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Retaining critical competences in nuclear energy sector: national initiatives and best practices, instruments and tools

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Abstract
The main objective of this study is to give an overview of new initiatives and best practices developed during the last few years on the national level. As the development of nuclear E&T is primarily defined by the policies and national regulations for the nuclear sector, and only secondarily - through the general policies that apply to the high education (HE) and vocational education and training (VET) systems, main attention is given to the educational activities specific for the nuclear field.
This report firstly focuses on the organisation of nuclear E&T in selected countries, investigating different types of institutions, programmes, qualifications, funding mechanisms and partnerships among academia, industry, labour market and social partners. Then the attention is given to the current status and further development of tools and instruments, that support the assessment, achievement and demonstration of personal and corporate competences in the nuclear sector. Finally there is a review of current trends in nuclear E&T and recommendations to maintain and develop the skills, competences and knowledge in nuclear and radiation safety in the EU.
The data on which this study is based is taken from desk research and interviews with several experts.

Retaining critical competences in nuclear energy sector: national initiatives and best practices, instruments and tools

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List of abbreviations

Acatech National Academy of Science and Engineering, DE
BNEN Belgian Nuclear Higher Education Network
CB-QS Competence Based Qualification System
Cedefop European Centre for the Development of Vocational Training
CEA Commissariat à l'énergie atomique et aux énergies alternatives (Atomic Energy and Alternative Energies Commission)
CB-QS Competence based Qualification System
CEIDEN Nuclear Fission R&D Technological Platform, ES
CFEN French Council for Education and Training in Nuclear Energy
Cogent SSC Cogent Sector Skills Council, UK
CPD Continuing Professional Development
CSFN Strategic Committee of Nuclear Industry, FR
DG DEVCO European Commission EuropeAid Directorate-General
DG ENER European Commission Directorate-General for Energy
DG EAC European Commission Directorate-General for Education and Culture
DG JRC European Commission Directorate-General Joint Research Centre
DG RTD European Commission Directorate-General for Research and Innovation
E&T Education and Training
EC European Commission
ECTS European credit transfer and accumulation system
ECVET European credit system for VET
EFTS Euratom Fission Training Schemes
EHRO-N European Human Resource Observatory for Nuclear
EIT European Institute of Innovation and Technology
ENEF European Nuclear Energy Forum
ENEN European Nuclear Education Network
ENS European Nuclear Society
ENSREG European Nuclear Safety Regulators Group
ENSTTI European Nuclear Safety Training & Tutoring Institute
EN3S European school for Nuclear Safety and Security
ESARDA European Safeguards Research and Development Association
ESCO European Skills/Competences, Qualifications and Occupations
ESFRI European Strategy Forum on Research Infrastructures
EQAVET European quality assurance in VET
EQF European qualifications framework
ETF European Training Foundation
EU European Union
EURATOM European Atomic Energy Community
HE High Education
Foratom European Atomic Forum, trade association for the nuclear energy industry
FP7 Euratom Seventh Framework Programme of the European Atomic Energy Community
IAEA International Atomic Energy Agency
IGD -TP Implementing Geological Disposal of Radioactive Waste Technology Platform
INPO Institute of Nuclear Power Operations, USA
IRSN Institute for Radiological Protection and Nuclear Safety, FR
I2EN International Institute for Nuclear Energy, FR

KIC Knowledge and Innovation Communities
KSC Knowledge, Skills and Competences
LLL Life Long Learning
LO Learning Outcome
MELODI Multidisciplinary European Low-Dose Initiative
MoU Memorandum of Understanding
MS Member State
NCP National Contact Point
NEA OECD Nuclear Energy Agency, Organisation for Economic Cooperation and Development
NES Nuclear Energy Sector
NESA Nuclear Energy Skills Alliance, UK
NI Nuclear Institute, UK
NIA Nuclear Industry Association, UK
NIC Nuclear Industry Council, UK
NITF Nuclear Industry Training Framework, UK
NJT Nuclear Job Taxonomy
NPP Nuclear Power Plant
NSA National Skills Academy for Nuclear, UK
NTEC Nuclear Technology Education Consortium, UK
NUSHARE Project for Sharing & Growing Nuclear Safety Culture Competence
R&D Research and Development
SAT Systematic Approach to Training
SCK•CEN Nuclear Research Centre, BE
SEETI Sustainable Energy Education, Innovation and Technology
SET-plan Strategic Energy Technology Plan
SKC Swedish Nuclear Technology Centre
SNETP Sustainable Nuclear Energy Technology Platform
STEM Science, Technical, Engineering and Mathematics education
TSO Technical Safety Organisation
VET Vocational Education and Training

Table of Content

1 Introduction

According to all energy mix scenarios, presented in the European Commission's (EC) Energy Roadmap 2050[12], nuclear energy will remain in the energy mix to support the challenges of security of supply and to meet the ambitions set out in the Carbon Plan[9]. Even if currently only the half of the European Union (EU) countries are supporting further development of nuclear energy sector, safe and successful operation of all nuclear power plants (NPPs) in Europe is in the interests of all EU nations. Educated and trained workforce as an essential prerequisite of the nuclear safety, has to be considered in a EU context. Besides power production, nuclear technologies are increasingly used in the various industrial and medical applications, raising concerns regarding the supply of the experts with very specific knowledge, skills and competence (KSC).

European and national strategies to maintain and strengthen nuclear competence require a strong and effective vertical and horizontal coordination of all relevant innovation and knowledge policies. The issue of nuclear E&T (Education and Training) is multidimensional. On one side it refers to the vertical policy relationships, i.e. the relationships between strategy/ actions/ instruments/ measures on the European, national, regional and organisational levels. On the other side, a horizontal policy dimension is dealing with the coordination of the strategies in all relevant economic areas – nuclear industry, education and training, labour market and employment policies, etc. In this regard, it is necessary to point out that the main objective of this study is to give an overview of new initiatives and best practices developed during the last few years on the national level. As the development of nuclear E&T is primarily defined by the policies and national regulations for the nuclear sector, and only secondarily - through the general policies that apply to the high education (HE) and vocational education and training (VET) systems, main attention is given to the educational activities specific for the nuclear field.

This report firstly focuses on the organisation of nuclear E&T in selected countries, investigating different types of institutions, programmes, qualifications, funding mechanisms and partnerships among academia, industry, labour market and social partners. Then the attention is given to the current status and further development of tools and instruments, that support the assessment, achievement and demonstration of personal and corporate competences in the nuclear sector. Finally there is a review of current trends in nuclear E&T and recommendations to maintain and develop the skills, competences and knowledge in nuclear and radiation safety in the EU.

The data on which this study is based is taken from desk research and interviews with several experts. Most of the experts consulted shared the views and recommendations of the contributors to the recent publications - SET-plan Study and Roadmap on Education and Training (2014)[90, 93], documents of interdisciplinary symposium on HORIZON 2020 "Benefits and Limitations of Nuclear Fission for a Low-Carbon Economy" (2013).[77]

2 Background

The importance of keeping critical competences in nuclear industry has been acknowledged by the nuclear community already in the 90-ies[37]. In recent years, a number of studies have been undertaken to examine the concern that nuclear education and training are in decline. In its conclusions of December 2008 the European Council emphasized strongly that *'the preservation of skills in the nuclear field requires a general effort involving public and private players and in particular the nuclear industry*.' [20] European Commission alongside other international organisations took a leading role to ensure the continuity of knowledge and expertise in this field. 2nd Situation report on education and training in the nuclear energy field in the European Union - the most recent Commission Staff Working Document, issued in October 2014[1], gives overview of the latest E&T efforts and formulates recommendations in line with the enhanced requirements to nuclear safety in the EU.

Current developments in E&T in nuclear industry sector (NIS) are based on various activities and funding instruments both at the EU and national levels. Within the Europe 2020 strategy for smart, sustainable and inclusive growth[14], new flagship EU initiatives dedicated to the triangle research, energy and education, namely Innovation Union - Turning ideas into jobs, green growth and social progress[2], Resource-efficient Europe - Towards a resource-efficient, low-carbon economy[3], Rethinking Education: Investing in skills for better socio-economic outcomes[4], propose several research and E&T actions in energy sector.

Energy policy is the competence of the state. According to the Euratom Treaty (1957)[7], art. 33, each MS has a responsibility to ensure that adequate expertise is available in the nuclear field, delivered through the E&T. New Directive, amending Directive 2009/71/Euratom establishing a Community framework for the nuclear safety of nuclear installations, adopted in July 2014, further stresses the importance of E&T in nuclear sector[13]. Directives 2011/70/EURATOM[18] on the management of spent fuel and radioactive waste and COM(2012)242,[19] laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, both set the requirements for maintaining high level of competences in the relevant fields.

The continued contribution of nuclear power in the energy mix and other nuclear technologies applications requires sufficient skilled people to construct, operate, decommission and regulate nuclear facilities, as well as to work in the areas of radiation protection, medical uses of irradiation and radiobiology. It is paramount to the nuclear safety to satisfy these requirements, but it's challenging. The technologies needed to use nuclear energy in a safe and sustainable way are complex, often – cutting-edge, and multidisciplinary. The costly infrastructure required to educate and train the several hundred thousand highly skilled persons working in this sector across EU have to be considered too. The nuclear energy sector is also characterized by lengthy time frames - a commitment of at least 100 years is needed to sustain nuclear infrastructure throughout plant operation, decommissioning and waste disposal.

Since 2009, the European Human Resource Observatory in the Nuclear Energy Sector (EHRO-N) has monitored the situation with nuclear workforce. Its report on demand/supply in the nuclear labour market[51] (2012) quantifies the current status of nuclear education in the Member States (MSs) and stresses that competences in critical

nuclear technologies are becoming difficult to sustain. The demography of those working in the industry, research and academia indicates that given the ageing workforce profile there is the danger of competence being deteriorated and ultimately lost. In the situation when nuclear industry cannot afford further reduction in existing competences and needs to develop new ones in the fields of decommissioning and waste management, strategy has to be developed to attract young people, retain staff and attract experts from other industries.

Crucial to the strategy is the need for partnership between government, industry, educational and training providers and science and research communities. There is great value in maintaining and sustaining support for existing and potential technology platforms, such as the SET (Strategic Energy Technology) Plan. One of its tasks is to assess the educational and training needs of the future professionals in the field of nuclear energy. The European Commission DGs, namely DG RTD, with the initiatives Sustainable Nuclear Energy Technology Platform (SNETP) and specifically its Education, Training and Knowledge Management (ETKM) Working Group, Implementing Geological Disposal of Radioactive Waste Technology Platform (IGD-TP), Multidisciplinary European Low-Dose Initiative (MELODI), European Nuclear Education Network (ENEN)[50]; DG ENER with its initiative European Nuclear Energy Forum (ENEF) and DG JRC with its EHRO-N, ESARDA (European Safeguards Research and Development Association) and EN3S (European school for Nuclear Safety and Security) have actions in the field of education and training among their long-term objectives. One of the main goals of the Euratom research and training programmes is to contribute to the sustainability of nuclear energy by generating knowledge and developing competences. Good example is Euratom Fission Training Schemes (EFTS)[61] in specific areas where a shortage of skilled professionals has been identified. At the Member States level a number of National Education Networks, most of them collaborating under ENEN, have been established. International programmes in nuclear E&T and research offer the possibility to share facilities and costs. They are open to all stakeholders under the leadership of EC, NEA, IAEA.

Growing concerns about the global competitiveness of European economy brought the focus on its human resources, their skills, competences and knowledge. Aspects such as student and worker mobility, lifelong learning, recognition, transfer and validation of learning outcomes have become more important in EU and national education policies. These are supported by the EU agency Cedefop (European Centre for the Development of Vocational Training) in coordination with DG EAC (Directorate-General for Education and Culture). One of the current challenges for knowledge management and competence building in the EU nuclear industry sector is to create, test and implement the instruments that meet the requirements of both industry and learners, with emphasis on borderless mobility and lifelong learning. ECTS, ESCO, EQF and especially important for the nuclear E&T, European Credit System for Vocational Education and Training (ECVET) are among them.

3 Stakeholders in retaining competences in nuclear energy sector

Main groups of stakeholders in nuclear sector are presented by:

- Higher education and vocational training institutions;
- Research organisations;
- Energy providers and systems suppliers;
- Nuclear regulators and TSOs;
- Government and civil society (polycymakers, interest groups, non-government organisations, media).

'A key element … is to bring about a structural change in the European education and training landscape by enhancing the coordination and integration of national capacities through dedicated networks and fostering industrial involvement through targeted instruments and partnerships at EU level,' is stated in the Strategic Energy Technology (SET) Plan Roadmap on Education and Training[90]. While there is a broad agreement on importance of close cooperation between the industry, universities and government on nuclear E&T and in most countries measures have being taken to include more stakeholders, the effectiveness of these practices does not appear to be the same throughout the European Union MSs.

The EU countries have similar characteristics within their E&T systems, such as state driven education policy, delivered through various public and private institutions, regulatory oversight for the creation of standards and qualifications, established standards for awarding bodies and training delivered through accredited training providers in the high or vocational education institutions. The role of government is to provide policies and funding supporting the development and operation of industry and academia. The role of the industrial stakeholders is to help E&T actors in the system to continually adapt to changes in the labour market and to the demands of industry. Diverse types of interaction between E&T providers and industry include work-based assignments and company based thesis works, apprenticeships, private corporate education and training initiatives, courses tailored to company needs, fully work-based learning, joint research programmes, etc. Among other methods of stakeholder inclusion in education and training institutional governance, consultancy, guest lectures and curriculum development are to be mentioned (Fig.1).

European nuclear industry and education are relying on a dynamic research and innovation. R&D performed in the universities or by the students at the R&D facilities revitalizes the education system by introducing new courses, providing topics for theses, encouraging academics to become engaged with the industry. The Knowledge and Innovation Communities (KICs) under the European Institute of Technology (EIT) are considered good vehicles to proceed.

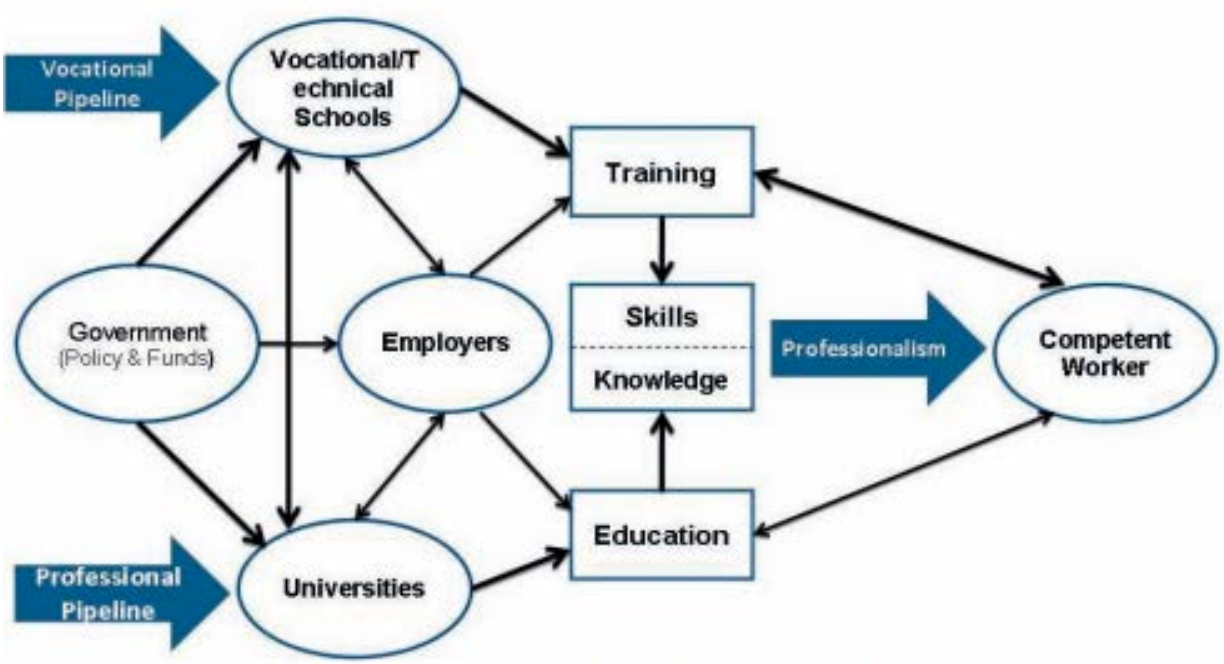


FIG. 1. Government–university–industry interaction to produce competency.

IAEA, 2011, Status and trends in Nuclear Education [24]

4 Examples of the EU Member states initiatives in forecasting of missing competences and keeping nuclear competences at high level

While there is broad agreement on the importance of retaining competences in nuclear safety and in most EU countries measures are being taken in its support, the effectiveness of these practices is not even throughout the MSs. This chapter focuses on the various initiatives in the Member States, that could be considered useful for the stakeholders within the national and European context.

4.1 Belgium

Although nuclear power phase out is foreseen by 2025, Belgium remains very active in nuclear E&T area, including national networks and international collaborations. Still, according to the conclusions of the IAEA IRRS mission, 2013, *'a national policy and strategy for nuclear and radiation safety including management of radioactive waste and spent nuclear fuel management should be developed'* in Belgium. Putting this strategy in place will definitely make the efforts of Belgian nuclear community to keep key competences in nuclear safety more efficient and effective.

The Belgian Nuclear higher Education Network (BNEN)[86], a consortium of six Belgian universities and the *Belgian Nuclear Research Centre SCK•CEN*[85], was created in 2002 and has become a European pole of reference for education in nuclear engineering. The primary objective of the BNEN programme is to educate young engineers in nuclear engineering and its applications and to develop and maintain high-level nuclear competences in Belgium and abroad. BNEN organises a master-after-master (one-year, 60 ECTS) academic programme in nuclear engineering. Its content and format have been discussed and adopted with agreement of representatives of the major nuclear companies and other nuclear stakeholders that are the first potential employers of the graduates. It is an excellent example of collaboration between universities, research institutions and industry. BNEN served as a role model for the European Nuclear Education Network (ENEN), which now has become an association of 64 members (universities, industry, regulators, research centres), aiming at facilitating mobility in Europe for students in nuclear engineering. The collaboration with SCK•CEN makes it possible to include actual use of facilities in the curriculum, supporting the development of skills and competences in a research environment. All subjects are taught by academics appointed by the partner universities, whereas the practical exercises and laboratory sessions are supervised by the experts of SCK•CEN. The final thesis offers an opportunity for internship in industry or in a research laboratory.

