures will be critical to R&D. They are best funded by national programmes in combination with private funds, supplemented by EC funding for making available R&D capacity. Such large infrastructures are necessary for nuclear research and must be supported in Europe.

Human resources, mobility and training

Changes in nuclear technology will coincide with changes in the workforce. This is both a challenge and an opportunity. There is a need to accelerate the development of a skills pipeline between university and industry to attract young talented people.

Engineers hired in the boom period of the 1970s will soon reach retirement age. Experience acquired over the intervening decades by operators, research centres, regulators or Technical Safety Organisations is a priceless asset that must be transferred to younger generations. It should be stressed that the current high level of nuclear safety is critically dependent on retaining and recruiting people with the necessary scientific competence and know-how.

Collaboration between these organisations and universities should be deepened.

- **Need for new recruitment and the education & training of new staff;**
- **Maintain state-of-the-art research infrastructures;**
- **Transfer of knowledge from the nuclear industry to academia (and remedying the lack of teachers).**

To guarantee the availability of suitably qualified researchers, engineers and technicians in the long-term, further development of scientific competence and human capacity (for instance through joint training activities) is necessary. Coordination between educational institutions across the EU, with networks such as the European Nuclear Education Network (ENEN), should be further improved, and the training and mobility of students and scientists facilitated. Coordinated training initiatives, such as the European Nuclear Energy Leadership Academy (ENELA) proposed by industry, must be promoted.

Nuclear education and training schemes will be further harmonised and extended to meet stakeholder needs in areas of reactor systems, radioactive waste management and radiation protection. This will help provide attractive international opportunities for young people wanting to enter the field.

This truly pan-European approach will provide the incentives for a new generation of nuclear scientists and engineers who will face tomorrow's scientific and technological challenges in an increasingly integrated sector on behalf of Europe's citizens.

3.7.2. Improving Nuclear Fission R&D coordination at the EU level

To reduce fragmentation of efforts, topics and actions presented in the Strategic Research Agenda should be prioritised and the research effort more effectively organised.

The prioritisation process has been launched in 2009 and will be completed by mid-2010. The most important research topics have to be identified, with funding and research activities being concentrated on the most critical issues.

SNETP will then be in a position to propose an initiative aimed at organising effectively the carrying out of nuclear fission R&D by European stakeholders.

This would cover the following issues:

- programme and project definition;
- funding;
- selection of appropriate R&D actors;
- assessment of results;
- implementation, dissemination of results.

The participating stakeholders therefore need to be able to carry out collectively:

- an R&D joint programming process, bringing together nuclear stakeholders to discuss strategic R&D needs, identify near- & long-term issues, provide strategic & business guidance to R&D staff, allocate budgets, decide programme launching or closing, select R&D providers;
- an R&D delivery process, covering the operational progress of each project, assessing value of new and on-going projects, ensuring that deliverables meet the objectives on time and with expected added value and quality.

SNETP is ready to assess in 2010 the implementation of a 'smart structure' which will make it possible to share R&D needs and R&D resource leverage. The needs should be expressed mostly by utilities, vendors, Technical Safety Organisations, but also by research organisations for upstream R&D. The resources should be provided mostly by research organisations, but also by other stakeholders when relevant.

Three Workings Groups (one for Gen II and Gen III reactors, one for Gen IV fast reactors and one for nuclear cogeneration) were launched in 2009.

An "Implementation" document / Action plan will be elaborated in 2010 to describe how research will be organised in all three working groups. Therefore a common methodology will be used to prioritise the research needs. Cross-topic issues will be covered within each of the relevant working groups.

After initial implementation feedback, a suitable mode of operation for SNETP stakeholders will be proposed.

The group on Gen II and Gen III will work with the existing NULIFE network (devoted to the long-term operation of the current fleet) where the end-users have already defined some projects on a case by case basis.

The group will act as the driving force to establish a European Industrial Initiative with reference to the 2020 objective of the SET-Plan "maintain competitiveness in fission technologies, together with long-term waste management solutions".

3.7.3. Longer term perspectives for SNETP

In the longer term, SNETP can play a leading role in all nuclear-related R&D activities.

