

Nuclear Education and Training

Key Elements of a Sustainable European Strategy

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Working Group
on Education,
Training
and Knowledge
Management
(ETKM)





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Preamble

Education and training are key to the sustainability of the nuclear industry, and this is truer today than at any point in the past. With lifetime extensions of many existing nuclear power plants, the growing demands for decommissioning and nuclear waste disposal solutions, the growth of the industry worldwide, and an ageing workforce, the shortage of appropriately educated and trained personnel risks becoming a severe constraint. In view of the strong competition from other hi-tech industries and the lower appeal of science and engineering degrees in general, meeting the industry's growth and accommodating an ageing workforce are challenges needing a cohesive and integrated strategy for the whole nuclear sector.

Education and training has always been a key concern within nuclear energy programmes and the respective requirements and obligations have been laid down in key documents such as the EURATOM Treaty and the Convention on Nuclear Safety. More recently, the Council of the European Union (EU) considered the specific challenges related to the current situation at its 2891st Competitiveness Council meeting¹. The Council's conclusions make a number of observations and conclusions, highlighting challenges such as:

- the lack of engineers and researchers in scientific sectors;
- the need to take appropriate measures to ensure that nuclear energy remains a safe option in those Member States that have chosen or will choose it;
- the long-term availability of qualified human resources in view of the continued exploitation of nuclear energy in several Member States, whereby 152 reactors currently supply the EU with 31% of its electricity;
- the need for and the importance of training and teaching of skills through involvement in R&D in all subject areas: design and construction, radiation protection, radioactive waste and

materials management, operation of installations and decommissioning;

- the age profile within the workforce, in particular the many retirements likely in the short term;

pointing out that:

- *there is a real risk of the loss of nuclear knowledge for the European Union if no measures are taken, and*
- *preservation of skills in the nuclear field requires a general effort involving public and private players and in particular the nuclear industry.*

The Council further highlighted needs such as:

- the creation of appropriate conditions for mutual recognition of nuclear professional qualifications throughout the EU;
- a review of professional qualifications and skills in the nuclear field for the EU, paving the way for drawing up a pan-European chart of skills and knowledge relating to occupations in the nuclear field to facilitate the mobility of employees;
- reinforcing the teaching of basic scientific skills in preparation for energy-related occupations, and giving a new impetus to the teaching of mathematics, physics and chemistry at every level;
- developing generally the provision of programmes in different languages specifically geared to energy-related and especially nuclear-related occupations;
- assessing ways of attracting more European and non-European students to these programmes by improving the competitiveness of scientific and technical careers in public and private companies within the EU;
- equipping European universities and institutions involved in nuclear-related teaching programmes with the capacity to accept such students;
- where necessary extending the network of institutions and universities offering this type of teaching, and ensuring mutual recognition of qualifications obtained in other Member States;

1 - Council of the European Union, Conclusions on the Need for Skills in the Nuclear Field, 2891st Competitiveness (Internal Market, Industry and Research) Council Meeting 1&2 December 2008, Brussels

- improving the visibility of European nuclear training as currently organised in associations and networks, which constitutes a recognised global reference;
 - making available common European technical documentation and teaching material, in particular through the use of new information technologies.
- *with respect to institutional capacity-building, E&T needs to focus on the legislative and regulatory framework, nuclear safety, safeguards, security and physical protection, radiation safety, emergency preparedness and response, and radioactive waste planning.*

The present challenges for nuclear education and training were also highlighted at the 2009 G8 Summit (G8 NSSG)². The communiqué largely addressed institutional capacity building for countries embarking on nuclear power programmes. The NSSG Italian Presidency stated:

- *special attention to the issue of education and training (E&T), as an essential tool to build capacity at the institutional level, including the establishment of an adequate and sustainable regulatory framework was needed. These countries need to ensure that they are in a position to implement their programmes in compliance with existing international instruments and internationally recognised safety standards and security guidelines;*
- *countries planning to initiate nuclear programmes need to develop the supporting national infrastructure in order to meet safety, security and safeguards requirements as a long-term commitment;*
- *the development of institutional capacity is a government responsibility. E&T is an essential building block in the build-up of capacity at the institutional level, and in the establishment of an adequate and sustainable legal and regulatory framework;*

It is also worth recalling in this context the EU's recent Nuclear Safety Directive³, a major step towards establishing a common legally binding EU framework for the safety of nuclear installations. In Article 7, devoted to expertise and skills in nuclear safety, the Directive states:

“Member States shall ensure that the national framework in place requires arrangements for education and training to be made by all parties for their staff having responsibilities relating to the nuclear safety of nuclear installations in order to maintain and to further develop expertise and skills in nuclear safety.”

The ETKM Working Group has considered the situation in more detail, in particular the identifying of recent developments, whether any gaps are apparent and what developments are still needed.

This report reviews the challenges related to nuclear education and training, the initiatives recently undertaken to meet them, and the future needs with regard to the present day situation and the expected future developments. It identifies common ground between these initiatives, the approaches to address current and future needs and recommends appropriate actions.

2 - G8 NSSG Nuclear Education and Training - Institutional Capacity-Building, 2009, http://www.g8italia2009.it/G8/Home/Summit/G8-G8_Layout_locale-1199882116809_Atti.htm

3 - Council Directive 2009/71/Euratom, Brussels, 25 June 2009

The ETKM Working Group

The European Sustainable Nuclear Energy Technology Platform (SNETP) was created in September 2007 by stakeholders of the nuclear sector (industry, research organisations, universities, technical safety organisations, learned societies and other European organisations) to accelerate the research and development and deployment of fission technologies in Europe. The Platform assists in the efficient co-ordination of European, national, regional and local research, development and deployment programmes and initiatives and ensures a balanced and active participation of the major stakeholders. It helps to develop awareness of the role that nuclear fission energy plays in Europe's current energy mix, and could play in Europe's future low-carbon energy mix. It helps foster future co-operation, both within the EU and on a global scale.

In parallel with the development of the Strategic Research Agenda (SRA) and Deployment Strategy, it was agreed that work on education, training and knowledge management should be an important cross-cutting activity within the SNETP agenda. The Working Group on Education, Training and Knowledge Management (ETKM) was established to deal

with this area in close co-operation with the Strategic Research Agenda and Deployment Strategy Working Groups (Figure 1 - p 38).

The objectives of the ETKM Working Group were initially agreed to address these concerns/challenges with specific reference:

- to identify a course of action to secure an adequate resource of well educated and trained young professionals to support the research recommended in the SRA;
- to identify the steps required to meet the demand of industry and R&D organisations for new competent personnel and the need for teachers in academia;
- to collate the facilities, both existing and required, to develop the future human resource necessary to support the SRA.

The initial work of the ETKM Working Group clearly indicated that the challenges and needs of the nuclear industry transcend beyond the research community to include operations, health and safety and many other activities that underpin the industry. This resulted in a generalisation of the Working Group's objectives to enable the broader group of EU nuclear stakeholders to be accommodated and not specifically address the SRA needs.



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1. Introduction

Nuclear education and training has always been closely related to the use of nuclear energy. Recognising the scientific and interdisciplinary dimensions of nuclear technology and the high significance of human qualification for its safe use, all major nuclear energy programmes included the establishment of an education and training (E&T) infrastructure in parallel to the growth of the industry. Generally the current E&T infrastructure can be traced back to the needs of the research programmes in the 1950s and 1960s.

The evolution of the nuclear industry however has not been smooth, the ups and downs in the industrial perspectives influenced the attractiveness of nuclear technology for students and the growth and decline of the nuclear education and training infrastructure. A particular problem was the strong public and political opposition to nuclear energy after the accidents at Three Mile Island (1979) and Chernobyl (1986) and the resulting stagnation in the building of nuclear capacities in the 1980s and 1990s. These effects were particularly strong in Europe and North America. Several European countries took political decisions either to phase out existing nuclear programmes or scale back further expansion.

These developments resulted in tremendous manpower challenges for the nuclear energy sector. With the declining expectations in nuclear energy and a dramatic loss of employment opportunities, the attractiveness of nuclear professions for students decreased to extremely low levels. The investment in teaching nuclear engineering and in nuclear research declined, many undergraduate and post graduate programmes were discontinued, research reactors and other facilities needed for nuclear education were closed.

The significance of the related challenges was increasingly recognised towards the end of the 1990s. The shortage of young engineers and

scientists to replace the older generation of nuclear engineers approaching retirement would create a very difficult situation not only for the potential revival of nuclear energy but also for the continued safe operation of existing plants.

This is an unprecedented challenge caused by an aging work force, increased competition for qualified and experienced workers coupled with a precarious skills supply chain. Many nuclear energy Member States acknowledge that their industry manpower shortfall over the next decade is measured in thousands and these estimates in many instances exclude skills needed for new-build. The relevant skills are across the complete spectrum of the industry and include regulatory, legislative organisations along with operators, R&D, consultants, service providers, engineering organisations and educational establishments all needing to increase manpower and replenish skills over the next two decades, either to replace retiring staff and/or prepare for new build.

There has been considerable response worldwide; a number of special programmes have been initiated to remediate the situation including measures to stabilize academic research and building new forms of national and international co-operation to raise the quality of education programmes and increase the attractiveness of nuclear education for students.

The problem is not merely one of nuclear energy but is imbedded in a more general issue related to the insufficient attractiveness of science, engineering and technology careers in general, a problem addressed by the European Research Advisory Board (EURAB)⁴ in 2002. EURAB recommended a variety of initiatives ranging from enhancing public awareness of science to stimulating creative teaching of science and technology in both primary and secondary education.

The industry has awoken to these challenges; manpower shortfall and shortage of science and

4 - EURAB, 'Increasing the Attractiveness of Science, Engineering and Technology Careers', Recommendations, 02.054 final

engineering disciplines are recognised. Education, in particular tertiary, has re-kindled new courses, undergraduate recruitment in science and engineering is on the increase, new professional training programmes have been developed, schemes for retaining personnel near/past retirement age, collaborations between the industry and educational establishments are increasing, secondments from industry to academia and vice versa to improve understanding is being actively promoted, additional research investment both in programmes and infrastructures are showing positive signs and many more initiatives are evident.