All teaching activities take place at SCK•CEN. Courses are organised in English and in a modular way; teaching in blocks of one to three weeks for each module allows optimal time management for students and lecturers, facilitates registration for individual modules, and allows easy access for international students.

Next to the BNEN programme described above, two Belgian institutes organise an academic master in industrial sciences with a specialisation in nuclear sciences. Historically these programmes have been created to cover the need for nuclear

professionals working outside the nuclear energy sector, for example the medical sector, radiological industry and even the non-nuclear industry (NORM-industry).

On the Flemish side *UHasselt* and *KU Leuven* jointly organise a five-year master in industrial sciences in nuclear technology with three options: nuclear techniques, medical nuclear techniques and environmental sciences/radiochemistry. A similar programme is offered on the French side by *ISIB*. The strenght of the courses offered by these institutes is their good partnership with industry, offering interesting internship and master thesis opportunities to the students.

To enhance the coordination and to strengthen the education and training activities fostered by SCK•CEN in the past years, the *SCK•CEN Academy for Nuclear Science and Technology* was launched in 2012. Within the SCK•CEN Academy, 60 years of expertise and experience from SCK•CEN's research projects is collected. The education and training activities of the SCK•CEN Academy are internationally renowned. They deal with

- guidance of early-stage scientists and engineers,
- organisation of academic courses in collaboration with universities and tailored training courses for industry,
- policy support with regards to education and training,
- caring for critical-intellectual capacities.

In addition, the SCK•CEN Academy also foresees training courses for professionals in almost all nuclear topics, SCK•CEN performs research on (radiation protection, nuclear engineering, materials issues, emergency management, decommissioning, waste and disposal issues, radiation biology, -ecology, -chemistry, ethical aspects of nuclear applications and nuclear technology assessment, etc.). These training courses are tailored to the needs of the trainees in terms of programme, duration, level, language (Dutch, French or English), location, etc.

Among the lecturers are physicists, engineers, biologists, medical doctors, technicians and social scientists who all bring insights and ideas from their specific expertise into the course programmes. As SCK•CEN staff members, they have a solid knowledge and experience in their field, and can thus directly transfer their theoretical knowledge and practical experience into the various courses. Within the course programmes lectures and practical sessions can be complemented with visits to several nuclear laboratories and research reactors. These technical visits enable trainees to enrich the acquired knowledge with the practice of real-life situations. Critical competences are given special attention. Among the trainees of the SCK•CEN Academy are employees from the nuclear industry, the medical sector, the non-nuclear industry as well as governmental and research institutions, who are directly or indirectly faced with applications of radioactivity in their professional environment.

The SCK•CEN Academy is currently working on the introduction of the ECVET approaches in its training courses. Learning outcomes in terms of knowledge, skills and competences are being introduced. *SCK•CEN's Knowledge Centre* has been created to collect and conserve the nuclear scientific, technological and technical documentation. In order to ensure better retrieval and access of existing data and tacit knowledge, dedicated web-based portals sustaining interactive research communities are developed.

Another good example of cross-border networking is *CHERNE*, an open European academic network for cooperation in Higher Education on Radiological and Nuclear Engineering, formed by the Universities from Belgium, Spain, Czech Republic, Germany, Italy, Portugal, Greece and non-EU countries. The possibility to share their competences and facilities when organising teaching activities for their students to learn from each other brings recognised added value to their courses.

European Master in Nuclear Fusion Science and Engineering Physics (*FUSION-EP*) is delivered by a consortium, coordinated by Ghent University. It aims to provide a high-level multinational research-oriented education in fusion-related engineering physics. Student mobility is an inherent part of the programme structure as well as maximum flexibility to accommodate students with different interests and backgrounds.

The E&T in radiation safety in Belgium deserves special attention. Besides training courses in radiation protection provided by the SCK•CEN Academy for Nuclear Science and Technology, few Belgian universities (KU Leuven, Ghent University, Vrije Universiteit Brussel and other) have programmes in Nuclear & Radiation Physics and medical radiation physics.

The *Radiation Protection Expert (RPE) course* is an academic course of 20 ECTS, including all topics required by the Belgian law as described in the Royal Decree of July 20 2011, art. 73.2, which is based on the definition of the qualified expert as stated in the European Directive 96/29/Euratom. On the Flemish side this course is organised by UHasselt and SCK•CEN, while a French version is organised by ISIB and IRE. Almost all participants are (young) professionals working in the nuclear sector, medical area, research or the non-nuclear industry, who want to specialise their radiation protection competences. Although the course was set up for those who need to obtain a certification as Radiation Protection Expert form the regulatory authority (the Federal Agency for Nuclear Control FANC/AFCN), only a minority of the students actually follow the course with this aim.

This course is given in one year, covering a total of 120 hours. The programme consists of courses on nuclear physics, radiation physics, radiochemistry, applied dosimetry, radiation biology, principles of radiation protection and applied radiation protection and Belgian and European regulation and legislation. Specific attention is given to the introduction of practicals complementing the theoretical classes.

GDF SUEZ currently employs about 6,000 people with specific nuclear skills. In the next 5 years, more than 2,000 engineers and technicians will join the group to replace retiring staff and to face the needs of the 11 nuclear entities of the Group. Therefore, in 2006 GDF Suez started its own training programmes. The first one is for newly recruited engineers. *The Nuclear Trainees Programme (NTP) for Juniors* combines theoretical learning and field experience under the supervision of a coach and allows junior engineer to improve his nuclear knowledge and become a nuclear generalist while developing a solid network within GDP Suez. Training is organised as a one-year course, containing 400 hours of hands-on training in France and Belgium on all aspects of nuclear energy with reinforced attention on safety. An evaluation system is organized after each training module and at the end of the programme. Continuous professional development of the staff consists of in-house training as well as the courses delivered by external providers.

A second programme for experienced engineers of the Group with no nuclear background was launched in 2010. This NTP for MAJORS has a duration of 3 weeks.

All staff members of *Electrabel*, license holder of the seven reactors in Belgium, and its subcontractors attend compulsory trainings. Electrabel has dedicated training facilities with full-scope simulators for operators and practical simulators for human performance. The mandatory trainings are *safety passport* course (3 levels), job passport and additional technical training, defined by the position of the employee. Safety passport includes initial and/or refresher training on health and safety, nuclear safety, radiation protection, environment and site security.

Both junior and more experienced professionals of Tractebel Engineering benefit from training & development in *Tractebel Engineering School*, which uses common tools and best practices throughout its regional offices, opening the possibilities for the professional mobility.

4.2 Finland

In Finland four nuclear power plant units are in operation, a fifth - generation III pressurized water reactor (EPR) - is under construction, two more are proposed. First geological disposal for spent fuel shall be ready in early 2020. In July 2010 Parliament ratified the Government's Decisions-in-principle to build two new units[1]. At the same time Parliament required from the Government to create preconditions for as extensive as possible use in new build nuclear power projects of Finnish labour, knowledge and business life. The Finnish Ministry of Employment and Economy set up the committee to assess the long-term competence needs of nuclear sector as the first step to ensure that a skilled workforce, able to deliver the new nuclear programme in time and within budget without compromising the effective continuation of current operations and decommissioning, is in place.

The study, implemented by a group of experts representing various stakeholders from nuclear sector, had the tasks to:

- survey the present personnel resources of nuclear organisations;
- conduct an extensive review of the needs of Finnish basic, further and supplementary education and training;
- investigate the opportunities for Finnish participation in the forthcoming major nuclear projects;
- survey the research infrastructure available for nuclear actors;
- explore Finnish participation in international research activities;
- review the situation regarding research reactor of VTT Technical Research Centre of Finland.

Report[74], published in May 2012, indicates the nuclear skills shortage, that the country will face by the middle of next decade. Finland will need around 2400 new nuclear sector professionals by 2020, as around 1200 of the 3300 employees in the nuclear sector are

[1] These Decisions-in-Principle are currently under discussion due to a) change in the Fennovoima plant type and b) extension request for the TVO plant. On the 18th of September 2014 Government approved supplement to Fennovoima decision-in-principle. For decision on TVO further studies were required.

due to retire. At the same time construction of new nuclear power plants and progress towards the completion of final disposal of spent fuel in addition to current activities means that the sector's work force will rise to around 4500. In addition, more university instructors will be required for major and minor subject studies and postgraduate education in the field of nuclear energy. Among the main conclusions of the report are:
- universities, polytechnics, training institutions, research institutes, companies and other stakeholders within the field should participate in further cooperation;
- international cooperation, general and educational, is essential;
- attention to be paid to the new areas of training - nuclear security and radiation protection, particularly within the health care sector;
- in the area of research there is a necessity to define nuclear R&D long-term strategy.

Following recommendations of the survey, the Ministry of Employment and Economy started preparation of research strategy through 2030 with participation of more than hundred experts from the stakeholder organisations. This extensive survey enabled development of detailed list of competences required and potentially at risk in Finnish nuclear industry sector.

The strategy, issued in April 2014, includes following recommendations:
1) The focal areas of nuclear energy research need to be organised into extensive national programmes.
2) The scientific level of Finnish research in the nuclear field needs to be raised.
3) Active participation in important to Finland international research that is through extensive national and multidisciplinary collaboration.
4) To secure the quality and quantity of researcher education in the nuclear field, an extensive and comprehensive national network of doctoral programmes needs to be established.
5) Building, maintaining and utilizing of the NES infrastructure needs to be coordinated at the national level. Financing needs to be considered strategically.
6) In research activities the emphasis needs to be on the development of innovations, growth and internationalization.
7) The establishment of an *Advisory Committee for nuclear energy research and operation* under the Ministry of Employment and the Economy is being proposed as a permanent expert body to support decision-making in national issues related to nuclear energy.

Strategy highlights that the safety and the overall good of society continue to be preconditions for the use of nuclear energy in Finland. Consequently, regardless of the development of nuclear energy on the national and global levels, there will be a need for research focusing on nuclear safety.

As an additional means to tackle the challenge, the Ministry of Employment and the Economy, regulatory body STUK, VTT Technical Research Centre, Aalto University, Lappeenranta University of Technology and the Finnish nuclear energy companies have collectively organized basic professional courses on nuclear safety since 2003 (*YK course*)[45]. The YK course is an excellent case put into practice for nuclearisation of the staff, ensuring excellent integration into the nuclear field for the graduates and professionals who have done their researcher education in other field. A very special feature of the YK course is that there are no course fees for the participants or their employees. Each organisation obtains a number of seats on the basis of the number of lectures that organisation provides for the course. This is of big support as the funding

for the continuing education in Finland is private and for doctoral programmes – partly private.

Another course - Nuclear Waste Management (*YJH*) – has similar to the YK-course set-up, where the content is produced jointly by the participating organisations[44]. It provides a basis for the new professionals to fully understand the wide range of multidisciplinary issues that need to be addressed in nuclear waste management.

National research programme on the radioactive waste management *KYT*2014, financed by the State Nuclear Waste Management Fund with total funding of 2,6M €, has the purpose to to maintain national knowhow in nuclear waste management and to promote collaboration between authorities (the Radiation and Nuclear Safety Authorities), nuclear industry and scientists. Training of the experts new to the field is among its central tasks.

The objective of the Finnish Nuclear Power Plant Research Programme *SAFIR2014* is to develop and maintain experimental research capability, safety assessment methods and nuclear safety expertise of Finnish nuclear power plants and to develop research infrastructure. Under the programme particular attention is paid to training of new experts. Projects are intended to include young researchers who, for example, carry out their thesis work under the programme. These projects make an ideal growth platform for future experts in nuclear safety. The programme is also open to postgraduate studies. Of special interest is SAFEX2014 project Sustainable and Future Oriented Expertise, which aims to generate new knowledge, methods and practices on development of expertise and competence management in Finnish nuclear energy organisations. SAFIR2014 programme research projects have received around 10 million euros in annual funding. Around 60% of the funding comes from the National Nuclear Waste Management Fund which collects it annually from nuclear power companies. The other main financier is VTT Technical Research Centre of Finland[63]. The programmes for two follow-up projects KYT2018 and SAFIR2018 have been finalised and the first calls opened in September 2014.

Aalto University, University of Helsinki and Lappeenranta University of Technology proposed long-term collaboration on postgraduate education within nuclear engineering and radiochemistry (*YTERA*, 2012-2015). Its goal is to educate high-quality researchers and experts for the needs of universities, industry, national authorities. Recently also a national networked doctoral programme was launched and the waste management course established on a more permanent basis.

4.3 France

France derives over 75% of its electricity from nuclear energy, produced by 58 nuclear reactors (1 reactor is in construction, 1 - planned, 1 – proposed). This is due to a long-standing national nuclear policy based on energy security. Still, recently French President Francois Hollande has announced that the share of atomic energy in France's electricity mix has to be cut to 50% from 75% by 2025. French regulator ASN is expected to give first opinion on whether reactors can be granted life extensions, in 2015 and a final one - in 2018-2019. How does this current uncertainty influence French nuclear workforce and its capabilities?

The assessment of the existing and projected capacities and capabilities of the French nuclear workforce has been requested by the French Ministry for Higher Education as

early as 2008. This report clearly indicated that the number of newly graduated engineers in the nuclear domain could not match the expected industrial demand and recommended significant extending of capacities and coordination of the efforts in nuclear education and training, stressed the importance of R&D for training and knowledge transfer. For the coordination of the actions recommended in the report, *French Council for Education and Training in Nuclear energy (CFEN)* has been created. It includes representatives from the nuclear industry, higher education institutions and research organisations.

At the moment there are 125,000 jobs directly linked to the nuclear industry in France including 100,000 technical ones. Over the next ten years, domestic and international nuclear power activities in France will call for the recruitment of about 13 000 engineers with Master of Science or PhD degrees, and 10 000 science technicians and operators with Bachelor of Science degree. Created in 2011 with participation of all nuclear stakeholders *Strategic Committee of Nuclear Industry (CSFN)* has recently validated the commitments of the nuclear industry. Several of them are directly connected to the activities in the nuclear E&T, namely:

- Promote employment and training. Regional actions to be initiated in order to match the needs of the industry. Emphasis will be placed on actions to strengthen the attractiveness of careers in the industry and establish a common pool for 5500 positions for "combination" training (also called "cooperative education").
- Coordinate French offer of international training tailored to industrial projects in the sector. France wants to address the present need for competence building in nuclear energy production by offering training opportunities in both French and English.
- Support innovation. R&D is an important condition of sustainable industrial competitiveness of the sector. With 1.8 billion Euros in R&D funding per year, nuclear sector holds fourth position among the most innovative sectors of France.
- Promote of French international offer is the task of the *French Association of Industrial Exporters (Nuclear AIFEN)*, which represents more than 300 French companies and organisations. First World Nuclear Exhibition, organized by AIFEN, has been held in France in October 2014. E&T is taken on board with a real Career Fair organized within the event. It provided an ideal venue for the International Institute of Nuclear Energy (I2EN) to put forward training proposals for the nuclear sector representatives from other countries.

I2EN (International Institute for Nuclear Energy), organized on Government's initiative in 2011, provides foreign partners in nuclear energy with the best solutions in education and training. Above all, it shares best practices in nuclear safety and all the knowledge required for a responsible management of a sustainable nuclear industry. I2EN brings together all the actors in training: from the leading universities and engineering schools to the main research organisations and nuclear industry, in addition to the French ministries (higher education and research, industry, environment, and foreign affairs).

The aims of the Institute are:
- to assess the adequacy between the education offered, the population of students in different curricula and the industrial and research needs;
- to assess new curricula and provide expertise to CFEN to certify the quality of these curricula in accordance with international standards;

- to analyse training requests from the foreign countries and prepare proposals based on their specific needs. For individuals the I2EN website maintains an up-to-date register of the nuclear training courses in France, including skills and requirements;
- to promote systems of grants/scholarships funded by industry and government for the best students;
- to operate a centre of excellence, providing seminars and forums on scientific and sociological subjects, related to the sustainable development of nuclear energy.

Among its activities I2EN runs 'train the trainers' programme under a contract with the *France International Nuclear Agency (AFNI)* and the nuclear energy department of the Polish Ministry for the Economy. The programme consists of a set of basic courses in nuclear energy science and technology, complemented by practical internships at leading French institutes. AFNI offers support to all countries interested in developing nuclear energy within the context of intergovernmental cooperation. Its main goal is to help foreign governments prepare the institutional, human and technical conditions required for setting up a civil nuclear programme that meets the requirements to safety, security, non-proliferation and environmental protection.

The I2EN set up a workshop, calling on experts from several countries to discuss in depth what critical knowledge has to be acquired prior to launch or re-launch of a nuclear energy program. The working sessions has been held in January 2013. It was a first step for regular exchanges between the institutions and companies from the countries interested in nuclear education & training.

Higher Education

The tertiary education system in France is complex. Behind this complexity is the tradition of creating new institutions and new programmes to meet emerging education and training needs in society. Presently, about 20 engineering schools and universities offer nuclear related curricula at a master level in France. These schools and universities are spread all over the country. This broad availability of competences led the government authorities to encourage them to build a national network.