SNETP is paramount in bringing together nuclear energy stakeholders. It will continue its activities and aims to play a leading role in:

- coordinating and implementing research, development and demonstration initiatives;
- coordinating collaborative efforts within EU Member States willing to engage in the further development of fission energy, as well as with non-EU countries via a mutual benefit approach;
- Promoting actions in the field of Education & Training;
- Providing strategic technical advice to the European Commission, e.g. possible orientations of Euratom Framework Programmes.

International Cooperation

Many countries have been pursuing ambitious research programmes in nuclear fission for decades and effort is now accelerating on the eve of a nuclear renaissance worldwide. Gen IV research in particular is a key area in the race for the deployment of advanced nuclear systems.

Outside Europe, Russia, Japan and India have each accumulated significant experience with sodium-cooled reactors. China will commission its first sodium-cooled research reactor in the near future. South Africa is supporting the high-temperature Pebble Bed Modular Reactor; China plans to commission its own pebble bed reactor as early as 2013, and is already involved in site construction; the US-DoE has strongly increased funding for the US HTR project.

All countries interested in Gen IV reactors have gathered in the so-called Generation IV International Forum (GIF). Other research programmes for Gen IV reactors were set up in recent years. This demonstrates the global interest in advanced reactors.

SNETP is a European forum and will therefore focus on the R&D agenda of interest to Europe. But research topics of common interest with third countries are likely to emerge and an international collaborative framework will need to be set up to best represent European stakeholders and find optimal solutions for all parties.

However, it must be recognised that EU industry and R&D organisations should first have their own well-funded Gen IV R&D programme in order to strengthen their technology leadership and be in a good position to negotiate international cooperation agreements.

International cooperation in the field of education and training is also strongly recommended. For countries with longstanding nuclear programmes or for nuclear newcomers, education and training is the best way to promote a common understanding of nuclear standards and safety approaches and to share best practices. This will ultimately open up numerous business opportunities. SNETP will therefore bring interested European stakeholders together and recommend a framework for collaboration in education and training activities.

Knowledge dissemination

SNETP will also promote:

- **the dissemination of knowledge from nuclear R&D to the public through appropriate communication activities;**
- **the establishment of a true scientific basis for decisions, based on maximum transparency.**

What next?

This Deployment Strategy identifies the key actions necessary to implement SNETP's Strategic Research Agenda (released in 2009), overcome the technical and non-technical barriers, deliver its results and communicate its benefits and impact to decision makers and the general public.

The next step is the issuing of the Platform's Implementation Plan, expected to be published by the end of 2010.

The Deployment Strategy will be periodically reviewed and updated.

Glossary of acronyms & Contributors

Glossary of acronyms

- EERA European Energy Research Alliance www.eera-set.eu
- ENELA European Nuclear Energy Leadership Academy http://www.enela.eu/
- ENEN European Nuclear Education Network http://www.enen-assoc.org/
- EPR European Pressurised Reactor
- ESNII European Sustainable Nuclear Industrial Initiative www.snetp.eu/esnii
- ETP European Technology Platform http://cordis.europa.eu/technology-platforms
- EUR European Utility Requirements www.europeanutilityrequirements.org
- FNR Fast Neutron Reactor
- GFR Gas-cooled Fast Reactor
- GIF Generation IV International Forum www.gen-4.org
- HTR High Temperature Reactor
- IAEA International Atomic Energy Agency http://www.iaea.org/
- IEA International Energy Agency http://www.iea.org/
- IGD-TP Implementing Geological Disposal of Radioactive Waste Technology Platform http://www.igdtp.eu/
- LFR Lead-cooled Fast Reactor
- LTO Long Term Operation
- LWR Light Water Reactor
- MSR Molten Salt Reactor
- NPP Nuclear Power Plant
- NEA/OECD Nuclear Energy Agency of the Organisation for Economic Co-operation and Development http://www.nea.fr/
- SCWR Supercritical Water-cooled Reactor
- SET-Plan Strategic Energy Technology Plan http://ec.europa.eu/energy/technology/set_plan/set_plan_en.htm
- SFR Sodium-cooled Fast Reactor
- SNETP Sustainable Nuclear Energy Technology Platform www.snetp.eu
- SRA Strategic Research Agenda
- (US) DoE United States Department of Energy
- (V)HTR (Very) High Temperature Reactor

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