This report deals with the challenges for the education and training of the workforce required in the nuclear power sector. It describes the status of recent nuclear education and training initiatives, the resulting achievements, and what

should be done during the coming years to ensure sufficient knowledge and skills are available for the continued safe operation of existing nuclear power plants, for a sustainable growth of the European nuclear industry, and for the key stages of the nuclear fuel cycle.

Obviously this scope covers only part of the nuclear education and training issues which are significant for the future of nuclear energy. Further important topics are, for instance, the teaching of energy topics in primary and secondary education, the education of opinion builders and communicators, and education and training for nuclear non-power applications. The fact that these topics are not addressed within this report is not related to their lower significance, rather that the ETKM Working Group believes they are not sufficiently close to the scope of SNETP activities.

2. Current Status

2.1 The Situation in the Late 1990s

At the end of the 1990s the nuclear education situation was quite dramatic in most OECD countries and particularly in the EU Member States. It was rather evident that the lack of young engineers and scientists with nuclear qualifications and willing to work in the nuclear industry could very soon become a problem for the safe long-term operation of nuclear power plants and a hindrance to the potential revival of nuclear energy. An important international study by the OECD⁵ expressed severe concerns that the situation would put the maintaining of expertise in nuclear science and technology at risk. In most countries there were significantly fewer comprehensive, high-quality nuclear technology programmes at universities than before and the ability of universities to attract top-quality students, to meet future staffing requirements of the nuclear industry and to conduct leading-edge research was seriously compromised. The reports called for immediate action and recommended a series of measures ranging from revitalising research and developing high quality training to enhancing collaboration and sharing best practices.

2.2 Progress to Date

There has been a considerable response during the last decade in many countries⁶; special initiatives were started to maintain infrastructure and personnel for nuclear education at universities as well as to keep nuclear research as a vehicle for nuclear education. Particular initiatives worth mentioning are:

- Efforts of the European Commission and some European Member States to maintain research in nuclear technology and nuclear safety with close

links between the appropriate research and education and training.

- Support by the industry, regulators, and research centres to help universities in maintaining academic education in nuclear technology when the number of students would not be sufficient to warrant financial support from government and/or education authorities.
- Building of national and international networks with the objective to strengthen the co-operation between different universities, promote co-operation between universities, research centres and other nuclear stakeholders, facilitate the exchange of information, collaboration and the sharing of best practices in nuclear education and training, and make studies in nuclear energy more attractive for students.



Networking was a natural response to the decline of educational capacities and nuclear research infrastructure. In a situation where nobody could expect big investments in nuclear education, where many retiring university professors were not replaced, networking opened a way to share the remaining resources and thus to maintain the quality of nuclear education at a level which could not be assured by individual institutions alone.

The type of networks varied, depending on the particular needs and practices of the respective countries, regions and institutions. In some cases, for instance, universities co-operated to jointly offer a nuclear education program, in other cases networking focused on co-operation in research and education.

5 - OECD/NEA, Nuclear Education and Training: Cause for Concern?, Nuclear Energy Agency, 2000

6 - Status and Trends in Nuclear Education, IAEA Nuclear Energy Series No NG-T-6.1, Draft April 2010

Table : Types of national networks relevant for nuclear education

Type of Network	Examples
Joint offer of a nuclear education programme	<ul style="list-style-type: none"> ■ Belgium Nuclear Education Network (BNEN) ■ UK Nuclear Technology Education Consortium (NTEC) ■ Czech Nuclear Education Network (CENEN)
Co-operation in nuclear research and education	<ul style="list-style-type: none"> ■ Italian Consorzio Interuniversitario per la Ricerca Tecnologica sull' Energia Nucleare (CIRTEN) ■ German Alliance for Nuclear Competence (Kompetenzverbund)

7 - ENEN
<http://www.enen-assoc.org>

8 - <http://www.enen-assoc.org/en/activities/for-students/master.html>

At the European level the European Nuclear Education Network (ENEN Association⁷) was created with a view to establish international models for co-operation between universities capable of increasing the mobility of students in nuclear technology and to improve the mutual recognition of course achievements. Under the umbrella of the Bologna process, ENEN has instigated several initiatives that allow easy movement from one country to another within the European Higher Education Area – for the purpose of further study or employment. In 2003 its 50 university members agreed and implemented a reference curriculum and course credits for nuclear engineering; now several major European nuclear research institutes are members. ENEN is promoting and rewarding student mobility by delivering the certificate of European Master of Science in Nuclear Engineering (EMSNE⁸) to students having acquired at least 20 credits in a university abroad. Furthermore, ENEN has linked teaching and training with research by contributions to research projects, by organising advanced courses for PhDs and young professionals and promoting the exchange of research results and experience at special events, workshops and seminars.

This European Higher Education Area initiative provides Europe with a broad, high quality and advanced knowledge base, and ensures the further development of Europe benefiting from a cutting edge European Research Area. Its attractiveness is further increased as many people from non-European countries also come to study and/or work in Europe. To date, ENEN has concluded agreements with universities in South Africa, Japan and the Russian Federation and with nuclear education networks outside Europe to facilitate mobility of students and mutual recognition of courses and curricula in nuclear disciplines on a world-wide level.

The networking initiatives contributed significantly to stabilizing and revitalizing nuclear education across Europe. The situation remains difficult, however, and the European Nuclear Energy Forum (ENEF), set up by the European Commission in 2007 to bring together all concerned stakeholders to discuss nuclear issues, has identified nuclear education as one of highest risks in the nuclear industry. Moreover the nuclear renaissance poses new challenges for nuclear education as the growth of the industry critically depends on increasing faster the number of engineers properly educated in a wide spectrum of nuclear disciplines.

In view of these needs a growing number of nuclear organisations have started setting up new initiatives in line with the Council conclusions calling for more efforts from public and private players to preserve the skills in the nuclear field. These new initiatives include education and training programmes as internal programmes or as public-private partnerships in co-operation with universities. Typically these programmes are run directly by the respective stakeholder or by a group of stakeholders, generally with a large international dimension. Some of them are based on partnerships with educational institutions, labour organisations, community organisations or federal, regional and local government agencies:

- In France, for example, EDF created a foundation for the development of education and training in the field of energy providing grants for students and financing chairs in various academic organisations such as École Polytechnique and École Centrale de Paris. Chairs in École des Mines des Nantes and in Ecole Nationale Supérieure de Chimie in Paris are being financed by Areva and Andra. Moreover, the French industry, research organisations and academic organisations co-operate in the creation and the strengthening of educational and initial professional programmes such as:



- an international master degree in nuclear energy delivered by a consortium with ParisTech, University Paris-Sud at Orsay, INSTN and mainly supported by EDF and also CEA, AREVA and GDF-Suez;
- education programmes in energy and nuclear technology at École Nationale Supérieure des Techniques Avancées, École Centrale de Paris, University of Paris VI, Institut National Polytechnique de Grenoble, ENSICAEN, more specialized curricula in chemistry at the Ecole Nationale Supérieure de Chimie de Paris, École Nationale Supérieure de Chimie de Montpellier and University of Montpellier II as well as in materials at ENSAM in Aix en Provence and ENSCI in Limoges;
- new bachelor degree programmes and more specialized craft education programmes.

In 2009 AREVA created the AREVA University - together with its campuses in Germany and in the USA - in the south of France, near Aix-en-Provence. The campus is tasked to host all the engineers and executives recruited by the group throughout the world. In-depth classes on AREVA core skills and its fundamental values, where safety and security head the list, will be given.

- In Germany, all four nuclear utilities are engaged in supporting universities in creating new professorships and academic programmes in nuclear technology. Moreover they created a common utility-led international program for graduates in nuclear technology and management which has operated since 2008 at the Technical University Munich.
- In Finland, the nuclear organisations re-evaluated the man-power situation and established an organising committee to develop and organise basic post-graduate professional training of new recruits and staff members. A basic professional training course on nuclear safety (duration: 6 weeks with 24 full training days) has been organised since 2002. The training aims specially for the acute needs of the new nuclear power plant project, but also to provide in the long term a new generation of nuclear experts to replace the generation, which will retire within the next ten years. The organising committee included representatives of the following organisations: Radiation and Nuclear Safety Authority STUK, nuclear power utilities TVO and Fortum, the Technical Research Centre of Finland VTT, the Lappeenranta (LUT) and Helsinki Universities of Technology (TKK, now Aalto University), and the Ministry of Employment and the Economy TEM. All the lecturers come from these organisations that

also share all the training positions representatively. Although the training is partly based on a similar course developed by the IAEA, it has been adapted to the Finnish conditions. A large part of the material is completely new and it contains also parts tailored for the future needs connected with increasing generation capacity and new Gen III type reactors. By 2010, altogether 473 persons have participated in the training.

- In Spain, reinforced joint ventures have been undertaken at different universities. Universidad Autonoma de Madrid in close collaboration with CIEMAT (the national research centre on energy and environmental matters) has launched a “Master on Nuclear Engineering and Applications (MINA)”. The Spanish nuclear sector has been deeply involved both in the financial support and in the definition and teaching of the academic program, with a clear leadership in the supervision of Master theses. This initiative is not unique. The Polytechnic University of Madrid, for instance, has recently reshaped its nuclear studies in the form of a Master on Nuclear Science and Engineering. These initiatives have raised a growing interest in nuclear energy, for example in case of MINA has led to an increase of the student numbers by nearly 100% in three editions.
- In Sweden, the three Swedish nuclear power plants, Westinghouse and the Swedish Radiation Safety Authority jointly fund education and research at KTH, Chalmers and Uppsala universities. A joint organisation, SKC, the Swedish Nuclear Technology Centre has been formed to coordinate these activities.
- The European Technical Safety Organisations (TSO) created the European Nuclear Safety and Tutoring Institute (ENSTTI) to provide a common culture in nuclear risk assessment to regulators and TSOs within Europe and contribute to the needs in expertise and research in the field of safety for the development of civilian nuclear energy programmes throughout the world.
- Six European companies (AREVA, Axpo AG, EnBW, E.ON, URENCO and Vattenfall) signed an agreement that covers the strategic, financial and legal aspects of the European Nuclear Energy Leadership Academy (ENELA)⁹. The academy was launched on 28 January 2010 and aims to educate tomorrow’s European nuclear leaders; the training centre will be located in Munich (Germany). The creation of the academy was decided by industry

9 - European Nuclear Energy Leadership Academy, 28 January 2010, www.enela.eu

players during the discussions at ENEF.