The most famous curricula in nuclear training are undoubtedly to be found at the *Institut National des Sciences et Techniques Nucléaires (INSTN).* INSTN provides continuing general and vocational education (nearly 210 education sessions in its catalogue) in a variety of forms and is involved in several frameworks: ENEN, European projects, bilateral collaboration with CEA (Atomic Energy and Alternative Energies Commission), IAEA technical cooperation programmes. Specific initial nuclear training available at INSTN is Génie Atomique. Its courses are organized in modules of learning outcomes according to the recommendations of ECVET with the objective of facilitating the mobility of students across Europe. Thanks to INSTN proximity to CEA laboratories, students benefit from many experimental facilities. The INSTN also has its own facilities, such as the experimental reactor ISIS and associated computing tools (PWR simulators for normal operation or accidental situations), a 2 MeV Van de Graaff accelerator, scanning and transmission electron microscopes fitted with an energy dispersive X-ray analyser and teaching laboratories.

A consortium of engineering schools (Paris Institute of Technology and Ecole Centrale de Paris-Supélec), in cooperation with the University of Paris at Orsay and INSTN, has created an international two-year masters level programme in nuclear energy, fully taught

in English. The curriculum covers all aspects of nuclear energy activities. This state of the art programme receives support of industrial enterprises (EDF, AREVA, GDF-SUEZ).

Grenoble Institute of Technology (Grenoble INP) offers a total of six different education programmes in the nuclear energy - 5 programmes at the Phelma (Physics, Applied Physics, Electronics and Materials Science) school and one program at Ense3 (Energy, Water and Environmental Sciences). Every year about 100 students with Bachelor, Engineering and Master degrees in the field of nuclear energy are graduated from the institute.

With more than forty years of experience, Phelma has the oldest academic nuclear engineering training programme in France together with INSTN. Five nuclear training programmes offered at Phelma cover most of the aspects of nuclear energy: reactor operation and design, continuous improvement of safety and control of industrial risks, next generation reactors, development of advanced nuclear fuels, reprocessing of waste, economic, social and political issues of nuclear energy, fundamental and applied research in nuclear physics, accelerators and more.

Ense3 trains high-level engineers and doctors able to take up the challenges associated with the new energy order, with the increasing demand for water and with the sustainable development and country planning. Ense3 offers one engineering degree in nuclear energy taking advantage of its pioneering expertise in thermohydraulics, electrical engineering and automation.

Among the above mentioned commitments of nuclear industry, formulated by CSFN, is to support "cooperative" education by establishing of 5500 positions for its participants. Cooperative education programmes include apprenticeship and professional training schemes. Young people choosing for one of these schemes benefit from a first paid professional experience while completing their education in school or university. Even though cooperative education facilitates professional integration, it is much more demanding path for graduation than traditional education. It has added value in all aspects of nuclear education, but especially for the formation of students' behavioural and organisational skills, which are essential in nuclear sector. Cooperative education requires close collaboration between academic supervisor and industrial employer of the student. It is a good opportunity for the academia to be informed on current needs of industrial companies in terms of skills, evolution of professions and field realities, which helps to develop more operational curricula. It is equally important that cooperation education is funded by regional authorities, and/or employers, and/or state-authorized joint commission for collective training.

The *French Institute for Radiological Protection and Nuclear Safety (IRSN)* as the main nuclear research institute of France, contributes to E&T in the fields of radiation protection, nuclear safety and nuclear security. It organizes inter alias training courses directed at professionals working in the health sector and workers exposed to occupational hazards.

At *Paris-Diderot University* vocational degree Physical Energy Processes has been launched. Its advantage is that it offers direct integration into the working world, thanks to a combination of classroom training and hands-on experience. Unlike an ordinary degree, the vocational degree is not designed to be followed by a Master's degree, but through validation of prior experience and learning, students can subsequently complete their training with a Master's degree if their career leads them to hold positions as engineers.

There is a strong demand from industry for this vocational training dimension. Industry provides University with €5,000 grants for this course that can be combined with the salary equal to 2/3 of the French minimum wage. If engineers really appreciate working with vocational degree holders, the recruiting companies still do not fully understand what vocational degree really is about.

Industry's initiatives

It is worth noting that as French nuclear industry mostly comprises of large partly public corporations, most of the employees in these major companies are trained 'on the job' through internal processes.

EDF, a large electricity operator, is a good example of the company, which developed a strong internal organisation to train its personnel. As 40% of EDF nuclear sector managers and engineers are expected to retire till 2017 and because the company is also developing new projects outside France, it needs a significant amount of additional engineers, workers and technicians in the coming years and is seeking to recruit more than 5,000 nuclear engineers and 5,000 technicians over the next decade.

EDF's training system consists of Academy for Operations - for all newcomers to the Nuclear Generation Division; Academy for Engineering; nuclear education and training courses for people in charge of operations (operators, safety engineers, etc.) – initial and periodic; specific and specialized courses in a variety of domains.

EDF reinforced interaction with engineering schools and universities, both in France and abroad, to help strengthen existing nuclear education programmes and to create an international master well adapted to industry's needs. 10 schools and universities joined forces and EDF tried to ensure that all the disciplines and knowledge needed for the industry were covered by the MSc so that it serves not only to educate future teachers and researchers but also those, who will work in the industry with EDF or other company. EDF created the European foundation for tomorrow's energies — to promote the development of energy related higher education both in France and abroad. Its commitment is in the closest possible alignment with the expectations of students and the needs of industry.

How EDF goes about seeking skills needed? Prior to being recruited the new employees are expected to have a master's degree and/or be a graduate of prestigious engineering school. But it is once they have been recruited that their specific nuclear training begins. EDF provides initial training and integration, continuous vocational training, specialised training and collective mentorship – and it is through this process that the new employee generally picks up individual and collective skills.

To assist with training EDF has full scope simulators as well as specific ones for process and/or visualisation of physical phenomena; mock-ups for fuel loading and unloading. To enhance nuclear education attractiveness EDF invites young people to spend three days in their simulators, giving them an opportunity to get hands-on experience.

Another prominent French nuclear company *AREVA* created the AREVA University, aiming to train engineers, executives and managers of the group or from partners companies/ institutions to maintain and develop skills and anticipate new requirements. The AREVA University has also developed an initial training for the engineers and executives recruited by the group worldwide. Two to three thousand people per year are

enjoying the benefits of an eleven-day professional proficiency course. In-depth classes on AREVA core skills and its fundamental values, where safety and security head the list, have been given. In 2014 the Nuclear Learning Tour, an eight-day training program open to all, has been introduced by AREVA. The program includes courses, visits of six French nuclear sites, and conferences by top experts in energy.

One of the questions relevant to many industrial companies - how to deliver training courses that give commercial context to nuclear engineering? In France a nuclear law course has been developed to make personnel coming into the licensing sector aware of the legal aspects. The expectation is that it will help to avoid the situations similar to the one when AREVA underestimated the licensing laws in Finland when participating in tender.

International cooperation

In cooperation with European Technical Safety Organisations (TSO), IRSN has created the *European Nuclear Safety Training and Tutoring Institute (ENSTTI),* providing vocational training and tutoring in the methods and practices required to perform assessments in nuclear safety, nuclear security and radiation protection. ENSTTI offers short applied training sessions and longer tutoring periods for both junior and experienced professionals in the nuclear sector. In order to give value to learning achieved in the training programme, ENSTTI will apply the ECVET through validation, transfer and recognition of learning outcomes.

The *Burgundy Nuclear Partnership (PNB)* has been launched by International Nuclear Academy (INA) to offer in cooperation with institutional and university organisations, representatives of public service companies, as well as local firms, training programmes, refresher courses and retraining for the staff of companies working in the nuclear sector.

The *Franco-Chinese Institute of Nuclear Energy (IFCEN),* officially opened in 2010, is offering a French-style training to approximately 100 Chinese nuclear engineers yearly to meet the growing demand in Chinese industry and amongst French partner companies in the field of civil nuclear energy.

Several new bilateral/international initiatives are to be mentioned:

- The French and UK governments' joint declaration of January 2013, announcing their commitment to developing safe nuclear energy, sound business relations and unique skills in the field;
- Agreement between France and IAEA, signed in November 2013, enabling French nuclear organisations to play a bigger role in IAEA activities in nuclear education and training, especially with newcomer countries. The agreement plans for access to France's nuclear research reactors and nuclear facilities for education and training purposes, the organisation of workshops for IAEA newcomers, scholarships to enable students in nuclear research and engineering to pursue their studies in France, organisation of meetings and conferences to disseminate knowledge and experience, share best practices on nuclear education.
- SFEN (French Nuclear Energy Society) and Polish Nuclear Society signed a cooperation agreement in Warsaw in November 2013, which plans - among other things – to promote the exchange of information via conferences and congresses and to encourage bilateral relations among experts, young professionals and students. I2EN had already signed two Memorenda of

Understanding with Warsaw Polytechnique University and Cracow University of Science and Technology.

- I2EN signed a framework agreement with the Finnish University of Aalto on developing R&D and training within an interdisciplinary framework of the highest international level.

4.4 Germany

Following Fukushima nuclear accident in March 2011, Germany has permanently shut down eight of its 17 reactors and promised to close the rest by the end of 2022. This decision has already caused negative trend in the numbers of students taking nuclear courses. For example, in master programme "Nuclear Safety Engineering", RWTH Aachen, from 17 enrolled students 8 left; "Radioactive Waste Management" course, TU Clausthal, has been cancelled, because there was no applicants for it at all. Still, according to industry estimates, about 1000 new skilled professionals are needed in Germany annually.

'Phasing out nuclear power must not be regarded as synonymous with "phasing out" nuclear expertise. Long after Germany has completed the phase-out, such skills will continue to be essential for activities such as ensuring reactor safety, radiation protection, decommissioning, ultimate disposal of radioactive waste and crisis management, and also for maintaining a critical outlook on international developments' – has been stressed in *Acatech (National Academy of Science and Engineering)* Position Paper "Phasing out nuclear power safely. Why Germany needs nuclear expertise for decommissioning, reactor safety, ultimate disposal and radiation protection"[78]. Furthermore, the tasks to be executed demand very high level of expertise.

German Government supported this strategy by adopting the 6th Energy Research Programme "Research for an environmentally sound, reliable and affordable energy supply"[79]. The document highlights that nuclear expertise in Germany has to be maintained, focusing on research of reactor safety and disposal of nuclear waste. National expertise '*to perform, assess and, if necessary, further develop independent checks on safety concepts of manufacturers and operators*' has to be ensured through state funded research. Research in radiation protection, including non-nuclear areas as medical sector and other fields where ionizing radiation is used, is supported as well. Radiation does not stop at national borders, and Germany, having well-developed nuclear technology and safety culture, has to maintain its presence on European and global stages, also by collaborating with other countries on the hazards and risks associated with nuclear technology, especially with these who are new to nuclear.

According to the National Academy of Science and Engineering (acatech), Germany *'must use its scientific and research excellence to provide nuclear training at all levels – to serve both domestic and global markets.*'[78] The *Alliance for Competence in Nuclear Technology* is the central body for maintaining nuclear competence. It includes representatives of all nuclear stakeholders. A survey commissioned by the Alliance found that nuclear education in Germany focuses mainly on reactor technology, reactor safety technology and radiochemistry and that training in the areas of decommissioning, repository management and radiation protection is insufficient. It recommends that particular efforts have to be made to strengthen these areas and new teaching and training modules must be designed in close cooperation with industry and the licensing authorities. Special attention is to be paid to the funding of young scientists. In addition to the existing

funding of doctorate posts in research projects, other funding instruments have to be offered to promote the next generation of young scientists.

In response to the acatech's position paper the industry launched the initiative "Preservation of competence in nuclear technology – Research needs from the viewpoint of industry" with the aim to formulate industry's joint proposal for nuclear public research projects. This work has been presented and approved by the universities and research institutes in collaboration with the Alliance for Competence in Nuclear Technology. The results have been presented to the agencies of Federal Ministries in charge. And they took the proposal into account when making decisions on public research funding. This initiative has been beneficial for all parties involved – the industry, public research, universities and research institutes.

Under funding of the Federal Ministry of Education and Research (BMBF) within the "Basic Energy Research 2020 +" project "R&D work in nuclear safety and waste management research for the promotion of young scientists and for maintaining competence" has been launched. The purpose of this funding initiative is to train and promote young researchers to become high-level experts, in sufficient numbers, in all relevant areas of nuclear safety, also on a European scale. To ensure international networking and efficient transfer of knowledge and experience of other institutions and countries to young scientists, as well as their mobility, international cooperation initiatives, such as summer schools, postgraduate training, meetings and conferences, have been included in this project. The cooperation between universities and government funded institutions has been further intensified in order to provide as many students with the best possible education. The preservation and extension of radiochemical, radiation protection, radioecology, radiobiology competences in Germany has been among the goals of this call.

Promotion of young talent is one of the priorities of the initiatives "Nuclear Safety Research" and "Waste management research", carried out in coordination with the Federal Ministry of Economics and Technology (BMWi), "Radiation Research" and "Nature Conservation and Nuclear Safety" – with the Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU).

In order to maintain its excellent expertise, the *Helmholtz Association of German Research Centre* is involved in training and support of young scientists who are working in the field of nuclear safety research. Groups of young scientists and junior professionals, set up in cooperation with partner universities, industry and two national Alliances for Competence in Nuclear Technology and Radiation Research, can benefit from the researchers' outstanding scientific and technical expertise and the unique infrastructure, which includes complex facilities for large-scale testing. The activities are based at the Helmholtz Centre Dresden-Rossendorf, Forschungszentrum Jülich and the Karlsruhe Institute of Technology.

In order to cope with the challenges of phase-out, *Karlsruhe Institute of Technology (KIT)* established a new department providing special education and research in nuclear decommissioning and dismantling of nuclear facilities. The connection between science and practical engineering allows to communicate experiences of current decommissioning projects, transfer knowledge to students and show career opportunities. In addition, a further course is offered at the AREVA Nuclear

Professional School at the KIT, addressed to professionals who want to expand their knowledge.

Good example of the employer from supply chain with an active position in maintaining personnel competence in nuclear technology is *Siempelkamp nukleartechnik (SNT)*, a manufacturer of components and systems solutions as well as a provider of engineering services for nuclear facilities. In order to maintain and expand personnel competence SNT is pursuing a number of strategies:

- attracting and training students at an early stage of their studies by offering course related general internships and supporting students during their mandatory internships;
- students from the local community have the opportunity to deepen their practical experience by taking a course related job at SNT;
- support to students during bachelor's, master's, and diploma theses, which, after their completion, leads to full-time employment.

As part of the company's commitment to the training of young people, SNT offers a complex trainee program. In cooperation with E.ON, Vattenfall and KIT, SNT provides the opportunity for in-service training for 12 - 15 months, including an assignment at a power plant. As a result the trainee gains a plant-specific knowledge through an effective transfer of expertise from the co-workers.

KWS PowerTech Training Center is a private organisation, which delivers training to NPPs' personnel. To ensure the secure transfer of nuclear knowledge and expertise, the company tries to engage in the training more than one employee and to plan it in advance to guarantee availability and capability of new professional in case of e.g. retirement of the expert. KWS and KSG/GfS have developed a HPO-Training (Human Performance Optimization) - very practically oriented training scheme, enforcing safety and quality.

KWS PowerTech Training Center works in close collaboration with *VGB PowerTech* - an association of companies, for which the power plant operation and related technologies are in the core of their commercial activities. VGB PowerTech is also the body to define training standards. It is developing the methodology of defining Knowledge, Skills and Competences in the framework curricula and provides access to qualified expertise for all its members.

The fact that in Germany major training schemes for nuclear purposes have been set and accredited by the government and are a part of a legal system, facilitates comparability of standards for training and qualifications, enabling mobility and retention of experienced personnel.

4.5 Spain

There is a robust nuclear energy programme in Spain, with seven NPPs in operation and one - in the process of decommissioning.

Spanish universities are actively involved, in cooperation with the industry and R&D organistaions, in the development of a number of Post-Graduate and Master Courses. In the current years these became open also to foreign students. In order to improve the quality of nuclear engineering education and training programmes a Multimedia on

Nuclear Reactor Physics is being developed by Technical University of Catalonia. The multimedia has been distributed through IAEA to 126 institutions from 52 countries and can be used for education and training:

- in Master of Nuclear Engineering at universities;
- for engineers, chemists at Nuclear Power Plants (modular course of 2 weeks);
- for the operators of Nuclear Power Plants.

Since 2008 Spanish nuclear industry has been engaged in cooperation with the Institute of Nuclear Power Operations (INPO), USA, in the area of education & training of its personnel. First of all INPO performed gap assessment of the training capabilities and programmes of Spanish nuclear sector, which served as a basis for the development of action plan to cover the existing gaps in nuclear E&T. Among the main recommendations of the action plan were:

- implementation of SAT (Systematic Approach to Training);
- development of a Shift Manager training programme;
- development of leadership skills;
- improvement of simulator training;
- improvement of on-the-job training;
- review of the training programme content.

Numerous activities took place and are still on-going to fulfill these objectives, mostly on the level of industrial companies. *Tecnatom* is among the organisations, which developed their own action plan, based on the assessment, and signed an assistance contract with INPO. As a result, important improvements in training programmes and practices have been implemented.

Tecnatom is engaged in training activities as business services, namely:
- Training and Plant Operation Support. Tecnatom, having capacity of 500 Training Units, is able to adapt the courses to the requirements of the customers. The company also offers employers its expertise in the affiliation of new personnel to the NPPs (recruiting, selection, contracting and training of the candidates).
- Simulation and Control Rooms. Fukushima Daiichi accident reinforced the need for training on severe accident management in nuclear power plants, and full scope training simulators are one of the primary tools to address these new needs. Therefore Tecnatom completed a project aiming at extending the use of simulators to the emergency center staff for training purposes in emergency drills[73].
- Safety Management. Tecnatom's best practices in this area include identification of the new relevant competences, seminars, coaching for the development and application of competences, evaluation and improvement of the Organisational and Safety Culture and integration of safety in the management system.
- New Reactors. The expertise of Tecnatom in this area includes collaboration in FOAKE (First Of A Kind Engineering) programmes in relation to the GE ABWR and ESBWR and Westinghouse AP600 and AP1000 advanced reactors, generation IV advanced reactor (PBMR in South Africa), the Jules Horowitz European research reactor (JHR) and ITER fusion reactor projects.

CEIDEN (The Nuclear Fission R&D Technological Platform) is an entity for the coordination of the R&D needs and efforts in the field of the fission technology in Spain. E&T is among horizontal topics of its Strategic agenda and is under responsibility of *CEIDEN F+ (FORMACION)* permanent Working Group.

Study of CEIDEN[71] on the capabilities of the Spanish nuclear industry to deal with a new nuclear project was finalized in 2012. Its main objective was to analyse the Spanish nuclear industry's capacity to tackle the project for the construction of a new NPP in the situation when no new nuclear power plants have been built during the last 23 years. For the purposes of the study it was necessary to classify activities needed to carry out a nuclear project. 14 large groups were defined and for each of them the level of the existing expertise has been established. The conclusion of the analysis is that the Spanish nuclear sector has the capacity to handle 77% of new nuclear project at present, which would go to 82% within 5 years after the launch of a new nuclear programme in the country. The survey gives a very good basis to analyse the state of competences of the human resources of Spanish nuclear sector per activity and skills needs of the supplier chain for the new nuclear projects.

Another study[72], performed by CEIDEN's F+ WG, made an effort to identify the potential strengths and weaknesses of the E&T capabilities of Spanish nuclear industry. Used methodology, relying on three sources – ECVET, NEA data, EHRO-N's nuclear job taxonomy, allows to establish a taxonomic reference in classification of job-oriented training capabilities. The main conclusion of this first analysis is that there are no critical weaknesses in the catalogue of training courses of the Spanish nuclear industry, due to the fact that even if the course is not currently available in certain area of specialisation, there is a potential for its development. The areas showing some weaknesses are those dealing with nuclear fuel cycle and the security of nuclear facilities. The training capability catalogue of the Spanish industry is updated regularly and is accessible through the CEIDEN website (http://www.ceiden.com/programas/indice-formacion/). It includes the courses available, job oriented training capabilities that may be developed by the companies, tools and training methods.

CIEMAT (Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas) promotes and executes R&D activities in the fields of energy, environment and technology, including nuclear energy. Education, training and tutoring constitutes a major part of the activities of its nuclear division. Postgraduate programmes on nuclear technology (e.g. MINA), virtual centre for E- and B-learning, specialized programmes (Radiation Measurement and Dosimetry, Waste management, Safety Assessment Methodologies for Near Surface Radioactive Waste Disposal, occupational training programs), participation in FP7 Euratom E&T projects are among them.

The *Foro Nuclear (Nuclear Forum or Spanish Nuclear Industry)* is a civil non-profit organisation, which has the following specific objectives:
- Reporting and communication activities on the use of the nuclear power.
- Promoting the public image of the nuclear power, especially the provision to the public of information on the reality of the sector.
- Encouraging training and education on nuclear power related issues.
- Encouraging the participation of the Spanish nuclear industry in the public events at the international level.

For the teachers from all levels of education Foro Nuclear offers training through the organisation of different courses on energy issues. It has also created a nuclear energy manual for journalists.

Spanish Young Generation in Nuclear (JJNN) is a non-profit organisation that depends on the Spanish Nuclear Society (SNE). As one of its main goals is to disseminate the

knowledge about nuclear power, several technical tours to different nuclear facilities to understand different stages of the open fuel cycle, lectures explaining evolution of Spanish nuclear power program are organised for young specialists.

As for the new developments with experimental and research facilities in Spain, the Government agreed at the end of 2011 to initiate the construction of the ATC (Temporal Centralized Storage) for HLW waste, which will open up more possibilities for the education and training.

4.6 Sweden

The Swedish nuclear industry, which operates 10 reactors at the moment, is in a state of renaissance. In 2011 a new law allowing building of new nuclear reactor to replace existing old one, was adopted. There has been estimated that in the coming ten years, 6000 new staff will be employed - number of jobs in the whole nuclear industry nowadays[64].

In the early 1990s after Swedish government stopped funding universities, nuclear courses practically disappeared from their offer. Long before Swedish government's policy changed, industry and regulators approached universities with the offer to provide funding if the numbers of students following nuclear programmes could be increased. Today a typical educational institution obtains 2/3 of its funding from non-government sources. An education programme is also supported by financial contributions to senior positions at the universities, so it is common in Sweden for the professors to have direct contacts with the industry.

Till recently Sweden did not even have a dedicated bachelor level nuclear engineering programme. In 2010 a new course has been introduced in Uppsala University, where an existing education programme in mechanics engineering has got a third-year specialization in nuclear engineering. Higher nuclear education is mainly concentrated in the Royal Institute of Technology, Stockholm (KTH), Chalmers University of Technology and Uppsala University. The three Swedish nuclear power plants (Forsmark, Ringhals, Oskarshamn), Westinghouse and the Swedish Radiation Safety Authority (SSM) jointly fund education and research at these three universities. The *Swedish Nuclear Technology Centre (SKC)* [75] has been formed to coordinate these activities. Till the end of 2013 Swedish regulator SSM collaborated directly with industry on academic funding, which was unique in the world nuclear sector. After Vattenfall, the largest Swedish nuclear operator, submitted an application for the construction of new reactors, which SSM has to assess, the regulatory authority found it unsuitable to continue joint activities with the organisation it is assessing. At the beginning of 2014 SSM left SKC, but continues to support education financially at the same level. It should be pointed out that Sweden has no technical support organisation as mediator between industry and Regulatory Authority.

SKC's main goals are:

- Increase the interest among students to enter nuclear technology education
- Make sure that the needs of the SKC financing parties to recruit qualified personnel are met through the universities' offer of relevant basic education, executing research projects and supporting continued education of engineers already active in the nuclear technology area
- Offer attractive education in the nuclear technology area

- Create strong and internationally acknowledged research groups within areas which are vital and unique
- Create organisations and skills at the universities of the level that can support research.

Besides SKC, all universities have bilateral collaboration with industry as well as with the regulatory authority. Typically, the nuclear power plants support the closest university. In 2009-2010 Swedish universities received an all-time high funding through two projects: GenerationIV research - special grant from the Swedish Research Council and joint research and education collaboration with France in nuclear, as well as in other fields. The latter framework guarantees for Swedish students access to training reactors in Saclay, transfer of nuclear physics experimental research equipment to the GANIL laboratory in Caen; access for Swedish PhD students to the research centres in Cadarache, Marcoule and laboratory tutorials. Involvement in the development of ASTRID sodium-cooled reactor and its fuel cycle has been one of the activities within the project. These collaborations are of a special importance for Swedish nuclear education and training, as Sweden closed its research reactors a few years ago. The only existing neutron facility is the cyclotron-based neutron source at the Svedberg Laboratory, Uppsala, which is operating at energies far above the reactor-relevant range. Uppsala uses the TRIGA reactor in Helsinki for its training exercises. Besides France and Finland, Mol in Belgium and the training reactor at Budapest University of Technology and Economics have been used. The Barseback NPP, which has been taken out of operation some years ago, is used for maintenance training. However, its deconstruction will start soon. Construction of a new training reactor is being considered in Sweden.

Student interest in nuclear subjects has improved also due to innovative forms of training the universities offer. A four week course, providing an overall view on nuclear technology and radiation protection, has been offered by Uppsala University. Industry is funding the course by paying for its participants. Places which have not been used by industry are filled by the university students. Main challenge of Swedish high education remains in the falling numbers of STEM students. To keep the number of technical students choosing for nuclear at sufficient level, a system has been set up to allow young people to do a 4-months' internships with the industry. It is addressed to the students who are interested in technology, but haven't made their minds about a certain sector. Vattenfall has funded the fifth month of this training, during which interns visit final year high school students to tell about their experiences. The campaign earned a lot of positive publicity and interest from the potential students. Another initiative is the Sigvard Eklund prizes to the best PhD and Master thesis in nuclear field, which are awarded annually by SKC.

'*Finding viable formats for maintaining strong academic education and research in the traditional nuclear engineering fields with simultaneous growth in materials research, in a situation of cost-cutting pressure presents a challenge in the coming years*', - said SKC director J. Blomgren[75].

4.7 United Kingdom

The United Kingdom's nuclear industry operates 16 nuclear reactors at nine plants and has plans to build up to 16 GW of new nuclear capacity by 2030 (4 reactors are planned, 7 - proposed). Projected demand from new build (a detailed labour market analysis has been carried out by Cogent SSC in 2009) will bring UK nuclear workforce to around 66.000 (currently – 25.000 are employed directly, 15.000 – through supply chain).

Constructing new stations, decommissioning activities, safe operation, maintenance and further life extension of existing fleet, building a UK nuclear export sector asks for a new strategic approach to ensure requirements are met across the whole sector. Taking into consideration the fact that 50-70% of the UK's experienced workforce is due to retire by 2025, the task becomes really challenging. The Cogent sector skills council research report 'Next generation: Skills for new build nuclear'[66] estimates that there is a demand for around 400 new Science, Technology, Engineering and Maths graduates, throughout the civil nuclear industry and supply chain, each year to 2025.

Reorganisation started at the government level. The *Office for Nuclear Development* was established in early 2008 with a remit to facilitate new nuclear investment in the UK and advise the Secretary of State on the exercise of his regulatory and policy functions in relation to the nuclear industry. In October 2008 the *Department of Energy and Climate Change* was created bringing together energy policy with climate change mitigation policy.

To address the challenge the UK Government adopted in March 2013 the Long-term Nuclear Energy Strategy[68], which '*sets out the Government's vision for the future of nuclear energy in the UK and strategy to ensure nuclear has the best prospect of reaching its full potential.*

Government has an important role to play. Successful delivery of the strategy will also require action from regulators, industry, academia and other interested parties. Delivery of the strategy will need secure underpinning in research and development. The document provides a clear framework against which decisions and priorities for policy and research can be assessed in a coordinated manner, guiding the development of detailed plans and actions.

Government and industry have a clear vision and comprehensive skills strategy for the nuclear industry, detailing clearly how skills gaps will be identified and addressed by Government and industry working together, supporting the effective delivery of the nuclear programme and leading to the creation of jobs, career opportunities and economic growth in the UK.'

The development of skills strategy for the nuclear industry is the responsibility of the employer-led *National Skills Academy for Nuclear (NSA)*, launched in 2008. The coordinated delivery of skills interventions across the sector is facilitated by the *Nuclear Energy Skills Alliance (NESA)*. It brings together relevant skills bodies with Government (Cogent SSC, CITB, ECITB, National Skills Academy for Nuclear, Semta SSC, Dalton Nuclear Institute, Department for Business, Innovation and Skills, Department of Energy and Climate Change, Welsh Government) to ensure an aligned and collaborative approach to address skills challenges [62]. *Cogent Sector Skills Council*'s main task is to ensure that the most appropriate qualifications, standards, training programmes and other initiatives are in place. Through the approved Nuclear Industry Strategic Action Plan, Cogent develops employer-led programmes, which are then delivered through the National Skills Academy for Nuclear (Fig.2). Working with the industry ensures that the initiatives meet real needs of the latter.

"The strategic approach to developing nuclear skills" includes:

- *Identify future nuclear projects activity and timing,*
- *Determine resources and skills required to deliver client and operator specification,*
- *Assess capacity and capability and define gap against future requirement*[68]

Cogent's Future Skills research programme provides information to define its own strategy and programme of activity, as well as providing employers with the trend data to support their workforce planning. The UK nuclear industry and its supply chain benefits from new Labour Market Intelligence (LMI) by using the Cogent operated Nuclear Workforce Model. NESA members are working with employers to input relevant research and labour market intelligence into a Nuclear Workforce Model. A key feature of the model is the ability to dynamically generate future skills scenarios to guide future interventions. It will highlight potential nuclear skills pinch points, identify opportunities for workforce transitioning and provide demand signals to training providers (see Chapter 5.1.6). NESA partners then develop a common Nuclear Skills Delivery Plan to address the industry's skills requirements and skills pinch points identified via the Nuclear Workforce Model. Key skills areas where there is a risk of skills shortages have been already identified.[46] Good example of dealing with identified skills shortage is launching of an £8 million Employer Ownership of Skills and industry joint-funded programme to train an additional 290 high-integrity welders over 2 years.

General workforce capability priorities have been identified[69] as:

- ☐ Educating new entrants on the basic requirements for working on nuclear sites in the UK and promoting awareness and understanding of the nuclear industry
- ☐ The flexibility and mobility of the workforce and supply chain
- ☐ The ability to demonstrate supply chain competence
- ☐ Trained and qualified craft and technician personnel.

Developed by Cogent[65], Nuclear Industry Training Framework (NITF) provides a database of qualifications and training relevant to the nuclear industry and has the benchmark function for skills gap analysis through the Nuclear Skills Passport. The NITF is a rich resource and includes nuclear Job Contexts, nuclear qualifications, national occupational standards and industry training standards and links the competences required for a specific role with the qualifications and training standards that will deliver the competences.

Capability Model [69] for the UK Nuclear industry, developed by NSA for Nuclear, enables companies to assess their workforce capability and then support the development of a competent, safe and secure nuclear workforce with the highest standards of nuclear professionalism. The model clearly articulates the various skills development tools and techniques, providing users with opportunity to apply good practice guidelines. NSA for Nuclear supports companies in recording the training, qualifications and experience of their workforce and their contractors by developing a standardised workforce competence and capability assessment.

- *Define training requirements up-skills, cross-skill, new, or combination,*
- *Identify funding solutions and deliver training in advance of need*[68]

The *National Skills Academy for Nuclear* is the leading body for an employer led strategy to develop a standardized and coordinated approach to education, training and skills in nuclear sector. Working closely with industry the Academy focuses on vocational and technical skills development, with clearly defined links to higher education. The focus is on developing the right and appropriate standards of nuclear professionalism (including behaviours, industry awareness and understanding) in all areas of the workforce, with nuclear safety and security principles embedded throughout. Delivery is via an effective

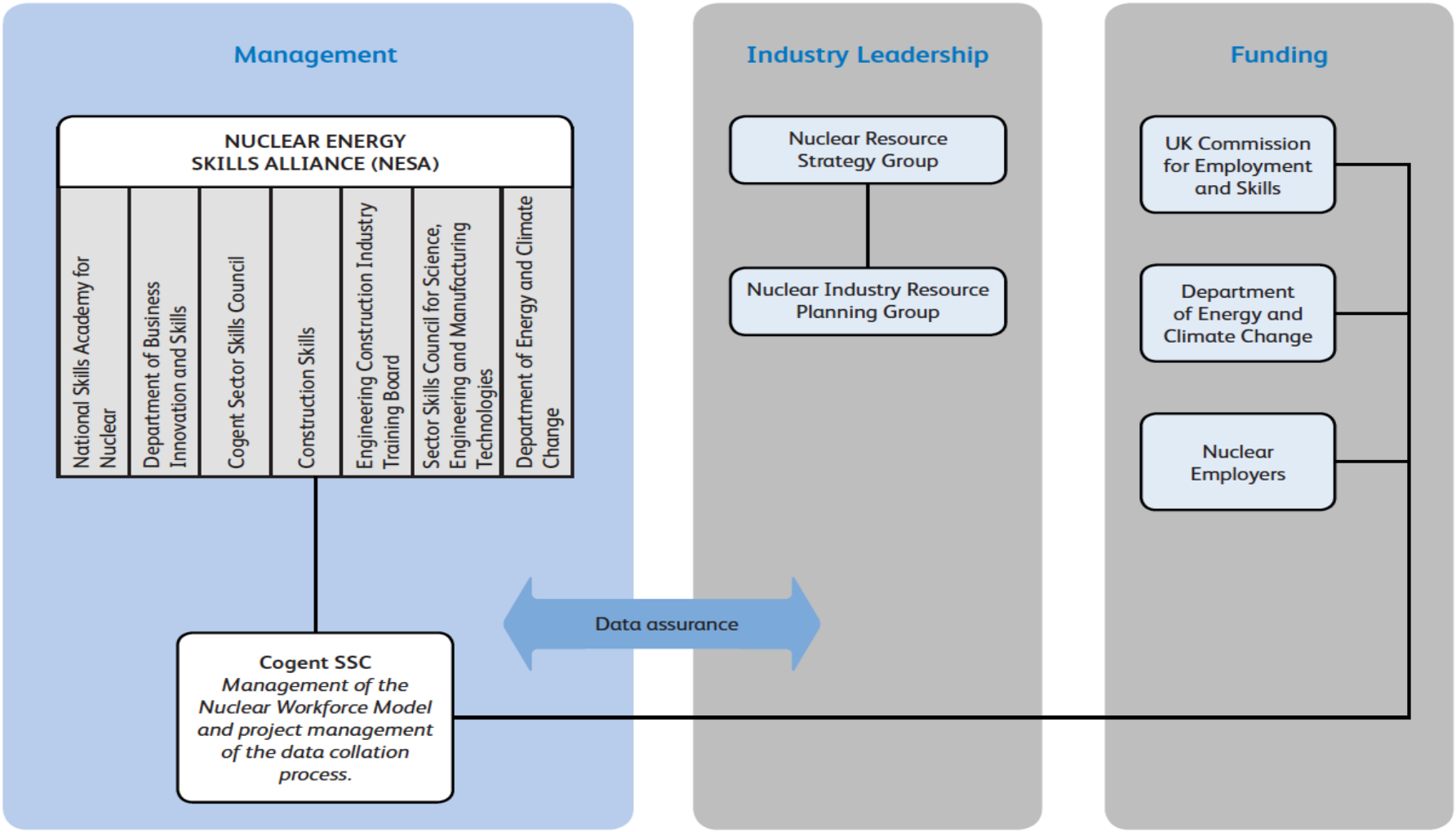


Fig.2 Project Management and Nuclear Industry Engagement. Cogent SSC, 201

network of High Quality Providers and through strong partnerships with members of the Nuclear Energy Skills Alliance, the Nuclear Institute and the Nuclear Industry Association.

The National Skills Academy for Nuclear offers a range of products to address the skills challenges facing the current and future UK nuclear programme, including the Award for Nuclear Industry Awareness, Certificate of Nuclear Professionalism, the Triple Bar, the Nuclear Skills Passport.