ENELA will offer three training programmes. The first one will train experienced professionals and senior managers to improve their managerial skills. The second is aimed at young graduates from different backgrounds (engineering, natural sciences, law, economics, social sciences...) with no professional experience to enable them to acquire skills in nuclear management. Finally ENELA will also serve as a think-tank and organise meetings to bring together representatives from the nuclear industry, the political world, the media and civil society.

Various organisations have been created to address the skills pipeline to ensure that appropriate and relevant educated and trained personnel will be available in future years. To raise awareness about careers in the nuclear industry, and to improve the knowledge of current and future skills gaps.

- In the UK, the *National Skills Academy for Nuclear (NSAN)*¹⁰ was set up to create, develop and promote world class skills and career pathways to ensure a sustainable future for the UK nuclear industry. The academy is an employer-led organisation established to ensure that the UK nuclear industry and its supply chain has the skilled, competent and safe workforce it needs to deal with the current and future UK nuclear programme, including all sub-sectors: operations, fuel cycle, decommissioning and waste management, defence, and more recently new



nuclear build. It has established a high quality training-provider network which is tasked with delivering excellence in nuclear skills.

- In France a Council for Education and Training in Nuclear Energy¹¹ (CFEN) was created by the Minister for Higher Education and Research in 2008. CFEN's objectives are:
 - Assess the adequacy between the education offered, the students population in different curricula and the industrial/research needs;

- Advise the Office of Higher Education on starting new academic nuclear curricula;
- Promote opportunities in the nuclear industry;
- Coordination of international recruitment of students;
- Promote international curricula such as the new International MSc in nuclear energy.

- In March 2010, at an International Conference on Access to Civil Nuclear Energy¹², the French president announced the creation of the International Institute of Nuclear Energy. This institute is intended to be a network bringing together the main elements of the French approach to education in the nuclear field. It will be a hub for institutions and students interested in nuclear education and training, including professional advice service especially for foreigners and newcomers. It will also be a think tank in conjunction with the French International Agency for Nuclear (AFNI), created in 2008 under CEA as a vehicle for international assistance in the establishment of civil nuclear programmes¹³. The institute will support the CFEN, promote a labelling of the education and training programmes for nuclear, and develop relationships with other networks.

- With regard to the need for having better knowledge of the nuclear skills gaps in the EU, ENEF initiated the creation of a European Human Resources Observatory in the Nuclear Energy Sector¹³ (EHRO-N), whose objectives are:
 - Produce and regularly update a quality-assured data base on the short, medium and long-term needs of human resources for the different stakeholders in nuclear energy and nuclear safety;
 - Identify gaps and deficiencies in the European nuclear E&T infrastructure and elaborate recommendations for remedial actions and optimisations;
 - Play an active role in the development of European scheme of nuclear qualifications and mutual recognitions;
 - Critically review results of existing national and sectoral surveys in order to ensure consistency with European energy supply strategies and likely medium- and long-term developments of the global nuclear sector;
 - Regularly communicate by appropriate means relevant data to EU Member States and appropriate public sector bodies, and academic and private organisations involved in nuclear education and training.

10 - www.nuclear.nsacademy.co.uk

11 - <http://www.cfenf.fr>

12 - OECD International Conference on Access to Civil Nuclear Energy, Paris, March 8 and 9, 2010

13 - Hohlefelder W., 'Status Report on WG Risks' ENEF Prague, 28/29 May 2009

Progress to Date

- ★ *There has been significant progress made in the past decade to off-set the demise in nuclear education and training of the 1980s and 1990s in EU countries; the European Commission has been a leader in this activity.*
- ★ *National research and education networks as well as the European Nuclear Education Network (ENEN) have played an important role in rekindling the flames of nuclear education and training. They have an important function in supporting industry in its ambitious and challenging aims.*
- ★ *Industry-driven collaborations and networks involving academic and industrial organisations are now extending beyond just the academic and research arenas to encompass education, training and provision of skills effectively in all sectors of the nuclear fuel cycle.*

To achieve the above objectives, EHRO-N would:

- analyse the quality of European education and training;
- benchmark human resources (HR) requirements with Asia and the US;
- identify bottlenecks in the HR supply chain;
- organise workshops on specific HR subjects.

EHRO-N was created in 2010 with a small dedicated staff within the European Commission JRC (Joint Research Centre) and a Senior Advisory Group (SAG).

2.3 New Needs and Opportunities

In recent years the perspectives for nuclear energy have once again increased as a result of the 5-times increase in the cost of oil, increased public awareness of climate change and global warming with the requirement to reduce carbon emissions and concerns for the security of supply of energy, all resulting in major shifts in energy policy in several EU Member States and North America. Opinions of the industry have improved, public support has increased, investment is now seen more positively and the contributions nuclear can make to reduce the energy industry's carbon footprint have created a new era for the nuclear industry. After many years of a slump in nuclear facility construction in Europe and USA, there is now a steadily growing interest in reversing or at least delaying phase-out policies or even in building new nuclear generation capacity:

- In many countries with nuclear power plants the operational life of nuclear power plants is being extended beyond the limits set by the original planning or by phase-out policies. In Europe,

decisions on lifetime extension have been taken, for instance, in Belgium, the Czech Republic, Finland, France, Hungary, the Netherlands, the Slovak Republic, and Sweden. Further decisions on lifetime extension are expected. The current German government, for instance, declared that it would decide on a lifetime extension of the nuclear power plants during the current parliamentary term.

- In France, one EPR unit is under construction at Flamanville and the construction of a second one has been decided for Penly. The Jules Horowitz Reactor, a state-of-the-art research reactor as well as a radionuclide production unit, should start operation in Cadarache by 2015.
- In Belgium, the government decided (in March 2010) to support the MYRRHA project of SCK•CEN, an experimental Accelerator Driven System (ADS), coupling a linear accelerator and a subcritical reactor of 100MW. This fast neutron facility is intended to study transmutation of actinides and to serve as a Material Test Reactor for GEN IV systems.
- The Finnish parliament confirmed (in June 2010) previous government decisions to permit the industry to build two new reactors in addition to the EPR under construction in Olkiluoto.
- The Swedish parliament decided (in June 2010) to reverse the country's long-standing ban on new construction and allow the building of new nuclear reactors to eventually replace the existing nuclear fleet.
- In the United Kingdom, a whole fleet of new nuclear reactors to replace the ageing ones is planned to be operational from 2017.
- The three Baltic States (Lithuania, Latvia and Estonia) and Poland agreed (in February 2007) to build a new nuclear plant at Ignalina, initially with 2 x 1600 MWe.
- The Italian government decided (in 2009) to lift the ban on nuclear new build.

- In the Czech Republic, the government recently expressed its support for the completion of the NPP Temelin with two additional units.
- The Czech and Slovak governments have agreed on a joint construction of a new unit at the site at Jaslovske Bohunice.

The nuclear renaissance requires additional human resources above and beyond those needed to replace the loss of skilled/experienced workforce owing to retirement. The figures are further increased by the trend towards extending



14 - These figures for EdF and Areva are not restricted to nuclear job profiles.

15 - World Nuclear News, 'Global Push for Nuclear Skills', 29 October 2008

lifetimes of existing nuclear power plants, the decommissioning programmes expected over the next two/three decades and the need to achieve visible progress towards demonstration of high-level waste disposal. Additional well educated, skilled personnel will also be needed for the new civil nuclear power countries.

Thus it is not surprising that the leading nuclear organisations have in the recent years commenced major recruitment campaigns. For example, the two main players in France's nuclear industry, EDF and AREVA (both involved in building nuclear plants), recruited a combined total of more than 15,000 new staff¹⁴ during 2008/2009¹⁵.

- EDF took part in what it called the first major European apprenticeship meeting with the aim of finding young workers to replace the generation approaching retirement: "Of the 15,000 employees recruited over the next five years, one in three will have gone through the apprentice scheme" said a company statement as it announced it would hire 3500 apprentices in 2008¹⁵.
- For its part, AREVA has hired a total of 12,000 new staff after organising events in Germany, China,

Italy, the USA and the United Arab Emirates as well as at home in France. The company said it would need to find 1,000 workers in China where it is building two of its EPR reactor units¹⁵.

Of course, not all the new employees within this framework are recruited for activities related to nuclear energy. The figures from EDF, for instance, include also the activities related to non-nuclear electricity generation, sales, and transmission grids. Nevertheless, the needs of the nuclear sector are high, and similar influx of new personnel has not been seen since the infant days of the nuclear industry. This fast speed of change implies the need to build new middle management capacities faster than is possible within the usual career schemes.

The new needs for education and training are not only related to the renaissance of nuclear energy; there are also changes in the structure of the industry and of regulation, which imply the need for an evolution of knowledge and skills of the future workforce. Among these changes are the increasingly international character of the industry and of the regulatory activities related to nuclear energy, a clear trend towards outsourcing of business activities, and a dependence of future developments on market forces. Characteristic features are:

- a growing market for products and services within the EU;
- growing demand for nuclear services from non-EU countries;
- harmonization of safety and regulatory practices;
- globalisation of nuclear standards and specifications;
- dependence on external influences such as carbon taxes, the ups and downs of the EU financial markets, and the impact of competitiveness from non-EU countries.



Obviously more international orientation is needed for a significant part of the future nuclear workforce. Higher mobility is therefore a key issue, in particular within the EU. Moreover, the increasing international dimension of nuclear



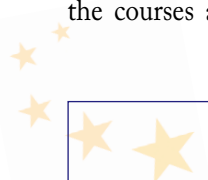
energy, nuclear safety and safety culture needs to be considered within future education and training programmes. This offers significant opportunities but equally challenges for both the EU nuclear education networks and for young people engaging in the field.