Award for Nuclear Industry Awareness enables entrants to the sector to develop their knowledge and understanding of working in a nuclear environment.

The aim of the Triple Bar standard is to prepare individuals requiring unescorted access to nuclear operational or decommissioning sites (Triple Bar Existing Sites), sites approved by UK Government for the construction of new civil nuclear power stations (Triple Bar New Build), working in the nuclear manufacturing sector (Triple Bar for Nuclear Manufacturing). All courses within the Triple Bar suite have been developed to Nuclear Industry Standards, can be recorded on the Nuclear Skills Passport and are available via the Skills Academy's e-Learning Portal, the Nuclear Training Network.

The Certificate of Nuclear Professionalism is being developed in partnership with employers and the Open University. This post-graduate qualification focuses on nuclear principles, safety, behavioural, commercial and project management skills delivered through employer accredited training/learning, distance learning and traditional lessons.

The Nuclear Skills Passport has been developed by NSA with industry consultation to provide the sector with a standardised approach to skills development and recognition (see Chapter 5.2.2). It enables organisations to effectively assess and plan their training, skills and people requirements and ensures industry agreed and cross site recognition of internal and external training. This competence recognition enables transferability of staff from one area of the nuclear programme to areas of growth and opportunity.

The *Nuclear Institute (NI)* is the membership organisation for nuclear professionals. Among its tasks is the improving of education and training of nuclear professionals, as well as the increasing of understanding of the nuclear industry from the wider public. This work is promoted by the NI Education and Training (E&T) Committee. National Young Generation Network (YGN) is a group created by the Nuclear Institute (NI) to offer the younger members the opportunity to further their knowledge and facilitate networking between generations.

Apprenticeships and graduates are seen as two key sources for skilled entrants for the nuclear sector. Apprenticeship is a structured programme of training which gives the learner the opportunity to work for an employer, learn on the job and build up knowledge and transferable skills that will be needed throughout a working life. It delivers a nationally recognized qualification, providing learners with a "passport" to rewarding careers, and employers with talented and competent employees. Remaining challenge is to develop apprenticeship framework as 'fit for purpose' and portable - to be used by wide range of employers across the industry.

UK employers obtain financial assistance from Government towards developing their workforce's skills. The National Nuclear Gateway, an industry and Growth Innovation

Fund co-financed project, providing an additional 3,000 apprentices in the supply chain by 2016, has been launched under NESA leadership.

Up to £10k Apprentice wage contribution is available to supply chain companies through The Skills Academy's Supply Chain Apprentices for Nuclear (SCAN) grant scheme. Apprentices can also apply for SCAN Educational Bursaries to help support their continued professional development in nuclear. Quality Assurance of training is guaranteed, as only training via the Skills Academy's Quality Assured Providers is supported.

Cogent's new subsidiary Technical Apprenticeship Service (TAS) supports employers, in particular SMEs. The TAS also offers progression routes to higher level education to apprentices who complete their frameworks, and an alumni programme - to support the promotion of apprenticeships to schools.

The National Skills Academy for Nuclear in collaboration with a Nuclear Decommissioning Authority (NDA) has funded Community Apprenticeship Scheme (CAS) to enable supply chain companies working in the nuclear sector to access additional funding to take on apprentices. The scheme has been designed to ensure minimal bureaucracy to make this a realistic opportunity for small and medium employers.

Higher Education

The National Skills Academy for Nuclear works with the Department of Business, Innovation and Skills to improve provision of science, technical, engineering and mathematics (STEM) education from school right through to higher-level post-graduate qualifications.

Cogent is developing the Higher Level Skills strategy which aims to build frameworks for greater employer engagement with higher education providers. One of the good examples of industrial placements in partnership with academic institutes is Nuclear Island initiative. It is a week long hands-on experience for engineering undergraduates, containing practical on-site training to prepare students for working in the nuclear industry. Another good example is the Working Higher project, providing flexible work-based solutions for workforce development and training. Through this initiative the foundation degree becomes an occupationally focused higher education (HE) qualification that integrates academic and work-based learning and is delivered through close collaboration between employers and programme providers. The purpose is to enable education providers to design and deliver a foundation degree of optimal relevance to the sector. Programmes incorporate e- and distance learning, on-site support, short residential blocks, work-based learning and can accredit in-house training.

The *Nuclear Technology Education Consortium (NTEC),* coordinated by the Dalton Nuclear Institute, delivers training designed to meet the UK's projected nuclear skills requirements in decommissioning, reactor technology, fusion and nuclear medicine. NTEC comprises the universities of Birmingham, Lancaster, Leads, Liverpool, Manchester, City University London, Sheffield, HMS Sultan, Imperial College London, UHI Millenium Institute & Westlake Research Institute. Together it represents 90% of the UK's nuclear postgraduate teaching expertise. Individual subjects are presented in 'short course' modular format, providing excellent access to the programme for

engineers and managers in full-time employment who wish to advance their skill and knowledge base.

Nucleargraduates is a very comprehensive graduate programme, which involves business, science, energy generation, the government, defence, environment and other stakeholders. The nucleargraduates scheme lasts for two experience-packed years and includes a series of three eight-month secondments in the UK, Europe or beyond. Throughout the scheme the graduate is fully supported in all aspects of the training, from behavioural to technical.

Quality and Standards

The NSA[67] plays a leading role in raising standards throughout the industry through the Quality Assurance of training providers and courses. Through a regional network of training clusters, acting as 'centres of excellence', the National Skills Academy for Nuclear is identifying, developing and assuring provision of high quality nuclear specialised training.

To unable nuclear organisations to choose their training providers with confidence, the NSA for Nuclear has established High Quality Training Provider Network. This Network forms the foundation for ensuring quality training delivery is maintained. The Network includes Quality Assured Providers, Employer Assured Training, Employer Nominated Providers, Higher Education Institution Members, Flagship Training Centres. Additionally a process is being developed jointly with the Nuclear Institute for the joint accreditation of programmes such as apprenticeships and CPD (continuing professional development).

Working via the Standards Advisory Group the NSA promotes best practice standards in all training requirements. For the "in-house" training assuring NSA and New Engineering Foundation Nuclear created training standard NEF Assured (Nuclear).

R&D and Research & Experimental Facilities

'The development of suitably qualified and experienced personnel (SQEP) for the nuclear industry requires around five to ten years of experience. The development of nationally or internationally renowned subject matter experts (SME) takes longer and requires engagement in leading edge R&D. The R&D community has historically provided a good training ground to export such staff into the wider nuclear community. The community itself also requires personnel developed in applied R&D skills, recruited both from education and re-trained into the nuclear research sector from other areas.'[68]

The *Dalton Nuclear Institute* at The University of Manchester has established the most advanced academic nuclear research capability in the UK and is a leading centre for higher learning in nuclear science and engineering. Through academic and industrial interdisciplinary collaboration, it has a key role in providing the knowledge and skills needed, ensuring that the programmes have direct relevance to the nuclear sector. The programme of nuclear skills training includes undergraduate course units and postgraduate qualifications, professional development courses for the domestic and international nuclear sector.

The *Dalton Cumbrian Facility* (DCF) is a state-of-the-art research base of the University of Manchester's Dalton Nuclear Institute, specifically designed as a national user facility. It provides academia and industry with the opportunity to carry out high-end research in

radiation science and nuclear engineering decommissioning, incorporating academic access to the active research facilities within National Nuclear Laboratory (NNL).

The *National Nuclear Laboratory* (NNL), holding an exceptional technical expertise, including many skills unique to the UK, is maintaining critical skills. It attracts new talented people to the industry through bringing academic research and industry together by setting up a number of University Research Alliances. NNL has a specific remit from the Department of Energy and Climate Change to maintain and develop key skills and capabilities in the nuclear R&D sector.

The University of Manchester and NNL have been awarded £8million to establish a *Nuclear Fuel Centre of Excellence (NFCE)*, *'… a unique academic research capability in a technology that is key to securing the future energy security of the UK, as well as providing an important skills pipeline from academia to the commercial nuclear sector'* (Professor Tim Abram).

Recently created *Nuclear Advanced Manufacturing Research Centre (NAMRC)* is at the heart of the UK civil nuclear manufacturing industry, combining industry expertise and university innovation, working with companies to improve capabilities and performance along the nuclear supply chain, delivering training and workforce development programmes and achieving nuclear standards and accreditation. Ask Nuclear is an information service for UK manufacturing companies from the NAMRC. Ask Nuclear allows non-nuclear companies to access specialist knowledge by drawing on the expertise of the NAMRC team and key partners in areas of manufacturing processes and technologies; quality codes and requirements; skills and training; market and supply chain information.

Energus is a new £21 million world class centre for the provision of vocational skills excellence (vocational and higher education) for the nuclear industry. It is a flagship centre of NSA, providing training for 250 apprentices and a range of industry programmes featured in Nuclear Skills Passport. It also works with the University of Cumbria to deliver programmes to 200 undergraduates and postgraduates.

Several new R&D projects recently announced have among their main aims to attract and develop high level skills in the UK nuclear sector. Thus, funded by the Engineering & Physical Sciences Research Council, the project *Decommissioning, Immobilisation and Storage solutions for Nuclear waste Inventories (DISTINCTIVE)* brings together the nuclear industry, the Government's nuclear advisors and the country's leading academic researchers. Having 10 of the UK's leading universities working collaboratively with the National Nuclear Laboratory (NNL), Nuclear Decommissioning Authority (NDA) and Sellafield Limited in an £8 million project, makes this a very significant programme, also for the development of knowledge and expertise of the participants.

Give2Gain (Growth through Collaboration) pilot project headed by NIS Ltd on behalf of a network consisting of 30 employers and coordinated through the National Skills Academy for Nuclear, has been successful in gaining funding from the Employer Ownership of Skills. The participating employers are given credits for activities they are engaging with to develop a talent pipeline, such as taking on apprentices or graduates, STEM Ambassadors' activities and offering student placements. Give2Gain will be building up a network of employers who will target resources more efficiently by working together.

Safety culture

Recent significant research and analysis of accidents, especially the one at the Fukushima Daiichi NPP, has highlighted the need to focus on the human performance aspects within the nuclear industry. Research on the implications of an event on the scale of Fukushima for the UK nuclear industry has found no fundamental problems with the UK nuclear safety. However, it highlighted that *'the UK nuclear industry should continue to promote sustained high levels of safety culture amongst its employees, making use of the National Skills Academy for Nuclear and other schemes that promote nuclear professionalism'*(Dr M. Weightman).

In this context new collaboration has been launched with the UK Nuclear Human Performance Forum to develop a set of 7 Training Standards for Human Performance Coach Practitioners. It brings a clear focus on maintaining nuclear safety and preventing accidents – particularly radiological leaks, explosions and fires.

NSA for Nuclear in collaboration with the NDA is working to support the development of Nuclear Industry Knowledge Management Portal to mitigate against the loss of knowledge from experienced retirees. NSA is also working with the Office of Nuclear Regulation and Safety Directors Forum to raise awareness of the importance of nuclear security and safety, especially within organisations - newcomers to the nuclear industry.

- *Monitor and evaluate the success of training in delivering appropriately skilled workforce*[68]

It is important to ensure that training is successful and results in an engaged and productive workforce with the right skills. *The Nuclear Industry Council (NIC),* the leading partnership forum between the UK nuclear industry and Government, will oversee implementation and the development of key performance indicators (KPIs) to monitor progress. Concerning the investment in the right skills, the KPIs are e.g. age profile of the workforce, the number of key vacancies, companies ability to expand. The NSA for Nuclear will monitor progress against the KPI's in line with normal business processes, with the Standards Advisory Group overseeing the effectiveness of implementation at an organisational level.

International Skills Development Collaboration

International collaboration of NSA with the International Nuclear Academy France (I2EN), the European Nuclear Energy Leadership Academy Germany (URENCO) resulted in them joining the Skills Academy's network of High Quality Providers. The NSA can offer its developed products and services abroad and employers in the UK can benefit from the offers from other European providers. *'Comparing our training standards and the ways we analyse the needs should lead to the improvement of our nuclear training proposals, in an international context. This issue is particularly important, as safety and security demand well trained engineers, technicians and workers'* (Jacques Figuet, I2EN).

The NSA for Nuclear is working in collaboration with the IAEA on security skills development initiatives. NSA for Nuclear, Cogent SSC, The UK Human Performance Forum and INPO are now working on the development of jointly agreed skills standards, first of all - the Human Performance Practitioner Training Standards.

The NSA and UK nuclear industry have developed in collaboration with the World Institute of Nuclear Security a competence framework for managers with nuclear security accountabilities, to be implemented world-wide.

5 Development and implementation of tools that support the achievement and demonstration of competences

To ensure that the most appropriate qualifications, standards, training and educational programmes and other initiatives are in place, relevant tools and techniques that support the achievement and provide evidence of competence have to be developed. All nuclear stakeholders have to be informed and become aware of the opportunities these tools offer. These instruments can help nuclear companies to demonstrate their workforce competence and capability to the national regulator and the public. By developing and engaging similar tools the employers will have higher return on investment in training by reducing duplicate training, implementing only adopted standards and qualifications, using only accredited training providers, enabling mobility and transferability of skills, etc.

Among the tools already in wide use by the stakeholders are those, developed by the IAEA. To mention a few, the Tool for Guidelines for Systematic Assessment of Regulatory Competence Needs (SARCoN), which becomes a standard in nuclear safety organisations; InTouch - a communication platform that allows users to complete and maintain professional profile online and to apply for a fellowship, scientific visit, training course, or for expert/lecturer assignments; the International Nuclear Information System (INIS), which supports transfer of knowledge and know-how and information processing. Our task was to present to the users the tools developed and operated by the national organisations and the JRC.

5.1 Instruments for the identification and assessment of personal, corporate and industry's nuclear competences and training needs

A standardised workforce competence and capability assessment provides a way of specifying the competence requirements for job within the nuclear sector. In a highly regulated industry the ability to demonstrate workforce competence is critical. Advantage of the training needs identification with a software tool is that it enables:

- employee to create a personal job profile and assess their current level of competence;
- corporate training needs analysis;
- the creation of a database of all skills possessed by the company and facilitates the ability to search for people with particular combinations of skills[2].

5.1.1 TRAIN, Idaho National Laboratory, USA

TRAIN is a training and records tracking system that allows to plan and schedule required training for employees efficiently and effectively. The system is based on

[2] First few systems further described are not nuclear sector specific, but can be used by nuclear employers as practical tools for their internal competence assessment. The tools presented in this chapter represented best examples from the world, not the EU only.

requirements-driven activities and can support large numbers of employees, significant workplace hazards and a wide variety of job/task assignments in addition to tracking training completions. It is capable of forecasting training needs and tracking qualification requirements for company jobs and supporting a timely and informed decision making process before workers are assigned job responsibilities.

5.1.2 'QuEST' (Qualifications and Experience System Tool), AMEC NNC, UK

'QuEST' is an enterprise solution to assist in identification and communication of skills and competences using a structured database approach based on web technologies. It allows particular expertise to be quickly located. The specific problems the system addresses are:

- identify and capture qualifications, skills and experience for staff to demonstrate it is competent in support of activities in the nuclear sector;
- provide evidence that staff is competent and experienced in the skill areas claimed;
- share information about staff skills and competences for use throughout the organisation;
- integrate skills information with other related issues such as training and development, CV's, academic and professional qualifications.

5.1.3 DACUM (Developing A CurriculUM), USA

DACUM, which stands for Developing a Curriculum, has been developed because of the need for competency-based training to meet the labour market demand for various trades and occupations. It is a means of researching and analysing a particular job that results in a chart listing the duties, tasks, and related information about the job. That information can be applied in the development of a curriculum or individual training plans to assure, that the content is directly relevant to what is required on the job.

While there can be some variations in the DACUM process, basically, a panel of high-performing incumbents develop a list of all duties and tasks associated with the job based on consensus. The panel also develops a list of knowledge and skills, tools, equipment, etc., that are essential for success. The final result is an occupational profile presented in a chart format, which describes a job in terms of specific duties and tasks that competent workers must perform. Often the same or a validation panel will set priorities in terms of how frequently a task is performed and how critical it is to the mission. Once peer reviewed and validated profile and the task analysis can then be used to develop a curriculum.

Key Elements of DACUM:

- It is a competency profile that can be used as a curriculum outline and an evaluation tool for a training program.
- It involves an analysis of the skills, knowledge and abilities required for an individual to perform effectively in an occupation.
- Its method divides an occupation into general areas of competence. Each of them is further broken down into specific skills. These skills are structured individually in small blocks on the DACUM chart. Each skill can serve as an independent goal for the learner.

- DACUM chart has a rating scale that evaluates an individual's achievement of each skill.
- DACUM method prescribes self-planning, goal-setting and self-evaluation by the learner.

5.1.4 MySkills, Atkins Training Academy (ATA), UK

Atkins Training Academy (ATA) has developed software application MySkills, which enables a specialist to create a personal job profile and by assessing his/her current level of competence to identify his/her current training needs. The training needs of all staff are then added together to facilitate a corporate training needs analysis. One of the outputs from this assessment process is the identification of technical learning needs within the company. This also enables review of the existing taught curriculum and development by the academia and vocational training providers of new courses, closely aligned to labour market requirements.

MySkills enables the user to select the skills, knowledge and attitudes from a skills menu, which has many levels, irrespective of whether they need to utilise these competences in their current role. This is a significant improvement over most human performance-based competence models that only require assessment against the skills required for a specific role. The users also need to fill in an evidence field for each particular skill. This individual assessment enables the creation of a database of all skills possessed by the company and facilitates the ability to search for people with particular combinations of skills. The individual's MySkills assessment is 'blind' reviewed by the individual's line manager or other nominated person. After discussion the competence scores are accepted or moderated by the "heads" of the disciplines the individual has claimed competency in, followed by the final dialog with the individual.