It is imperative that the most economic options are provided whilst maintaining quality. The availability of new IT technologies supporting e-learning and distance learning provide attractive opportunities for new methods of learning. With the rapid growth of internet technologies this will encourage greater use of distance e-learning¹⁶. Such developments are not new and there are already numerous examples of good practise¹⁷. Some of these e-learning programmes adopt a virtual class-room scene as the courses and programmes are delivered live

over the internet, an advantage of the online format is the availability of class recordings for students to replay anytime. A major drawback can be the time difference between the deliverer and the student, particularly valid for US and EU interactions. However, on a more localised scale, e-learning will offer many benefits as many nuclear installations are situated in rural areas that may not have the necessary education/training infrastructure. The alternative to the virtual class-room is for course material to be provided in e-format, the student can then work at their own speed. This option would however need to be supplemented with actual engagement with the deliverer for tutorial-type activities. E-learning could also allow for centralised simulators/demonstration facilities to be provided that would, because of time differences between countries, be used more cost effectively.

16 - <http://www.open.ac.uk>

17 - http://education-portal.com/engineering_degree_distance_learning.html



New Needs and Opportunities

- ★ *The nuclear renaissance requires new human resources above and beyond those required to replace the loss of skilled/experienced workforce owing to retirement. The figures are further increased by the trend towards extending lifetimes of existing nuclear power plants, the decommissioning programmes expected over the next two/three decades and the need to achieve visible progress towards demonstration of high-level waste disposal. Additional well educated, skilled personnel will be needed for the new civil nuclear power countries.*
- ★ *There are significant changes of the structure of the nuclear industry such as a trend to more outsourcing and an increasing international character of many activities related to nuclear energy which gradually change professional profiles. This calls for higher mobility of nuclear professionals within the EU and for more effective systems of mutual recognition of professional qualifications in line with the relevant national regulations.*
- ★ *The availability of new IT technologies supporting e-learning and distance learning provide attractive opportunities for increasing the effectiveness and the efficiency of education and training programmes.*
- ★ *Significant investment - in financial and conceptual terms - will be needed to ensure the availability of adequate numbers of high-quality E&T programmes and suitably qualified educators and trainers.*



3. E&T Challenges for the Next Decade

Education and Training remain a key challenge with regard to maintaining and strengthening the competitiveness of the EU in competition with established and emerging knowledge societies in other areas of the world. In recognition of this challenge the responsible ministers of the EU Members States identified important priorities for the coming decade in their Leuven Communiqué of 2009¹⁸. The Communiqué particularly emphasises the following points:

- **social dimension: equitable access and completion;**
- **lifelong learning;**
- **employability;**
- **student-centred learning and the teaching mission of higher education;**
- **education, research and innovation;**
- **international openness;**
- **mobility;**
- **data collection;**
- **multidimensional transparency tools;**
- **funding.**

Due to the past discontinuity in the perceived perspectives of nuclear energy and in the construction of new nuclear plants, there are now major additional E&T challenges in the field of nuclear fission energy. As explained in section 2.2, the nuclear industry in the past decade has taken some very positive actions to address them; however many of the initiatives are still in an early stage and it is not possible yet to assess their effectiveness.

Furthermore, many activities are confined to specific stakeholders and even to a few Member States only. In many instances these initiatives appear to lack cohesion and integration and this could reduce their value. Although these initiatives, i.e. the formation of academies for

example, will accommodate a number of students/trainees they can only accommodate a small percentage of the future human resource needs. The scope of these academies in many cases target specific functions such as development of special skills needed by the founder members, i.e. they are not addressing the full range of knowledge and skills required for a new generation of nuclear professionals working for various stakeholders requiring mutual technical understanding of their technical problems.

Thus there remain some critical challenges for nuclear E&T in the coming years which need to be met in order to maintain and further develop capabilities for the safe exploitation of nuclear energy in the EU.

Among the most critical issues are:

- **The identification of the knowledge gap in a sufficiently precise and predictable way so that effective short- and long-term measures can be defined to adapt the nuclear E&T programs to the needs in a sustainable way. As a first step a suitable taxonomy should be developed by the relevant nuclear stakeholders to define the qualifications required more precisely.**
- **Closer relationships between universities and nuclear stakeholders needing new human resources are a key factor for the further evolution of academic courses; closer co-ordination between these academic programmes and those leading to non-academic qualifications are also needed in order to produce the required increased numbers of nuclear experts and middle managers.**
- **Meeting the rapidly growing need for highly qualified trainers and university professors capable of educating and training a new generation of nuclear workers at a high level of excellence.**
- **Developing sufficient middle management training capacity, through appropriate nuclear education and training programmes, to satisfy the rapidly growing needs imposed by the expected**

18 - Communiqué of the Conference of European Ministers Responsible for Higher Education, Leuven and Louvain-la-Neuve, 28-29 April 2009

pace of nuclear renaissance and the growing number of new plants.

- Ensuring the availability and effective use of specific infrastructure for nuclear education and training such as training reactors, experimental and radiochemical facilities, simulators, and e-learning software. Transnational access to such infrastructure needs to be improved taking into account significant differences in the national conditions in the different EU Member States.

These challenges are not only relevant for the industry. They are similar for regulators and TSOs (Technical Safety / Support Organisations), as stated by André-Claude Lacoste, Head of the French Nuclear Safety Authority, in an interview with the Financial Times¹⁹:

The relaunch of construction, and monitoring that relaunch, are not simple. We have to regain experience. We have not built reactors for more than 15 years. ... How can an authority which may have lost some of its habits monitor the construction of a reactor when the construction groups have also got out of the habit?

It is also important to understand how the concepts for competence building need to be further developed to meet changing needs of the stakeholders in nuclear energy and nuclear safety with respect to the competences of their personnel. An important aspect is that competence building has to proceed beyond the traditional schemes of education & training. The needs of the stakeholders in their role of employers should be met more efficiently by ensuring careful and timely consideration of the relevant job requirements in the education and training chain.

Competence building needs to aim more directly at the ability to apply knowledge, skills and attitudes so as to perform a job in an effective and efficient manner²⁰. The principal question to be asked of professionals should no longer be “*what did you do to obtain your degree or your qualification?*” but rather “*what can you do now that you have obtained your degree or your qualification?*” Considering the international dimension of nuclear energy and nuclear safety, the demonstration of competence in that sense and its international recognition become key issues for future education and training schemes.

Moreover we need to ensure that future generations of nuclear professionals working for different stakeholders will have that common background of knowledge, skills and culture which is required for the mutual understanding of each other’s role and for achieving high quality of inter-stakeholder communication and working processes. Taking into account the fact that changes of experts from one nuclear stakeholder to the other have decreased considerably during the last decades, and the limited possibilities of the public sector to attract experienced experts from the industry, meeting this challenge is believed to be highly significant for the future of nuclear energy.

Last but not least we need to pay attention to the competition for the best brains between the nuclear energy sector and other technical fields including the non-nuclear energy sector. The renaissance of the nuclear industry is not unique, the renewables sector is experiencing an unprecedented expansion, and other hi-tech industries such as pharmaceuticals, health care etc. all provide attractive opportunities for educated, well trained and skilled personnel.

19 - Atom Watch,
30 November 2009

20 - See also IAEA Safety
Standard Series, RS-G-1.4
(2001)



Challenging Questions for Nuclear E&T in Europe

- ★ *How can the competences and qualifications required in the next decade for long-term safe operation of existing NPPs be identified, for the increasing number of decommissioning and waste management projects, for the growth of the nuclear industry, and for keeping pace with the increasing international dimension of many nuclear activities?*
- ★ *How are these competences and qualifications different from those emanating from existing E&T programmes? What are the knowledge and skills gaps that need to be filled and how much time is available for the implementation of related measures? What types of engineering, construction and project management skills will be in short supply with the advent of new build, particularly if other major construction projects are competing for the same workforce?*
- ★ *What changes and optimisations are required within the current E&T schemes in order to address recognised knowledge and skills gaps? Are new types of E&T programmes required? How should the relationships between industry, academia and other nuclear stakeholders be further developed in order to effectively address these questions?*
- ★ *How can a sufficient number of highly qualified trainers and university professors needed to educate and train a new generation of nuclear workforce be ensured?*
- ★ *How can the current methods for competence building be further developed so as to optimise the ability to apply knowledge, skills and attitudes and, as a result, carry out duties in the most effective and efficient manner?*
- ★ *How can the increasing needs for higher mobility of nuclear professionals within the EU and beyond be met? How should more effective systems of mutual recognition of qualifications and professional competences be established? Can the schemes established for mutual recognition of academic qualifications based on the Bologna process be used as a basis for future schemes aimed at a better mutual recognition of professional qualifications and competences? How can such developments with the relevant national regulations be coordinated?*
- ★ *How can be ensured that future generations of nuclear professionals working for different stakeholders will have the common background of knowledge and culture required for the mutual understanding of each other's role and for achieving the necessary quality of inter-stakeholder communication and working processes?*



4. Key Approaches

4.1 Identifying Knowledge, Skills Profiles and Gaps

There have been several, mostly national studies to identify the skills gaps relevant for the orientation of future E&T programmes. These show that the needs are high compared to the number of graduates produced by the nuclear departments of European universities, but still small compared to the total number of engineers educated (i.e. in all sectors). They further indicate that the bulk of the need is not for reactor technology specialists but rather for “conventional” engineers with only partial knowledge of nuclear topics.



In the UK, for instance, COGENT has provided a skills gap analysis categorised by nuclear industrial sector such as decommissioning, safety and security, waste and repository operations etc., but covering both professional and trade skills. A recent COGENT report²¹, which is the first stage in a comprehensive skills research programme, quantifies and qualifies the current UK civil nuclear sector, concluding that the UK industry:

- requires of the order of 1,000 new recruits per year (mainly new apprentices and graduates) for the next 15 years;
- could potentially draw in suitably experienced personnel from other sectors and possibly globally;

- is not expected to have a significant outflow of personnel to other sectors so that the loss of nuclear expertise through retirement would be the overriding attrition factor;
- in a scenario that includes new build, would need to recruit up to 8,000 new people in the operating workforce by 2025 in addition to replacement demand due to retirement.