The MySkills output is then used in three ways. Firstly, any gaps in the competences, which are required for the current role and/or future development are discussed to identify a suitable solution (including a selection from a built-in list of training solutions). Secondly, the database can be searched by persons looking for the human resources for their projects or for advice on a particular topic. Finally, the total of the individual data can be compared with the future capability model to identify any capability gaps within the organisation that need to be addressed. Associated training delivery can then be planned.

5.1.5 Competence Framework, UK

Many UK nuclear operators, utilities and large supply chain companies adopt different approaches to measuring competence. The NSA for Nuclear has consulted with its employer members in the development of a common framework for the definition and demonstration of competence.

The developed competence framework and tool to assess, record and verify competence has been made available via enhanced version of the existing online Nuclear Skills Passport. It contains a set of competences, which are grouped into categories of behavioural competences, core nuclear competences and technical competences linked to disciplines. These competences, together with generic levels of competence (levels 0-4), have been developed by the industry for the industry and set a common standard for deploying work within a nuclear environment.

Users are able to tailor content to their specific requirements by selecting competences relevant to the people who will be using the system. This 'personalisation' of the framework ensures and enables ownership of competence assessment within an organisation. In the initial stages of development 4 main technical competence areas have been built into the framework which:

- reflect the needs of the employers consulted;
- are aligned to the current skills shortages experienced at a national level (via the Nuclear Energy Skills Alliance).

These four areas are Electrical Control & Instrumentation, Nuclear Safety, Mechanical Engineering and Project Management.

The process requires an individual to complete a self-assessment by selecting an appropriate level of competence against each pre-selected competency area. Evidence has to be provided. Self-assessment is then sent to the line manager of the employee to complete a 'blind assessment'. Once completed, a joint review takes place and a final competence assessment is agreed. The process allows a further review step, if required. The 'discipline expert' provides his/her input to calibrate competence assessments.

The competence assessment process ensures that any gaps in competence are identified, understood and managed e.g. through training or appropriate supervision. Other advantages of introduction of the standardised framework are that it is aligned with the Systematic Approach to Training (SAT) and provides one voice and a standard for competence specification.

5.1.6 Nuclear Workforce Model, Labour Market Intelligence, Cogent SSC, UK

Modelling the nuclear workforce can ensure the right people with the right skills are available in the industry at the right time for a sustainable future. The Nuclear Workforce Model (NWM) has been developed by Cogent SSC with the co-investment from the UK Commission for Employment and Skills through the Employer Investment Fund, the Department of Energy and Climate Change and nuclear employers. Through the Nuclear Energy Skills Alliance (NESA), the skills bodies collaborate to develop an understanding of the workforce requirements for the breadth of the industry and its supply chain. A key feature of the model is the ability to dynamically generate future skills scenarios, providing demand and supply data which will inform potential interventions.

How does the industry benefit from NMW?

- The Labour Market Intelligence supports employers in developing mid to long-term recruitment and skills development strategies.
- By working with other skills bodies there is an industry-wide analysis.
- The data becomes crucial in making the case for government investment in skills.
- The data leads to the enhancement and development of skills interventions to make sure skills shortages are addressed.

The NWM allows nuclear employers, government and other stakeholders to have a comprehensive national view of the industry's current and future skills requirements. The model can give advance warning of potential national nuclear skills pinch points, prompt

timely skills interventions, identify opportunities for workforce transitioning, provide demand signals to training providers, reflect the impact of macro changes to the civil programme.

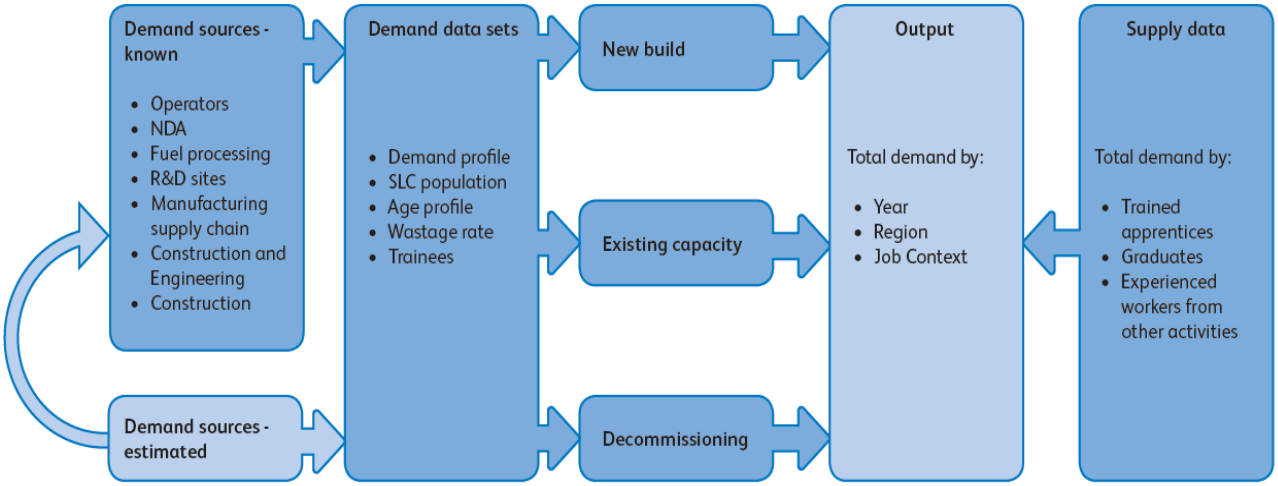


Fig.3 The Nuclear Workforce Model. Cogent SSC, 2014

5.1.7 Fit For Nuclear assessment for engineering manufacturing companies, NAMRC, UK

Fit for Nuclear ('F4N') is a programme for the supply chain companies to measure their current operations against the standards required to supply the UK's nuclear new build in order to identify any gaps in their performance. It is delivered by the NAMRC with the Manufacturing Advisory Service in partnership with industrial partners. The 'F4N' diagnostic covers six key categories of company's capabilities: Strategy and Leadership, Design and Project Management, People Excellence, Process Excellence, Safety, Quality.

5.2 Existing and planned electronic catalogues and databases on competences and training in nuclear E&T in the EU

5.2.1 Nuclear Job Contexts, Cogent SSC, UK

Nuclear Job Contexts has been developed to describe the role profiles across the breadth of the nuclear industry. As already mentioned in Chapter 4.7, the UK's Nuclear Industry Training Framework (NITF) developed this database of training standards and qualifications, to which the competences required for a specific role, are linked. These training standards, which have been produced by the Cogent SSC and other skills bodies where they are relevant to the nuclear industry, sit within a specific category, agreed with the national nuclear industry. The competences, training and qualifications are organised around four skills areas and associated qualifications:

- Technical Competence,
- Business Improvement, including quality and innovation,
- Compliance,
- Functional and Behavioural Skills

NITF qualifications are accredited by national qualification credit framework (QCF or SCQF). Developed Industry Training Standards are described using a template that identifies the learning objectives, so that it is clear what an individual who has been trained to the standard, will be able to do. Cogent is developing and maintaining standards that are required by the nuclear industry[67]. One of the current tasks is to develop a set of National Occupational Standards, vocational qualifications and Training Standards for the nuclear industry aligned with the development of Job Contexts, the Nuclear Skills Passport project and take account of the development of the qualifications and training standards in other industries to enable skills transferability.

The advantages of using Job Contexts are
- for the employers:

- industry wide skills benchmark for internationally recognized levels of competence;
- possibility to accredit and measure exisiting workforce skills and the identification of any skills gaps;
- transferability of skills across the sector and a reduction of duplicate training;
- possibility for workforce planning;
- signposting to the NSA for Nuclear accredited training courses;
- increased retention of high quality skilled employees, as they can be re-trained to an industry standard in a changing operating environment

- for the employees:

- nationally recognised framework for measuring and demonstrating individual skills;
- gaining competences accredited to national standards;
- career progression and continual professional development;
- the possibility to move from one skillset to another (for example from operations to decommissioning).

Sector wide initiative Career Pathways starts to use Job Context roles as the core of the nuclear career pathways. Career Pathways is web-based tool for employers and other stakeholders, playing an important part in securing the skills industry needs now and in the future. It provides a 'one-stop' shop for careers information and guidance targeted at students, teachers, career information officers, people within the industry considering up-skilling or reskilling and people from other industries considering a career change.

5.2.2 Nuclear Skills passport, NSA, UK

Developed by NSA and Cogent SSC in collaboration with industry, Nuclear Skills Passport gives all UK's nuclear organisations instant secure web access to information on their nuclear skills base, offering a detailed overview of the training completed by their and suppliers' workforce. The Nuclear Skills Passport is an effective tool for the introduction and cross-site recognition of internal and external skills development training. Until now the nuclear sites have trained their employees and contractors to their own standards, but when transferring staff to different facilities, the training that they have already completed was not recognised, and additional training was required.

The strategic benefits of the Nuclear Skills Passport include:

- increased flexibility and mobility - industry can successfully and safely respond to the peaks and lows of demand;

- increased retention of skills - employees can be re-trained and recognised as able to work in other sectors moving from operations to decommissioning or new build, and from defence to civil nuclear;
- possibility to demonstrate competences to regulators;
- attraction and career progression - nuclear industry is seen as a sector with clear career paths, offering development and career progression at all levels and for all entry routes;
- skills forecasting - clear picture of future skills needs can be developed using the Nuclear Skills Passport to enable effective forward planning and budgeting;
- efficiency of delivery - supply chain companies are able to operate in a more timely and effective manner as they will not be required to repeat training.

The Skills Passport Concept consists of five key elements (see Fig.4):

1. A web based accessible learner database that provides a registry of training records for individual passport holders and the facility to generate a skills passport card.
2. Dataset repository for Job Contexts. Job Contexts are agreed common job roles across industry with which associated competences are aligned (see above).
3. Benchmarking tool that supports and enables up-skilling and workforce mobility across the sector – enables existing employee's skills to be recognised and mapped against defined standard industry Job Context roles, highlighting gaps in skills and/or training.

Fig.4 Nuclear Skills Passport Concept. National Skills Academy for Nuclear, 2011

4. Training directory which supports up-skilling by signposting learners to Skills Academy Quality Assured training provision (courses/programmes /qualifications) to meet any identified skills gaps. Offers a simple modular approach to closing skills gaps through continuous learning and development with accreditation against national industry standards.
5. A reporting suite that generates statistics at industry, regional and corporate levels.

It is also important that implementation of the Nuclear Skills Passport is an easy process and organisations have the support and guidance of their Regional Manager, the Nuclear Skills Passport Manager and an IT helpdesk which provide support throughout implementation and beyond.

5.2.3 Training capabilities catalogue, Spanish nuclear industry (CEIDEN F+)

Study, performed by CEIDEN F+, made an effort to identify the potential strengths and weaknesses of the E&T capabilities of Spanish nuclear industry (see Chapter 4.5). Used methodology, relying on three sources – ECVET, NEA data, EHRO-N's nuclear job taxonomy, allows to establish a taxonomic reference in classification of job-oriented training capabilities. The training capability catalogue of the Spanish industry is updated and accessible through the CEIDEN website. Spanish nuclear industry possesses all training tools necessary to conduct the training activities for professional profiles.

The web search engine is structured as follows:

- Available courses
- Job oriented training capabilities that may be developed by companies
- Tools and training methods

5.2.4 EFTS projects' instrument for data management

The Euratom Fission Training Schemes (EFTS) have been initiated as FP7 indirect actions in the areas of nuclear sector where a shortage of skilled professionals has been identified [57, 58, 61]. The proposed training schemes consist of portfolios of units of learning outcomes, made of knowledge, skills and competences – KSC, that are needed to perform critical jobs or functions.

There are eleven European projects under Euratom FP7 programme related to nuclear education and training running at present or recently finalised.

- ECNET - EU-CHINA Nuclear Education and Training Cooperation: mirror project to be financed by the Chinese Atomic Energy Authority (March 2011 - February 2013)
- ENEN-III Training schemes - Generation III and IV engineering: addressing mainly nuclear systems suppliers and engineering companies (May 2009 – April 2013)
- TRASNUSAFE - Nuclear Safety Culture: addressing mainly the health physics sector (e.g., ALARA principle in industry and medical field) (Nov. 2010 - October 2014)

- CORONA - Regional Centre of Competence for VVER Technology and Nuclear Applications: focus on VVER personnel training (December 2011 – November 2014)
- CINCH-II - Cooperation in education and training In Nuclear Chemistry: focus on the European master's degree in nuclear and radiochemistry (June 2013 – May 2016)
- EUTEMPE-RX - EUropean Training and Education for Medical Physics Experts in Radiology: focus on Euratom Directive COM(2011) 593 (August 2013 – July 2016)
- GENTLE - Graduate and Executive Nuclear Training and Lifelong Education: focus on synergy between industry – academia (January 2013 – December 2016)
- NUSHARE – Project for sharing and growing nuclear safety culture competence: focus on policy makers; regulatory authorities; industry (Jan. 2013 – Dec. 2016)
- PETRUS III - Program for Education, Training, Research on Underground Storage: addressing mainly the radwaste agencies (September 2013 – August 2015)
- ENEN-RU-II- Cooperation with Russia in Nuclear E&T and Knowledge Management: mirror project by ROSATOM and MEPhi (March 2014 – Febr 2017)
- ENETRAP-III - European Network on E&T in Radiological Protection: addressing mainly the nuclear regulatory authorities and TSOs (March 2014 – February 2018).

Most of them have applied to some extend the ECVET principles in their training schemes, being worth to point out ENEN, ENETRAP and CINCH as the most active on this subject. First attempts are being made to develop, in synergy with the regulators, common EU approaches for assessment and validation of portfolios of learning outcomes related to specific jobs or functions. This is the case, in particular, of the E&T projects in radiation protection that are based on guidelines for learning outcomes expressed in terms of knowledge, skills and competences. They are discussing mutual recognition of qualification processes with authoritative expert associations such as ENSREG or HERCA.

In the course of these activities a huge amount of data has been generated in the form of lists of courses, qualifications, competences, units, learning outcomes and job profiles. The project ENETRAP has made several trials to create an instrument to store the data, using standard MS Office applications. However, at this moment it has become evident that only a powerful dedicated software would comply with the necessary functionalities. The need of this type of tool has been considered also in other projects, for example PETRUS.

Within EFTS projects' contribution to the lifelong learning and cross-border mobility the following list of jobs or functions in nuclear fission and radiation protection, based on learning outcomes, were completed:

- "Fluid System Construction and Commissioning Engineer" (ENEN III project)
- "Radiation Protection Expert" (ENETRAP II project)
- "Safety Analysis Expert for Deep Geological Disposal" (PETRUS II project)
- "Medical Physics Expert" (EUTEMPE-RX project).

5.2.5 EHRO-N initiative on a software tool for learning and competence management (NUVET). Concept and preliminary model

In 2011 the project EHRO-N of the Institute for Energy and Transport of DG Joint Research Centre, European Commission, undertook activities to promote the implementation of the European Credit System for Vocational Education and Training (ECVET) within the nuclear energy sector (see Chapter 6). Besides dissemination and training, these have resulted in the elaboration of a catalogue of nuclear jobs (the Nuclear Job Taxonomy)[52] and an associated database of relevant competences. In parallel, in the course of the activities under EFTS projects (see Chapter 5.2.4) a lot of data has been generated, which needs classification and further management.

In January 2014 a meeting attended by DG RTD, DG JRC and ENETRAP project representatives took place, where the project to build up a software tool for competence and learning management for the nuclear sector NUVET was outlined.

The NUVET tool is meant to be a cross-cutting initiative connecting the currently on-going European projects in nuclear education and training and especially those making use of the ECVET principles. By means of the participation and input of these projects it will be possible to adapt it to the needs of the final users. Being those users training providers as well as industry stakeholders, sharing a joint system offers the additional benefit of establishing a common language and contributing to bring closer qualifications and jobs. Furthermore, a regular communication with institutional actors such as DG EAC and Cedefop will ensure technical compliance and synergy with similar developments.

Requirements and features. The conception of NUVET arouse in first place from the difficulty to handle an increasing number of learning outcomes (LOs). Therefore the primary idea is a system to store and classify LOs and possibly help in their creation.

Whilst helping the individual users to design qualifications, NUVET would be also a space of synergy and mutual learning by means of a shared production repository and the use of the same inputs. Furthermore, it should facilitate a transparent correlation between qualifications and job positions.

There is a common agreement on some features that the NUVET tool should have:

- Versatility apt for different ways to formulate LOs. Since there is no established rule on how to write LOs, users should have the possibility to take different approaches: analytical or holistic, broader or more specific. But some constrains will be unavoidable, as the software will necessarily impose an overall boundaries for the components of a qualification.
- Inclusion of lists with standard expressions. This is meant to facilitate the adoption of a common language by means of predetermined inputs such as job profiles, library of competence items and lists of action verbs. Nevertheless, they will be rather informative than prescriptive, allowing users to use alternative expressions that can in turn be added to the input data.
- Hierarchical structure. The design interface would have three levels, corresponding to qualification, unit and learning outcome. As long as possible, no workflow for the design process will be mandatory.
- User friendliness. Data management and design functionalities should be as easy to use and intuitive as possible.

- On-line multiuser solution. It should work mostly or fully on-line, giving access to a common repository of data to all the users; the creation of private user spaces might be considered, perhaps at a later stage.

The definition of a standard for the LOs poses some issues derived from the different understanding of the concept of competence and its link with the learning outcomes. But the model increases its complexity when is set in the broader landscape of interactions with potential inputs and derived products. A first analysis allows identifying a number of components possibly making part of the software databases:
- Qualifications
- Units
- Learning outcomes
- LO assessment methods and assessment criteria
- Classifications of competences (knowledge, skills and attitudes)
- Lists of jobs
- Job profiles and corresponding key activities and job requirements
- European Qualification Framework (EQF) descriptors
- Normalised action verbs (Bloom taxonomy or similar)
- Training courses
- Bibliographies and other sources
- Metadata: time of creation, ownership, version tracking.

A sketch depicting this structure is presented in Fig.5.