Another example is a French study²² released in 2008, involving major French nuclear organisations such as AREVA, ASN, CEA, EDF, IRSN, GDF Suez and sub-contractors, addressing the industrial sectors and engineering disciplines and some scientific disciplines e.g. chemistry and metallurgy. The survey provided a breakdown of expertise required by design & process, industrial computing, safety and metallurgy disciplines in high demand and included qualifications and inter-personnel skills such as management aptitude, motivation, loyalty etc. It indicated that:

- industrial companies required annually about 1,200 engineers at Master degree level, among which AREVA, EDF and GDF Suez represent more than half the demand; in addition about 900 technicians at Bachelor level would be required each year and industrial organisations also require some of their new recruits at PhD level;
- ASN, IRSN and CEA are seeking each year an additional 100 engineers in total, most of them being PhD engineering graduates in nuclear engineering, safety and waste management;
- both AREVA and EDF consider that hiring skilled people is a major challenge;
- recruiting young people with an aptitude for management is desirable for many of the organisations consulted.

The existing gaps analyses provide useful data and clearly indicate the dimension of the problem. Most of them used questionnaires, in some cases (e.g. for the UK and the French analyses) dedicated staff took several months to

21 - COGENT, Renaissance Nuclear Skills Series, Power People-The Civil Nuclear Workforce 2009-2025, September 2009

22 - Huet E., and Zolotoukhine E., Étude sur l'Évolution des Métiers de l'Ingénierie Nucléaire, OPIEC, April 2008

gather the information. However, such analyses cover only a few countries and the level of detail of the information provided is mostly not sufficient. Most of the analyses do not provide detailed information at the level of industrial sector, such as fuel fabrication, reactor operation, spent fuel management, R&D etc., or of the various disciplines such as chemical, mechanical, electrical engineers or chemists, physicists, mathematicians etc. It is, however, important that such detailed information is available so that respective stakeholders can decide if the supply chain, i.e. academic institutions, will be able to supply these numbers. Similarly the academic institutions need to know the numbers required in each of the various scientific and engineering disciplines to judge which courses need strengthening and where there are gaps.

Strengthening the tool of skills gap analysis is therefore a critical issue in view of adapting education and training programmes to the present and future needs of the industry and the other stakeholders in nuclear energy and nuclear safety. A broad international perspective is needed as well as an appreciation of that job-specific combination of knowledge, skills, and professional attitudes, which characterize the competences required for professionals to perform in the most effective way under present day and expected future conditions. Skills gap

analyses performed on that basis can then be used to improve the education and training schemes in view of better and more efficiently producing the "learning outcomes" needed by the professional. The concepts adopted by the European Credit System for Vocational Education and Training²³ (ECVET) developed under the umbrella of the Copenhagen Declaration²⁴ opens interesting perspectives in that regard.

Focussing on nuclear fission in this context, a new EU strategy for nuclear competence building across the EU should help in developing the necessary instruments, for example:

- a well structured common terminology across the EU for the description of professional role profiles related to nuclear fission energy and radiation protection;
- a taxonomy of nuclear skills and competencies for each role as a basis of a common language for employment and education/training related to nuclear fission and radiation protection;
- specification of agreed learning outcomes and assessment criteria.

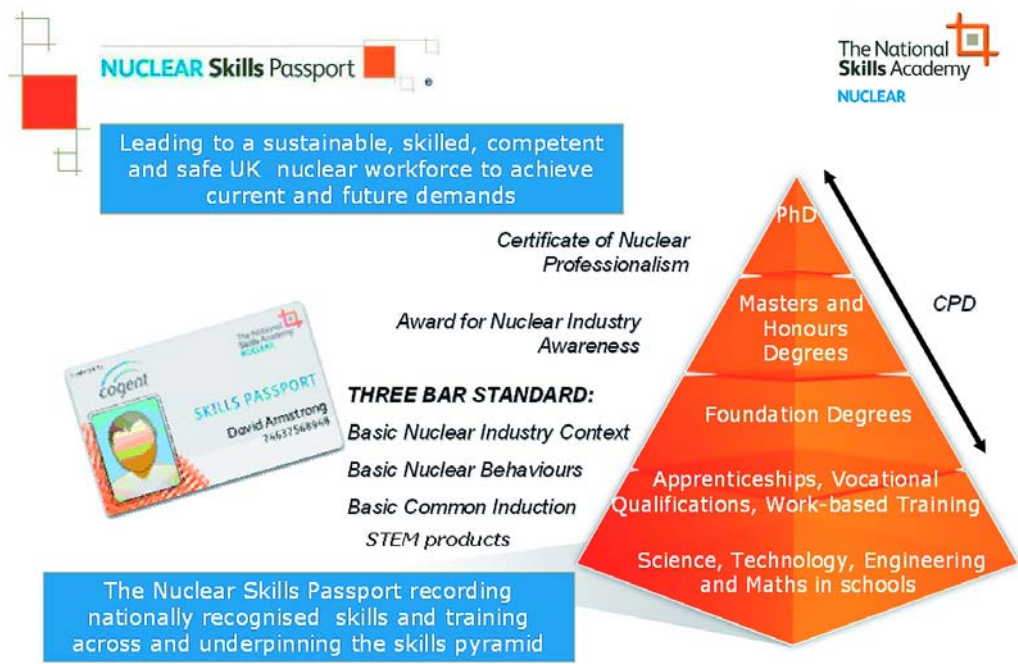
All stakeholders in nuclear energy and nuclear safety concerned with human resources and professional recruitment are invited to participate in this challenging discussion.

23 - http://ec.europa.eu/education/lifelong-learning-policy/doc50_en.htm

24 - Declaration of the European Ministers of Vocational Education and Training and the European Commission on enhanced European cooperation in vocational education and training, Copenhagen, 2002

Analysis of Knowledge and Skills Profiles and Gaps

- ★ *Although the industry, in particular EDF and AREVA, is currently recruiting significant numbers across a broad spectrum of disciplines partly to offset retirements, a better understanding of the knowledge and skills profiles relevant for the safe long-term operation of existing NPPs, the implementation of effective waste management and decommissioning solutions, and - more generally - for the further growth of the nuclear industry are all required.*
- ★ *Better analyses of knowledge and skills gaps are needed based on the most recent information and a perspective of the sustainable future needs. These analyses need to cover a wide scope including the relevant engineering, scientific and technical areas as well as managerial skills.*
- ★ *It is particularly urgent to identify those knowledge and skills gaps that could jeopardise the availability of industrial and regulatory capabilities needed to respond to the growing demand for new nuclear capacity.*
- ★ *Gap analyses need to be performed at a European level with strong links to the Member States and to the most concerned stakeholders. Particular attention should be paid to sustainability and the assurance of the quality of the results. An appreciation of the timescales involved is required, i.e. the time when knowledge and skills are needed as well as the delays between the start of the implementation and the appearance of the first results of new initiatives.*
- ★ *ETKM recognises the importance of the recently-established European Nuclear Human Resources Observatory (EHRO-N) for undertaking this analysis work at European level.*



The National Skills Academy
NUCLEAR

NUCLEAR Skills Passport

Leading to a sustainable, skilled, competent and safe UK nuclear workforce to achieve current and future demands

Certificate of Nuclear Professionalism

Award for Nuclear Industry Awareness

THREE BAR STANDARD:
Basic Nuclear Industry Context
Basic Nuclear Behaviours
Basic Common Induction
STEM products

The Nuclear Skills Passport recording nationally recognised skills and training across and underpinning the skills pyramid

The Skill's Pyramid

4.2 Education and Training Programmes

The scope and delivery of education and training is diverse and benchmarking at these levels would be challenging and a lengthy process with uncertain outcomes and value. In some instances university education has some peculiarities, for example French engineers are usually educated in special schools rather than at universities. Fortunately both higher education establishments and employers tend to rely on the final qualifications, i.e. for entry into higher education, students are judged on their certificates of education achieved in secondary education, whilst employers will assess potential professional employees generally on their first, Masters or PhD degree, and, where appropriate, work experience.

Regarding higher education establishments, there are now established methods in place for comparing qualifications and their value from one country to another, so accepting foreign students is a common occurrence. This is not the case in the jobs market in Member States, and on many occasions industries such as the nuclear sector have campaigned for some form of education/training commonality that would allow easier transfer of employees from one Member State to another.

The qualification commonality is promoted by Euratom in its policy for education²⁵. Euratom's

general education principles to match supply and demand of knowledge are:

- modular courses and common qualification approach;
- one mutual recognition system for Masters grade;
- mobility for teachers and students across the world;
- involvement of stakeholders.

This approach is being applied to Master's degree qualifications based on the European Credit Transfer System²⁶ (ECTS) developed under the umbrella or the Bologna Declaration. It is, however, more difficult to implement for undergraduate degrees and for vocational training. Nonetheless, approaches for mutual recognition of professional qualifications are being developed within the Copenhagen process^{22,27}.

The argument for mobility of qualified personnel is well founded, although challenging to achieve and to demonstrate commonality of qualification/experience. Demonstration could be accommodated by the provision of a 'competence passport' that would allow individuals to record all their skills development, training and experience in a coherent integrated manner recognised by all employers, thus encouraging mobility. Euratom believes²⁴ this would allow achievements of progress towards a competence profile to be readily recognised.