5.2.6 NUSHARE - Project for Sharing & Growing Nuclear Safety Culture Competence

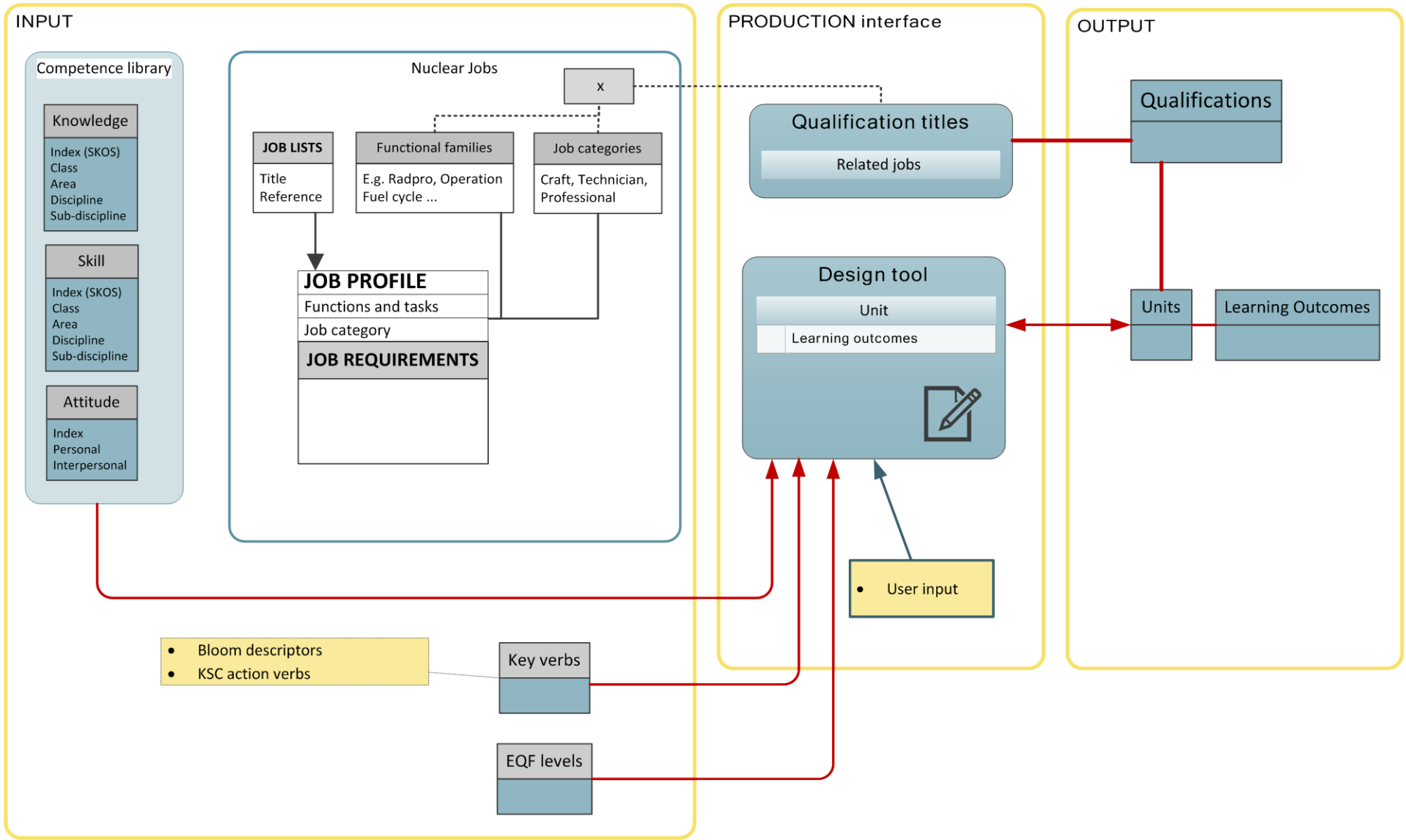
The Fukushima Daiichi accident on 11 March 2011 reinforced the need for education and training in nuclear safety. The way to prevent accidents is to help employees to improve their skills before the problems arise.

The NUSHARE project (Project for Sharing & Growing Nuclear Safety Culture Competence) has been proposed by the Cabinets of Commissioner Mrs. M. Geoghegan Quinn (Research and Innovation) and Commissioner Mr G. Oettinger (Energy) after the Fukushima Daiichi accident. This initiative, implemented in collaboration with DG ENER and DG JRC as well as DG EAC and DG DEVCO, has been launched under the modified Euratom FP7 work programme, 2012. With the funding of one million Euros (2013-2016), the project is being coordinated by the ENEN.

The objective of NUSHARE is to develop and implement Education, Training and Information (ETI) programmes aimed at strengthening safety culture in the nuclear sector and at sharing relevant best practices at the European level. Special attention is paid to safety culture competences in nuclear power plants and other nuclear installations, but other nuclear activities and security culture aspects are to be covered as well. In practice, project implementation involves designing Training Schemes and then running them in the form of modules, which eventually will be standardised. Phase 1 involves design of the modules and preparation of NUSHARE ETI catalogue. Phase 2 is focusing on testing of the training programme, to be implemented in 3 steps - pilot sessions, confirmation sessions, standardisation.

NUSHARE aims to develop safety culture training for a variety of audiences. Three target groups are considered:

- Target Group 1: Policy decision makers and opinion leaders at the level of national or regional governments, parliaments, international organisations (including EC), scientific communities (including relevant medical specialists) involved in crisis management as well as journalists and other opinion leaders;
- Target Group 2: Nuclear Regulatory Authorities and TSOs;
- Target Group 3: Electricity utilities and systems suppliers at the level of responsible personnel of organisations operating nuclear facilities (electricity utilities) and of suppliers of such facilities (vendors, engineering companies).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Competence library
Knowledge
Index (SKOS)
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x
JOB LISTS
Title
Reference
Functional families
E.g. Radpro, Operation
Fuel cycle ...
Job categories
Craft, Technician,
Professional
JOB PROFILE
Functions and tasks
Job category
JOB REQUIREMENTS
PRODUCTION interface
Qualification titles
Related jobs
Design tool
Unit
Learning outcomes
User input
OUTPUT
Qualifications
Units
Learning Outcomes
Bloom descriptors
KSC action verbs
Key verbs
EQF levels

6 ECVET within the nuclear energy sector. Pilot project to test ECVET implementation

6.1 ECVET in the nuclear energy sector

6.1.1 Current initiatives

Personnel knowledge, skills and competence are vital for ensuring safety of nuclear operations. Vocational education in NES deserves therefore special attention. The aim of the European Credit system for Vocational Education and Training (ECVET) is to offer better qualifications to the next generation of leading European talents, taking advantage of a variety of learning pathways, changing multicultural environment and networks of competences. Developments of the ECVET system over the period 2014-2020 will take place under the umbrella of the "Erasmus+" programme.

Developing transparency of qualifications in nuclear field in order to facilitate professional mobility at the European scale is an important task. Each MS has its own nuclear policy and nuclear regulator, many of the countries have developed national qualifications, which are overseen by national accreditation organisations. In this context, ECVET represents an opportunity to build bridges between the different national certifications for mutual recognition.

The ECVET use in the nuclear energy sector is well framed within the general time table of ECVET implementation in the EU as it is shown in the Fig.6. Main stakeholders of the Euratom R&T programmes (DG RTD, DG JRC, DG ENER) started in 2010 to lay the foundations of ECVET by developing a common approach regarding nuclear qualifications, vision and implementation instruments of ECVET in the nuclear energy sector[95].

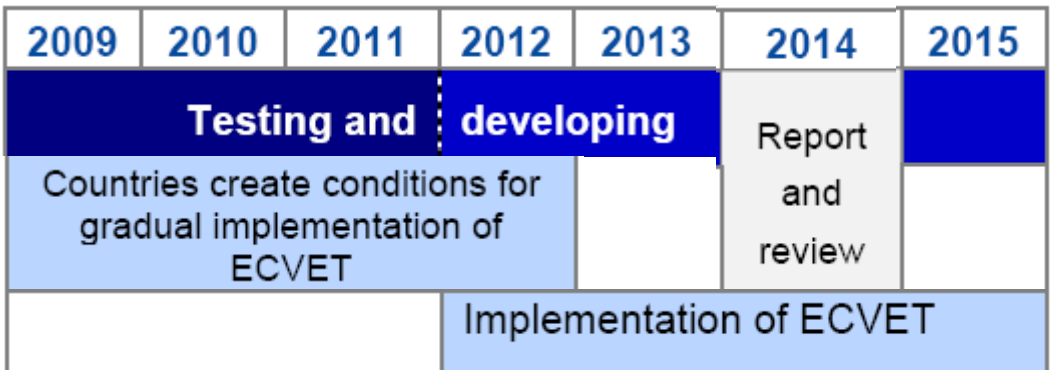

Fig.6 The ECVET implementation time table. ECVET Recommendations.

A sound scientific and technical basis for the ECVET implementation has been provided under the Euratom FP7 research and training programme (2007–2013) through indirect (RTD driven) and direct (JRC driven) actions. As far as training is concerned, there are two types of initiatives in the Euratom R&T projects:

- interdisciplinary training workshops embedded in large collaborative projects, aiming to promptly transfer scientific results to the research community;
- Euratom Fission Training Schemes, taking advantage of existing instruments and best practices in the EU (see Chapter 5.2.4) in their attempts to define job-oriented qualifications based on learning outcomes[81] and study cases of individualised learning pathways.

The EFTSs are in fact "coordination actions", taking into account scientific-technological and socio-political "end user requirements" and using the EU education and training instruments (i.e. ECTS in the Bologna 1999 process and ECVET in the Copenhagen 2002 process). These training schemes are ambitious VET or CPD programmes (usually 3 years long, with the total budget of circa Euro 1 million each). The EFTS is thus a significant development across the EU, aimed at structuring training and career development in the nuclear fission sector along the ECTS and ECVET lines.

In order to improve qualification of the processes for creation and transfer of KSC, the Euratom E&T programmes should better integrate higher education institutions and stakeholder organisations (industry, research organisations, governmental bodies, etc.) in areas where human resources could be at risk. Synergy with the end-users (including the human resource departments concerned) is required to improve the definition and the qualification process for safety related jobs and functions needed in nuclear installations.

First important precondition for the successful implementation of ECVET in nuclear sector has been already fulfilled by the development of Nuclear Job Taxonomy[52], which provides structured description of standard jobs. At the present stage, the NJT covers the jobs within the three life-cycle phases of a Nuclear Power Plant (NPP), i.e. New Build, Operation and Decommissioning. Firstly the jobs representative of the typical organisation in NPP have been identified, then the profile for each job has been developed with the focus on the job requirements, defined in terms of knowledge, skills and competence. During customised ECVET nuclear seminars these concepts for nuclear qualifications were tested in study cases, which are practical exercises of the transfer of job requirements into the formulation of learning outcomes and units.

The implementation of ECVET instrument is still voluntary in the European Union. Till now main efforts have been carried out within the education and training institutions and related student exchanges. JRC proposal for ECVET nuclear pilot project, if implemented, can become one of the first "reality" trials of ECVET involving NES industrial players. Involvement of employers in the design of learning outcomes based qualifications will guarantee that units are based on actual work processes in the nuclear sector, making the results of the project relevant for the future ECVET practitioner.

6.1.2 Nuclear qualifications particularities

The nuclear industry has certain particularities to be taken in consideration when developing projects related to training, education and professional qualification within the sector. It is obvious the omnipresence of safety and security aspects when it is referred to any nuclear activity, and also the environmental and public opinion issues intrinsically associated to energy production by atomic fission. Related to that, an extensive regulatory framework has been developed over decades, resulting in the highly regulated regime that rules nowadays the nuclear activities. The role of the national regulatory bodies introduces a great diversity in practices on the supply, demand and accreditation of education and training, making the implementation of ECVET additionally challenging.

It should be mentioned that the qualifications required by nuclear sector correspond mostly to the upper levels of the EQF, addressing research and industry workers with higher education levels, i.e. EQF level 6 to 8 (bachelor, master and doctorate levels or equivalent). Although transferability and comparability between ECTS and ECVET is an overall issue, it becomes especially relevant in the nuclear field, where the qualifications correspond mostly to the upper levels of the European Qualifications Framework.

Nuclear industry has a great degree of internationalisation, both for the regular movement of workers and materials and for the transnational agreements that govern it to a great extent. Moreover, safety concerns, intrinsically linked to nuclear activities, make the availability of sufficient workforce crucial. The competence of this workforce must be continuously up-to-date, demanding consistent lifelong training schemes besides initial learning upon taking up a job.

Together with the international scope, the movement of learners - either students or professionals - is also encouraged by the restricted availability of suitable facilities and expertise. In this context, synergies stemming from mobility become not merely beneficial, but essential. Completing the in-house and on-the-job training with learning periods in different organizations and countries is often necessary for acquiring and maintaining an appropriate level of competence. Finally, the prospective on the demand of nuclear experts in the medium term suggests the necessity for nuclearisation of a number of professionals with initial non-nuclear background.

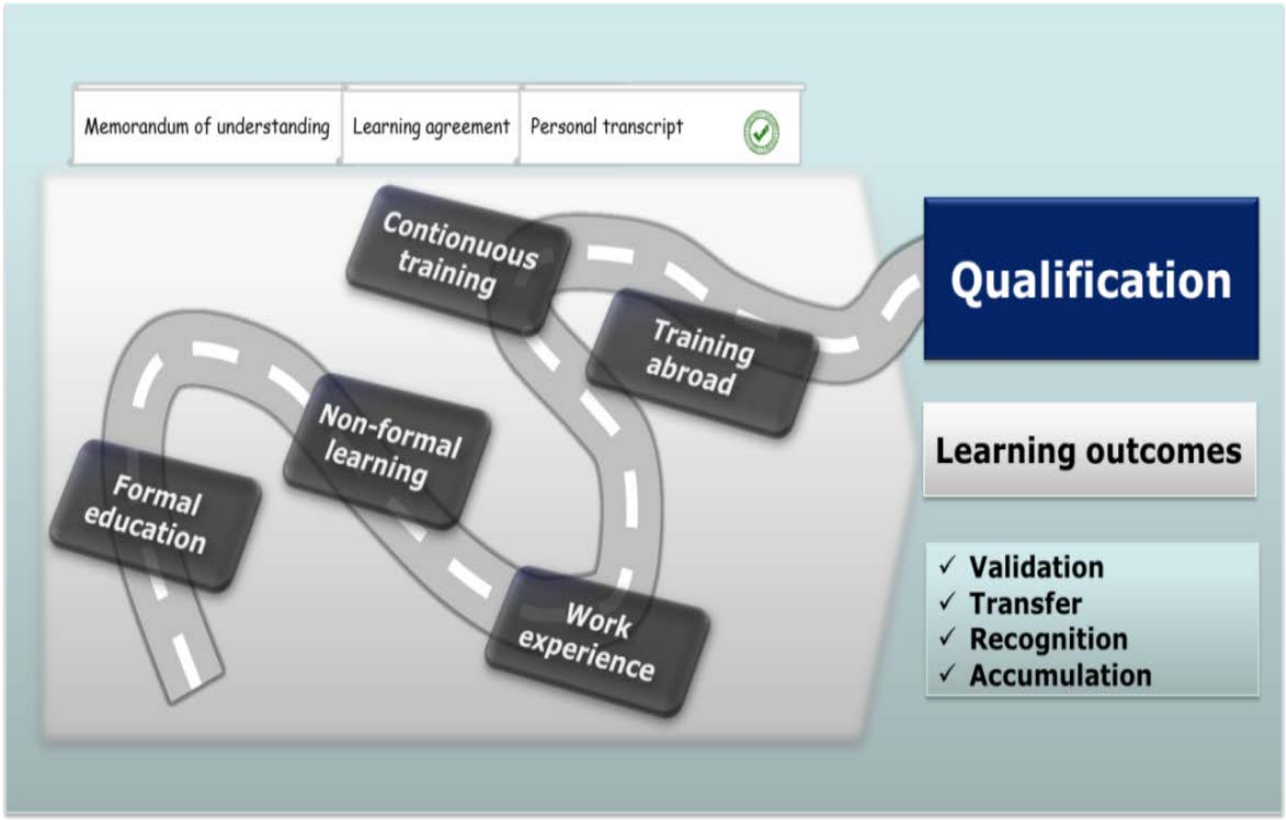

Fig.7 The features of the competence based qualification system. CEDEFOP. Terminology of European education and training policy.

The ECVET would support the improvement of the nuclear qualification system (see Figure 7) by:

- the shift to a competence based qualification system (CB-QS) that is more flexible;
- CB-QS enables competences accumulation (or Learning outcomes) no matter in which education system or sector and how long takes to accumulate competences/ LOs;
- CB-QS permits flexible learning pathways: formal, non-formal, work experience, Life Long Learning (LLL) and training abroad;
- CB-QS enables geographical mobility.

6.2 The NU-VET pilot project in the nuclear energy sector

6.2.1 Existing ECVET projects in non-nuclear sectors

Commitment of the EU Member States concerning the European Credit System for Vocational Education and Training is still very moderate [82]. To promote implementation of ECVET the European Commission issued a call for proposals to finance international partnerships aimed to test the implementation of the ECVET process in the contexts of mobility. As a result during the periods of 2008-2011 and 2011-2014 a total of nineteen ECVET pilot projects have been selected and completed.

In addition to the ECVET pilot projects funded under the lifelong learning action programme, other projects relating to the ECVET testing and development took place, namely the European Qualification Framework (EQF) projects and projects funded by the LEONARDO programme. Moreover, the thematic network NetECVET, which consists of 14 National Agencies of the Lifelong Learning Programme (LLP), promotes ECVET in the context of transnational mobility and supports the implementation process in the MSs through a bottom-up approach. It adresses VET practitioners and supports and guides them in the application of ECVET.