25 - G. Van Goethem, 'From Knowledge Creation to Competence Building', AtomiCareers Event, 4-5 December 2009

26 - ECTS
http://www.bologna-bergen2005.no/Docs/00-Main_doc/990719BOLOGNA_DECLARATION.PDF

27 - EC VET
http://ec.europa.eu/education/vocational-education/doc1143_en.htm

Competency/proficiency passports are not a new development; several years ago BNFL and EDF had introduced them into their organisations. In Italy ENEL has taken a training initiative to rebuild internal nuclear competences with a good deal of commonality²⁸. The model underpins technical skills, need for change and strategic/policy issues. Other organisations, such as NSAN¹⁰ have also advocated/introduced Skills Passports at national level. Employers from across the UK nuclear industry have come together to develop and implement the Nuclear Skills Passport via NSAN. The Skills Passport will record and recognise achievement of nationally agreed standards and job competencies, supporting mobility and transferability of skills across the industry. Competence profiles for specific jobs/roles have again been introduced by several nuclear organisations: NNL, EDF etc.

An important issue for academic nuclear education is the adaptation of the existing programmes to the changing needs of the industry and other stakeholders in nuclear energy and nuclear safety. Many existing programmes are still too much focused on nuclear technology and nuclear science, but this scope is too narrow considering the interdisciplinary character of nuclear energy and nuclear safety and the current conditions for nuclear energy. Academic programmes for nuclear education and, to some extent, academic nuclear research should therefore have some level of alignment to industry by addressing more interdisciplinary contents and management issues, by increased industrial interaction, by establishing links to relevant training programmes run by employers and by co-ordinating the intended learning outcomes with the findings of advanced skill gaps analyses.

Regarding the mobility of the nuclear work force within Europe, increasing application of the concepts developed within the initiative for a European Credit system for Vocational Education and Training (ECVET)²⁹ can be beneficial in several regards:

- provision of more mobile and appropriate skilled/trained personnel;
- improving the flexibility and mobility between existing national systems (ECVET does not aim at replacing national systems);
- taking advantage of a European context of good national solutions such as "Nuclear Skills Passport" developed in the UK by the "National Skills Academy".

Within a related European strategy the following approaches could be useful:

- identification of competent European institutions to provide qualifications (wherever they are required by national or EU nuclear regulations) or portfolios of learning outcomes (desired, for example, in the case of the nuclear "European Passport for Continuous Professional Development", envisaged in some Euratom 7th Framework Programme - FP7 - training projects);
- pilot exercises to apply the "learning outcomes" approach within ECVET partnerships;
- partnerships between home institutions and hosting institutions:
 - the home institution (the institution sending the learners and where the learner comes back to) will validate and recognise learning outcomes achieved by the learner;
 - the hosting institution will deliver training for the learning outcomes concerned and assess the achieved learning outcomes.

Another essential requirement is the strengthening of the role of nuclear stakeholders, acting as large employers, in the education and training of graduates. The many good initiatives already started need to be continued and receive further support. This holds in particular for the stakeholder-driven programmes mentioned in section 2.2. But more discussion and co-operation on nuclear E&T is also needed between academic organisations and other nuclear stakeholders in order to resolve remaining difficulties such as the insufficient availability of internships and to achieve the required optimisation of academic programmes. Particular attention is to be paid to the training of educators and trainers.

However, the increasing number and growing variety of academic and stakeholder-led nuclear E&T programmes could lead to increased fragmentation. This would be detrimental in view of the need to ensure that future generations of nuclear professionals working for different stakeholders have a sufficient level of common culture and mutual understanding of each other's role. More co-ordination between the different initiatives might therefore be required in order to avoid such difficulties.

Last but not least, the current negative perception of science and engineering by the public and more importantly by young people needs to be rectified. In many European

28 - Gilchrist D, 'Rebuilding Nuclear Competences', ENEN 2nd Special Event "Nuclear E&T Needs and Strategies", Ljubljana, Slovenia, 4 March 2010

29 - http://ec.europa.eu/education/lifelong-learning-policy/doc50_en.htm

countries, engineering and physical sciences are still unpopular fields of study, both academic and vocational, but it is from this same pool of students that the nuclear sector must recruit. Although there are promising signs of a resurgence in nuclear education, the challenges over the next decade are also not helped by the demographic changes in the 18-21 year-old age group. Outreach programmes from higher educational institutes and industry to schools should be supported to encourage children to consider science and engineering careers.

Improving the attractiveness of nuclear education in its widest sense therefore remains a crucial objective. Many of the approaches addressed above are expected to have beneficial effects in that regard. A further potential lies in a wider use of advanced information technology for the purpose of nuclear education and training. This can improve the access to relevant information, increase learning motivation, highlight the international dimension of nuclear energy, and make the field of nuclear energy look more modern for young people.

Nuclear Education and Training Programmes

- ★ *A wider mutual recognition of professional qualifications and competences is a prerequisite for increasing the mobility and the international orientation of nuclear professionals within the EU. Greater clarity of education and training standards needs therefore to be achieved. In some European countries the industry has already made significant progress to address normalisation of E&T.*
- ★ *It is important that normalisation of education and training standards is also achieved at the European level. Introduction of appropriate concepts should be carried out by the relevant nuclear stakeholders. The initiative for a European Credit system for Vocational Education and Training (ECVET), and the stepwise introduction of a European proficiency passport are considered promising approaches in that respect.*
- ★ *The academic nuclear education programmes and academic nuclear research should be better focused on the current needs of the nuclear industry, e.g. by opening classical technical programmes to include interdisciplinary contents (e.g. management issues), by increased industrial interaction, by establishing links to training programmes run by employers, and by coordination of intended learning outcomes with the findings of advanced skills gaps analyses.*
- ★ *Discussion and co-operation on nuclear E&T between academic organisations and other nuclear stakeholders have been considerably intensified during recent years. Further progress is needed, however, to resolve remaining difficulties such as the insufficient availability of internships and to optimise academic programmes. This process should include a systematic consideration of established good practices in E&T in the nuclear sector and in other disciplines.*
- ★ *The increased support and active involvement of the industry and other stakeholders in academic education and research activities is very important and needs to be further encouraged.*
- ★ *In view of the needs for more and better nuclear education and training and for adapting the respective programmes to the changing needs, the training of educators and trainers warrants particular attention.*
- ★ *The increasing number of nuclear E&T programmes and their growing variety requires better information at the European level and a minimum level of co-ordination between the different initiatives.*
- ★ *A wider use of advanced information technology for the purpose of nuclear education and training is needed in view of improving the access to relevant information, increasing learning motivation, supporting international co-operation in nuclear E&T, and - more generally - promoting the attractiveness of professional appointments in nuclear energy.*

4.3 Infrastructures

Access to research, test and demonstration facilities that provide hands-on experience is fundamental to the development of competences and expertise. In the nuclear industry's infancy there were ample facilities in Member States that stimulated the development of materials including their characterisation, fuel and reactor systems, waste management solutions etc. and produced numerous innovative, knowledgeable scientists and engineers with practical skills.

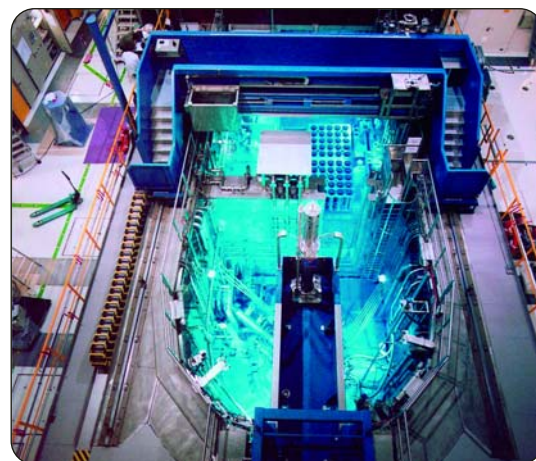
Some of these facilities were in the private sector, others in government organisations including universities. Some are still in operation having been refurbished, though too many have been 'moth-balled' waiting final decommissioning or have already been decommissioned. The facilities that remain are concentrated in a small number of Member States and their remaining life expectancy is usually shorter than the time needed to implement SNETP's strategic research agenda, which foresees activities to 2020 and beyond.

Effective education and training processes require close links between academia and research institutes, especially with their experimental infrastructure. Stagnation of nuclear energy and shrinking budgets for nuclear R&D in the late 1990s resulted in the closure of large experimental facilities and the disbanding of experienced teams, with a very serious impact on the professional competences and quality of education in nuclear disciplines.

The OECD Nuclear Energy Agency started systematically to raise this issue and highlight the risks. Its Committee on the Safety of Nuclear Installations (CSNI) issued the 2002 report entitled "Nuclear Safety Research in OECD Countries: Major Facilities and Programmes at Risk (SESAR/FAP)"³⁰. In an effort to prevent the closure of major experimental facilities, the OECD/NEA began to organise internationally funded research projects at selected facilities. With the advent of the nuclear renaissance, the OECD/NEA has continued with the mapping of the available experimental infrastructure suitable for research and development of existing and advanced nuclear reactors. In 2007 the NEA issued a report entitled "Nuclear Safety Research in OECD Countries: Support Facilities for Existing and Advanced Reactors (SFEAR)"³¹. In 2008 a new project TAREF was initiated in

order to seek experimental facilities suitable for safety R&D of Gen. IV reactors, primarily for gas-cooled and then for sodium-cooled fast reactors. The project to date has issued two separate reports for both types of reactors^{32,33}.

In parallel with the CSNI, the NEA Nuclear Science Committee also devotes significant attention to the experimental infrastructure, and established the Expert Group on Needs of R&D Facilities in Nuclear Science. The Expert Group prepared a report on the status of integral data and the future needs for nuclear science R&D and test facilities. These included: nuclear data, reactor physics, fuel behaviour, material science, chemistry, fuel cycle, nuclear production of hydrogen, high-performance computing and thermal-hydraulics. The group also established a database of nuclear science R&D and test facilities to help clarify the status and needs of these facilities³⁴. The Expert Group recently completed its work and the final report was published in 2009³⁵.



FRM II Research Reactor

The ETKM Working group reviewed nuclear facilities and infrastructures available for education in the areas "reactor technology and engineering" and their usage³⁶. This analysis concluded that:

- only 25 of the 53 presently operated research reactors and critical assemblies are effectively used for laboratory sessions at BSc and MSc levels, and that only 8 reactors are operated for this purpose during more than 120 hours per year each. These research reactors are also used for the preparation of MSc and PhD theses (around 70 theses per year);
- from the operator's point of view, an increase of at least 50% in the number of accommodated students is considered possible;

30 - OECD NEA No 3145, 'Nuclear Safety Research in OECD Countries: Major Facilities and Programmes at Risk (SESAR/FAP)', 2002

31 - OECD NEA/CSNI/R (2007) 6, 'Nuclear Safety Research in OECD Countries: Support Facilities for Existing and Advanced Reactors (SFEAR)', 2007

32, 33 - OECD NEA/CSNI/R (2009) 8, 'Experimental Facilities for Gas-cooled Reactor Safety Studies, Task Group on Advanced Reactor Experimental Facilities (TAREF)', 2009

OECD Experimental Facilities for Fast Sodium Reactor Safety Studies, Task Group on Advanced Reactor Experimental Facilities (TAREF) (in print)

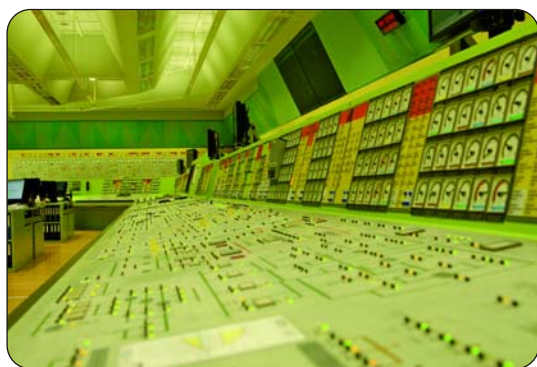
34 - <https://www.nea.fr/rtdb>

35 - OECD NEA No 9293, 'Research and Test Facilities Required in Nuclear Science and Technology', 2009

36 - SNETP-ETKM Report "Current and Future Uses of Nuclear Infrastructure for Education", February 2010



- thermal-hydraulics and severe accident facilities are relatively new compared to experimental reactors. There is not much duplication in those facilities;
- small nuclear research facilities located at universities or in research centres are in general used more intensively for teaching nuclear engineering than larger research infrastructures. Therefore special attention should be given to the ageing of the "small" facilities and their refurbishment or replacement;
- there is no systematic use of research facilities for teaching purposes. Hence, there is a need to promote a more coherent and extensive use of experimental facilities at universities;
- simulators are better used for practical sessions dealing with power plant steady state and transient operations, but not enough of these simulators are used for education and training purposes.



Full Scope Simulator

Fuel cycle related infrastructure is also highly relevant. At present only few organisations such as ITU and CEA provide such infrastructure for training in Europe, and only a limited group of students is trained systematically in working with highly radioactive materials. Integrating those laboratories more closely into the education and training schemes in Europe and maintaining a sufficient number of high class nuclear laboratories, where studies on real radioactive materials can be performed, are considered essential for keeping Europe's leading role in nuclear fuel development and treatment.

Altogether the surveys show that the use of state-of-the-art facilities for education and

training purposes is not sufficient for an industry that is expecting resurgence in its fortunes. The facilities that are available could accommodate about twice the number of students currently being trained. This inefficiency largely stems from the lack of good coordination between various parties.

There are encouraging signs, however, that modern facilities and infrastructures are again seen as key to the nuclear industry's future. The construction of the Jules Horowitz material test reactor³⁷ in France, the UK's NNL Central Laboratory³⁸ state-of-the-art hot cells and other laboratory facilities in Cumbria, the joint venture between the NDA and Manchester's Dalton Nuclear Institute³⁹ for a new laboratory housing accelerators and other experimental facilities again in Cumbria, and MYRRHA – a European fast spectrum experimental facility for demonstrating efficient transmutation and associated technologies – sited in Belgium are all good examples of redressing the trend of the 1990s.

Nevertheless it should not be forgotten that some of the facilities for education and training are ageing and may need to be replaced relatively soon. As only a few experimental facilities, largely for research purposes, are currently under construction, the capacities remaining for education and training during the expected new build era may therefore be insufficient. This will be exacerbated if, as expected, future education and training programmes are even more demanding of such facilities.

Last not least attention needs to be paid to the use for education and training of the huge amount of information produced by the research facilities operated in the last decades within different experimental programmes. The preservation of this information requires both the long-term, sustainable storage of the relevant data (including comprehensive experimental reports) and the "transfer" of the relevant knowledge to new generations of nuclear scientists and engineers. Linking data management and preservation activities with education and training by means of appropriate IT solutions should be used more to meet those objectives.

37 - JHR
<http://www-cadarache.cea.fr/rjh/index.html>

38 - NNL
<http://www.nnl.co.uk>

39 - NDA
<https://www.nda.gov.uk/news/nuc-research-centre.cfm>
29 January 2007

Facilities for Education and Training

- ★ *Research and training reactors, other facilities and measuring devices should be used more systematically within nuclear education to provide students with a more direct and more personal experience of nuclear phenomena and characteristics.*
- ★ *The use of large research infrastructure such as major experiments and state-of-the-art computer codes is highly relevant for the quality and the attractiveness of high-level academic education in nuclear technology, particularly within PhD programs.*
- ★ *At present the existing facilities for education on reactor technology and engineering provide sufficient capacity and could accommodate at least twice the number of students currently being trained. However many of these facilities are ageing and may soon need to be refurbished or replaced. As only a few experimental facilities, largely for research purposes, are under construction, the capacities remaining for education and training during the expected new build era may therefore be insufficient.*
- ★ *Fuel cycle related laboratories need to be more closely integrated into the education and training schemes in Europe. A sufficient number of high class nuclear laboratories need to be maintained where studies on real radioactive materials can be performed.*
- ★ *As the relevant infrastructure, particularly the experimental facilities, is not equally distributed across the EU, the initiatives undertaken within the Euratom Framework Programme to improve transnational access can ensure more efficient use of the existing infrastructure. These initiatives should be co-ordinated within an EU-wide policy for transnational use of the existing infrastructure with due consideration given to their long-term availability.*
- ★ *The opportunities provided by the advances in computational infrastructure should be better exploited for achieving a high standard of excellence in nuclear education and training. Of particular significance are visible European high-level products such as advanced simulation tools and e-learning platforms. Those initiatives should focus on a very small number of highly attractive and fully transparent initiatives, i.e. by use of open source software, in view of ensuring their attractiveness for future generations of students.*

4.4 International Cooperation

Strategies for education and training related to nuclear energy were traditionally focused on national requirements. International cooperation was essentially limited to the usual practices for international academic exchange and to the links with international cooperation in nuclear research. However, the scope has widened during recent years, and the activities of international nuclear education networks such as ENEN play a significant role



in that respect. More recently international cooperation in education and training is increasingly extending beyond Europe, motivated by the increasing international dimension of many nuclear activities and the significance of the large programmes for new nuclear build particularly in Asia. Euratom has been and continues to be a major player in this arena.

There are several reasons to further extend international co-operation in nuclear education and training:

- The cost of developing new reactor systems is significant and possibly unaffordable by any one Member State. Various initiatives⁴⁰ have been implemented to potentially off-set this burden, but in many instances have concentrated on the research aspects and have ignored the human resource challenges now and in the future.
- For more than thirty years the EU has been extremely proactive in promoting and funding collaborative research programmes (Framework Programmes) and more recently this has extended to education and training. However, this may not be sufficient to support the re-emerging nuclear

sector with the comparatively rapid decline, owing to retirement, of experienced, skilled personnel. Thus private organisations and governments should be more proactive in promoting cooperation/collaboration in education and training at all levels.

- There have been many good examples of collaboration including, for example, summer schools, visiting scientists, user facilities, networks of excellence, workshops, conferences, training courses, nuclear databases and information portals. Owing to the declining fortunes of the industry in the 1980s/1990s some of these initiatives have declined and others expired. However, when the industry was in its heyday, all were seen to be of value and were supported not only at the European level but also by private organisations. In the present circumstances, they are as important as, if not more important than before.
- There are some indications that the industry and other organisations are addressing the opportunities that collaborations and cooperation

within the EU and beyond can provide, outside FP activities. The base-line for DG-Energy and DG-Research is for greater cooperation and mobility of staff, but this needs to be fused with education and training competences and their globalisation. The existing international education and training networks such as, for example, ENEN, ANENT⁴¹ and WNU⁴² can provide a basis for developing future initiatives required to meet those challenges.

- It is the marrying of the theory with practical activities either in laboratories or with simulators that is necessary for the future education of young engineers and scientists. International collaboration/cooperation, although founded currently on education and training and rightly so, should transgress this particular arena to accommodate others that are equally linked with E&T such as access to infrastructures, demonstrators, funding etc. Such objectives in part are already addressed by actions of the IAEA^{43,44} but should receive even more attention in the future.

41 - Asian Network for Education in Nuclear Technology: <http://www.anent-iaea.org/anent/about.htm>

42 - World Nuclear University: <http://www.world-nuclear-university.org>

43 - IAEA Coordination Meeting 'Strengthening sustainability of nuclear research and development institutes in the modern science and technology environment' RER/0/031, 16-18 November 2009

44 - UN News Centre, 28 Dec 2009, <http://www.un.org/apps/news/story.asp?NewsID=33354&Cr=iaea&Cr1>

Cooperation beyond Europe

- ★ *International cooperation has been one of the major strengths of the nuclear industry and has largely underpinned national research programmes. Euratom has been and continues to be a major player but cooperation now needs to transcend the purely research arena.*
- ★ *Cooperation with non-European countries in nuclear education and training, especially with those engaged in larger programmes for new build, is highly beneficial for the further development of the nuclear knowledge base in Europe and crucial for the development of new modes of cooperation in a global environment. It can also help to increase the attractiveness of the nuclear energy sector in the competition with other industries for the best brains.*
- ★ *Considering the high significance of the cultural dimension of nuclear safety, the cooperation with non-European countries needs to address both building scientific and technical knowledge and achieving mutual understanding of each other's culture. This is particularly relevant for cooperation with Asia and South America.*
- ★ *The cooperation with non-European countries in nuclear education and training therefore needs to be intensified. Close links between research and E&T in cooperative projects are required in order to achieve this objective in the near future. The Generation IV initiative is a key example in this regard, and similar principles of cooperation could be applied in other areas. Linking the extension of E&T cooperation with new initiatives to optimise the access to E&T infrastructure at a European level should be part of the strategy.*
- ★ *The Euratom Framework Programme is an important basis for the cooperation between Europe and non-European countries. Taking into account the significance of a broad approach with involvement of different stakeholders, partnerships between public and private organisations should play an increasing role in the future.*



5. Good Practice

There are many successful examples of good practice in European Member States, and some of the recent international initiatives have also proven effective and could serve as a model for the further development and optimisation of nuclear education and training.

The major international nuclear organisations such as the IAEA and the OECD/NEA⁴⁵ have strongly advocated the enormous benefits that can be accrued from learning from each other. This good practice covers a wide spectrum of activities such as human resource development, cooperation between education and training institutions and industry, networking, use of technology/technical information such as the JRC's Nucleonica Website⁴⁶ and the transfer of ideas, products etc. from the laboratory to the market place. This good practice should be the foundation on which to build a much greater portfolio of best practice that will sustain the growth of the industry in a timely, economic and safe manner.

Examples of such good practice are:

- **Effective cooperation between key stakeholders in nuclear energy / nuclear safety and several universities or university networks to further develop curricula and provide financial support in situations where the conventional academic financing mechanisms are incapable of maintaining the academic structures at an appropriate level. Examples of this approach are**
 - the UK NNL's initiative to strengthen links with universities. Via a Memorandum of Understanding, NNL staff assist in supervising research, support undergraduate courses and develop specific courses/workshops. Several of the NNL staff involved in these activities have honorary roles (Visiting Professors, Fellows, Lecturers etc.) conferred by the appropriate university.
 - the new Master's study programme "Nuclear energy facilities" accredited by the Ministry of Education, Youth and Sports of the Czech Republic and implemented jointly by the Faculty of Mechanical Engineering at the Czech Technical University and the Nuclear Research Institute Rez plc, with senior experts from Rez delivering course lectures.
- **The process of retaining current industry leaders and other key experienced employees is complicated owing partly to the attractive nature of industry pension plans, with many employees reaching full pension entitlement in their mid to late fifties. To address this issue of continuity of knowledge and skills owing to a shortage of mid-career professionals, leading organisations are developing more innovative and appropriate approaches to leadership development as part of comprehensive talent management strategies.**
- **External sourcing represents a solution that provides the most immediate results. Given the fierce competition for new talent in view of the current expansion, companies often adopt innovative practices, the most successful being the hiring from abroad or from other industries and the outsourcing of parts of their recruitment processes to third-party experts.**
- **The French Council for Education and Training in Nuclear Energy (CFEN) associates institutions, academy, industry and R&D to create and co-ordinate the French educational offer at the national level, being also a think tank for all the stakeholders. Through the creation of the Agence France Nucléaire International (AFNI) these actions are being further deployed, more especially towards foreign countries including newcomers.**
- **The employer-led National Skills Academy for Nuclear in the UK, previously described in this report and increasingly recognised nationally.**
- **JRC's Nucleonica nuclear science portal as an innovative professional and technical resource for knowledge creation and competence building in nuclear science for the EU and worldwide nuclear industry. Its innovative feature such as web-based scientific applications and online wiki are particularly suitable for education and training of**

45 - NEA/NDC (2010)15, 'Draft Summary Record of the 2nd Meeting of the Adhoc Expert Group on "Education, Training and Knowledge Management" 27-28 May, 2010

46 - JRC
<http://www.nucleonica.net>

young scientists, engineers and technicians.

- JRC CAPTURE and SARNET2 initiatives for their attention to the sustainable storage of experimental data, to allow in the future to

continue the education and training of the new generations of the researchers using the significant amount of data available, especially for thermal-hydraulics and severe accident.

Examples of Good Practice

- ★ *Effective cooperation in the area of nuclear E&T between industrial and regulatory organisations and academic and research institutions has been very valuable in stabilizing nuclear education programmes and in their reorientation towards future needs.*
- ★ *Systematic approaches to a quality-assured skills gap analysis, e.g. the COGENT approach in the UK, are indispensable for sound and sustainable planning of future E&T programmes.*
- ★ *Advance IT solutions and databases for improving access to nuclear knowledge and information on E&T opportunities, e.g. the ENEN data base and JRC's Nucleonica, can play an important role in making nuclear education more attractive and in the effective development of a new generation of nuclear engineers and scientists.*
- ★ *Initiatives for enhancing cooperation in nuclear academic education with Asia, such as promoted by the ENEN Association, can be valuable triggers for the required expansion of cooperation in nuclear education and training beyond Europe.*
- ★ *Stakeholder-led programmes such as planned by the European Nuclear Energy Leadership Academy (ENELA) and the National Skills Academy for Nuclear (NSAN) can contribute to the required optimisation of nuclear education and training in view of meeting new needs in the nuclear energy sector.*
- ★ *Promotion of sharing and learning from good practice as advocated by the major nuclear agencies/organisations will further enhance the sustainability of the industry.*

6. Recommendations

- 1 - Key stakeholders in nuclear energy and nuclear safety should develop a 'common language' for employment as well as education and training for nuclear energy, including a common taxonomy of skills and competencies linked to jobs.
- 2 - Key stakeholders in nuclear energy and academic institutions should engage in a joint action to optimise the curricula of academic programmes related to nuclear energy with special regard to the needs by 2020 and to the potential synergies between academic and non-academic programmes for graduates.
- 3 - Private-public partnerships for nuclear education and training need further support and funding in order to be able to cater for the expansion in E&T programmes, the training of trainers and providing the necessary guidance.
- 4 - The framework for mutual recognition of qualifications should be further developed with the objective of gradually including non-academic qualifications and related vocational training. This should include the identification of 'Competent Institutions' in the EU that can provide qualifications or portfolios of learning outcomes, and pilot exercises to apply the 'learning outcomes' approach within ECVET partnerships.
- 5 - Recent European initiatives such as EHRO-N, ENEN and JRC databases, which depend on input from and cooperation with national organisations, should receive appropriate support.
- 6 - The existing European initiatives for facilitating transnational access to facilities for the purpose of education and training should be optimised and coordinated in view of building a European platform for E&T-related facilities and IT infrastructure.
- 7 - The existing European initiatives for cooperation with non-European countries in nuclear education and training should be strengthened and integrated as part of the general strategy of enhancing international cooperation in nuclear research and nuclear safety.
- 8 - Key organisations within the EU should cooperate in the further development and maintenance of European databases and IT platforms intended to support nuclear education and training and in the provision of information on related programmes and opportunities.

Box: ETKM within the SNETP

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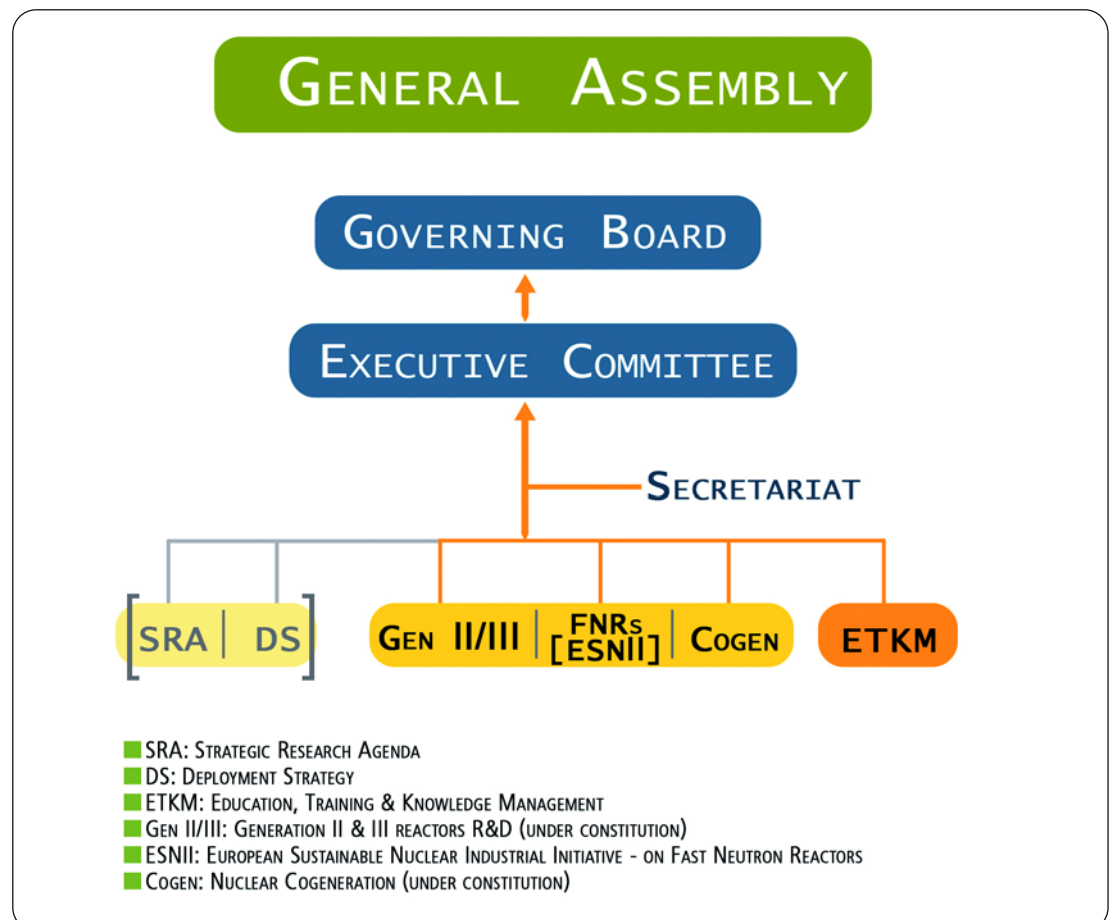


Figure 1: SNETP Organisation Chart



www.SNETP.eu