The pilot projects, developed in different economic sectors (aeronautical industry, tourism, catering, etc.), became an informative source on the practical application of ECVET by providing information about its implementation possibilities in different sectors and dissemination of information about the best practices, difficulties and results of the individual projects. In the conclusions of the final conference of the ECVET pilot projects of the first generation, 2012, it s stressed that there is a need to further strengthen the common European features of the credit system while adopting it to the national or sectorial environment, instead of merely picking up those elements that seem to easily fit. [82]

6.2.2 The scope of the NU-VET pilot project

Nuclear sector will become the next area for testing of ECVET. The NUclear-VET Pilot Project (NU-VET PP) has been launched in April 2014 by the EHRO-N, the Institute for Energy and Transport, Joint Research Centre (IET-JRC), EC. During the past four years its ECVET team put a lot of efforts to increase the awareness and familiarization of the European nuclear community with ECVET [83] through:

- organisation of ECVET seminars customized for nuclear stakeholders;
- development of nuclear job taxonomy (NJT) and organising a series of workshops to facilitate this task;
- development of a nuclear ECVET network;
- dissemination of the ECVET principles, tools and benefits among the nuclear stakeholders.

An EHRO-N report "Towards the implementation of the ECVET system in the nuclear energy sector"[56] states, that *'considering the particularities of the nuclear energy sector, the introduction of ECVET requires the development of initial tools, such as a well-structured common terminology across the EU for the description of professional profiles related to nuclear energy and radiation protection, the definition of roles and required competence and the design of agreed learning outcomes and assessment criteria'.*

The implementation of ECVET in the nuclear sector will be a challenging but rewording task, as it requires taking into account industry's particular characteristics, namely:

- qualifications required by nuclear sector correspond mostly to the upper levels of the EQF, which requires developing pathways and equal recognition between VET and higher

education (ECVET and ECTS). Testing of EQF level 6 qualifications, which are used for the occupations with limited exposure to the country-specific safety accreditations, at the start of the pilot project may be a good idea;

- high degree of internationalisation of nuclear industry;
- high requirements to safety in nuclear industry;
- absence or restricted availability of facilities and expertise in many countries, which makes synergies compulsory;
- nuclear industry is a highly regulated sector, demanding high level of certification on the national level. Regulatory systems differ in the MSs. Attention should be drawn to a potential barrier, as in several EU countries a national licensing process is required for specific jobs or functions (safety-related jobs, usually at higher education level);
- validation/recognition of non-academic and informal learning remains a major challenge, as their outcomes are not standardized. Methods and tools have to be developed and widely used to identify, assess and accredit these learning outcomes. This is to be achieved by applying the European Credit System for Vocational Education and Training (ECVET).

The main features of the JRC approach to the ECVET implementation process in the nuclear energy sector are:

- ECVET implementation is a stepwise process;
- there are six major components of the NU-VET system;
- whole NU-VET mechanism consists of six steps;
- each step has specific goals and activities as it is explained in the table 1.

ECVET com-ponents	**Goal**	**Activities**	**Findings/Achievements**
1	Scanning the HR demand of the nuclear energy sector /market	EHRO-N 1st survey - 2012	by 2020- nuclear experts deficit of 50 %
2	Shift from KB-QS to CB-QS/ from knowledge creation to competence building	- Nuclear Job Taxonomy preparation; - Job descriptions-job requirements defined in terms of KSC - Competence Catalogue: helps to define job requirements in terms of KSC/A (competences)	- 155 jobs; - 140-JD - 2200 new entries All these aim to serve as a tool for defining learning outcomes
3	Developing competence based-qualification system for NES	Designing nuclear qualifications based on ECVET approach	1st exercise on designing NPP Operator qualifications at 2nd ECVET Seminar - Budapest, HU (Oct. 2013)
4	Development of the mobility tools for NES	Memoranda of understanding, learning agreements and learners' transcripts of records	Covered by the indirect actions (EFTS projects) supported by the DG RTD
5	Qualification achievement process for NES	Developing specific tools for assessment, validation, recognition and accumulation of learning outcomes	Covered by the indirect actions (EFTS projects) supported by the DG RTD
6	Supporting implementation of ECVET in the nuclear energy sector	Organizing a series of WSs (5) and ECVET customized seminars	Test the ECVET implementation in the NES through a NU-VET Pilot project

Table 1. The NU-VET components

6.1.1 The NU-VET pilot project objectives

The overal objective of the NU-VET PP is to test the implementation of the ECVET system process in NES in the context of learner's mobility. Also, the NU-VET PP will demonstrate that an individual, working in a nuclear power plant, can upgrade his/her qualification by acquiring competences abroad (see Fig.8) at another nuclear power plant (or radioactive waste facility), and that the achieved learning outcomes could be transferred and recognized in his/her country of origin. The project will also serve as '*an example for the other fields and will enable not only to improve EU mobility of workers, but also the effective nuclear HR competence analysis, i.e. comparing competence existing with competence needs in the EU.*' [93]

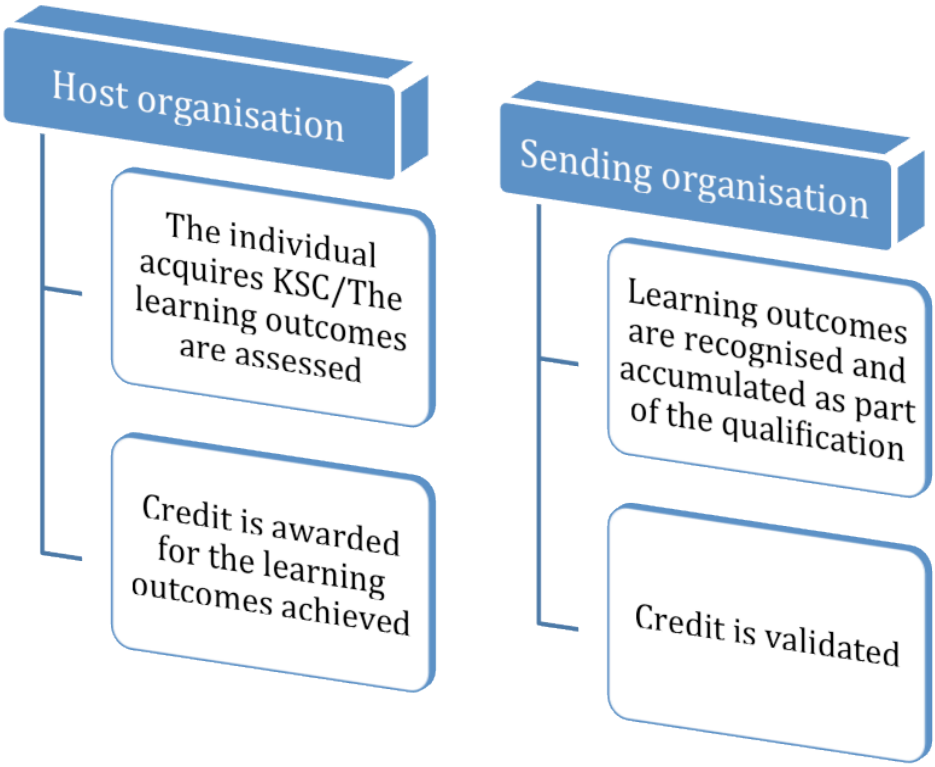

Fig. 8. Learning outcomes in NU-VET PP

The NU-VET PP has two specific objectives:

a) shift from knowledge qualification system to the competence based qualification system in the nuclear energy sector;
b) development of the best methodologies and tools matching with the ECVET framework and with NES particularities.

a) Shift from knowledge qualification system to the competence based qualification system in the nuclear energy sector

The core task of NU-VET PP is the implementation of vocational qualification and education system pivoting on Learning Outcomes. In particular, the NU-VET PP project is concerned with reshaping the approach to vocational education according to Learning Units or, in other words, to shift from knowledge qualification system to the competence based qualification system in the nuclear energy sector.

A Learning Unit is supposed to be the "brick" of learning programmes: it describes the outcomes of a learning process in terms of the acquisition or improvement of a competence. Learning

Outcomes describe in detail the single learning acquisitions, while the Learning Units aggregate Learning Outcomes according to competences. In other words, a Learning Unit is a set of Learning Outcomes related to a specific competence. The activities scheduled by NU-VET PP aim at redefining one or more professions according to competences and outpouring them into Learning Units.

Units of LOs are easier assessed, if they are well defined and designed in such a way that they are independent from each other. Certain principles for the formulation of learning outcomes have to be shared and adopted between partners from the beginning of the project as well as a specific vocabulary to describe learning outcomes precisely.

On the other hand the NU-VET PP would select one or more professions to be "nuclearized". The experimentations on the field, namely the development and execution of mobility programmes for vocational education of learners, aim at testing the success of the redefinition and validation process. Thus, the main goal of NU-VET project is to check if the system lasts and to highlight its criticalities.

b) Development of the best methodologies and tools matching with the ECVET framework and with NES particularities

The main concern for a successful NU-VET PP is to develop the best methodologies and tools matching with the ECVET framework and with Nuclear Energy Sector particularities.

Within the NU-VET PP assessment is used as a means of facilitating transfer and accumulation of learning outcomes between two national systems. The procedure has to be developed, jointly applied and tested. A Memorandum of Understanding contains main principles for the recognition of LOs, but the challenge remains in how to link already existing practices with the assessment methods chosen by the partnership.

It is to mention that a pilot project should not necessarily deal with all above mentioned objectives, but with a certain aspect. ECVET has to be seen as an accommodating system. Its flexibility is in the unit of Learning Outcomes, which can be acquired and assessed in one setting and transferred to another. Today the shift to learning outcomes and competence-based qualifications is mostly justified by its advantages for the future. This pilot project can demonstrate how the industry can benefit from it already now.[83]

6.1.2 Participants of the NU-VET pilot project

The participants of the NU-VET PP have to be representative of the NES. Therefore for the selection of the candidates for the partnerships several characteristics have to be taken into account, e.g. they have to be represented in a national nuclear E&T network, previous participation in activities related to the European Credit System for Vocational Education and Training (ECVET) will be a valuable asset. To identify in which areas of nuclear industry (e.g. new build, decommissioning, radioprotection, radwaste, nuclear systems suppliers, nuclear chemistry, etc.) ECVET implementation will have the highest added value, it is recommended to take into account the information from the previous activities – EFTS projects and Nuclear Job Taxonomy development.

National network of stakeholders from a Member State – a member of a partnership - should ideally consist of, at least, the following partners:
- National administration competent in qualification design and accreditation;
- Nuclear power plant or radioactive waste facility (nuclear employer);

- Nuclear E&T provider;
- Nuclear regulatory body.

Participation and close cooperation with regulatory authorities and competent national authorities, who design, award and recognize qualifications, are of particular importance. They have to be engaged in the project as early as possible, especially in case when national regulations have to be adapted to make recognition of learning outcomes assessed abroad possible. It's important to take into account the attempts, which have been already made to develop, in synergy with the regulators, common EU approaches for assessment and validation of portfolios of learning outcomes related to specific jobs or functions. This is the case, for example, of the EFTS actions (e.g. projects ENETRAP III and EUTEMPE RX), which are in discussions with European expert associations, such as ENSREG or HERCA. Involvement of the latter in the future project has to be given special attention.

As education is one of the competences of Member State or region, where higher education is usually under responsibility of universities and training – of regulatory and/or industrial organisations, project will benefit from cooperation with these existing structures already from the beginning. This can be effectively achieved through the participation of European Centre for the Development of Vocational Training (Cedefop) to the pilot project.

Regarding the practical implementation of the pilot project, on 12-14 November 2014 the Institute for Energy and Transport of DG JRC in collaboration with the ECVET Team of DG EAC is organising the ECVET seminar customised for the nuclear energy sector in order to support and assist the national nuclear E&T networks in setting up a Pilot project on European Credit system for Vocational Education and Training (ECVET) implementation in the nuclear energy sector. Various nuclear stakeholders, including universities and other education & training providers, nuclear power plants and other industry representatives, research institutions, national regulatory authorities, agencies and ministries, from 15 European countries have already applied for the event as the members of sixteen proposed networks.

7 Conclusions & Recommendations

7.1 General Trends

Even though the national nuclear policies in the EU are very diverse, especially between the countries with nuclear tradition and the newcomers to the sector, there are still common trends in nuclear E&T in the MSs.

Since the qualification of the workforce has impact on safety, the development of human resources is a requirement that is increasingly being placed explicitly on governments. The difference in level of government's involvement in the national nuclear E&T in the EU is really striking, but the common feature is that the funding is not sufficient in any MS. Some governments (UK, FI, FR)[68, 73] adopt the measures to ensure the required workforce will be available when decisions are made on building of new nuclear power plants. They recognise the need in the local experts with a global understanding of nuclear technology and the emphasis on safety. As a rule, government confidence in nuclear power leads to a more supportive public attitude. Among the representatives of nuclear community there is an opinion that within each national regulatory authority a core group of national experts with critical knowledge has to be established and kept sustainable, whereas the industry has to be responsible for the maintaining of a given level of competences, checked regularly by the regulatory authority (V. Slugen, STU, SK).

Nuclear safety is considered one of the most important competences in all MSs[77]. As nuclear safety is a common goal, the competition for the market success has not been an obstacle for cooperation in training activities. The best expertise can be made available to all interested stakeholders and the costs can be kept very reasonable through real collaboration. In accordance with Energy Roadmap 2050[12] number of skilled people engaged by nuclear industry has to expand substantially. This means the requirements for education and training will increase. Harmonization of standards will be absolutely necessary if a global nuclear safety culture is to be achieved. *'Getting a European consensus on safety standards will be the main objective of safety research. This would considerably help to respond to national, European and international requests and to take benefit from this nuclear market'* (D. Brochard, CEA)[77].

The existence of differences between MSs in terms of their education policy, stakeholder involvement and their motivations, technical issues like design and use of learning outcomes and their assessment and validation, is a challenge. But '*the richness and competitiveness of European education and training lies in this internal diversity,*'[84] if harmonization and standardization of qualifications are successfully implemented on national and European levels.

In most of the EU countries nuclear E&T system is not straightforward, as it is a result of progressive evolution from, for example, small scale cooperation on R&D in public facilities to the large international regulator-industry-academia consortia of today. On the other hand, Finland shows how national decisions at the government level can be directly translated into efficient and clear procedures all the way down to the design of training courses. The general trend in the organisation of nuclear education is towards a consortium (rather than a network) between universities, one of the motivations being a need to share the work due to the limited number of professors available. NTEC, UK, represents an excellent example of this practice.

As it has been reported at the Workshop on Nuclear Knowledge, January 2013, Paris, there are no major theoretical obstacles towards achieving the goal of sustainable nuclear knowledge management and training. Low social acceptability of nuclear energy (as it is in Poland) might be a

cause of uncertainty for the industry, but commonly this does not prevent progress in training. However, in many countries the courses which have been set up, have room for more students and the industry needs more graduates. Contradictory energy policies, shifting or deferred government decisions on the future of nuclear industry have negative effect on the interest and engagement of young people in the industry, especially taking into account present competition for the students among the different energy fields and generally – for STEM students. Bearing in mind the long period generally required for nuclear education and training, systematic planning decades ahead is necessary to change this trend essentially instead of dealing with its consequences.

The growing use of skills-based approach in the nuclear course design has been welcomed by nuclear community, especially by the industry. Traditionally most training programmes were structured around available knowledge. Today, the ECVET leads training providers to develop courses based on expected skills to guarantee future employability. The key question is "What are you capable of doing at the end of the course?" This new way leads to a training system with more visible outcomes that are comparable across Europe.[84, 88] After the results of the current evaluation of ECVET are published later on in 2014, further developments of the ECVET system will take place under the umbrella of the "Erasmus+" programme[15] over the period 2014-2020.

Accreditation of qualifications received during company or even site specific trainings is often hindered. Development of modular qualifications and training standards, backed by National Occupational Standards, directly related to job profiles, provides employers and employees with more ready pathways for re-skilling or up-skilling (UK). Many experts are supporting establishment of the European accreditation body in nuclear. Thus, Dr Y. Janev from the Nuclear Knowledge Management Institute remarked at the Workshop on Nuclear Knowledge, January 2013, Paris, that a pilot of a civilian aircraft is certified by International Civil Aviation Organisation (ICAO) wherever he/she has been trained. 'Do we have that in the nuclear industry?', - he queried.

'*Cooperation with other energy sectors is also increasingly important, for the development of transversal skills and competences oriented to the wellness of society, for the analysis of global socioeconomic challenges and for the creation of awareness of and acceptance of nuclear energy as part of the whole energy mix*'[77], - stressed the experts, consulted for the 2012 Interdisciplinary Study "Benefits and Limitations of Nuclear Fission for a Low-Carbon Economy", Dr F. Weiss among them. Inter-sectorial collaboration in energy is a necessity – pointed out the European Economic and Social Committee[22]. How this statement is reflected in practice? The "European Foundation for the energies of tomorrow", created by EDF, helps universities and Grandes Ecoles to provide students with appropriate training for low-carbon energy, promotes strengthening international and interdisciplinary cooperation and supports the enhancement of teaching and research. Another example of collaboration between energy sectors is SEETI **(**Sustainable Energy Education, Innovation and Technology), developed within SET-plan. Its Educational Programmes will result in a series of mutually recognised and accredited modules offered by partners as joint partner activities. A new certification board across Europe is needed for developing criteria and assessments, and go further than the existing European Qualification framework. This will lead to a number of programmes such as a European Graduate School, a European Industrial PhD Programme and a European School of Continued Education. All programmes have built-in mandatory mobility schemes. The Flexible Learning System will provide a structured approach to accommodating European networking and cross-disciplinary collaboration on real-life innovation projects. The unique integration of ICT, physical facilities, and a hands-on approach to entrepreneurship and innovation provides a stimulating framework, which mirrors the non-linear learning characterising students today. The flexibility of the system refers to the use of blended learning tools tailored to accommodate individualised learning in interactive learning modules. Modules are developed in accordance with shared quality standards and will be open for partners to use. The flexibility also refers to the strong involvement of industry in learning modules

and activities. This involvement will create a maximum of relevance for industry while providing students with the opportunity to work with real-life innovation challenges and cases.

International cooperation is a compulsory attribute of nuclear E&T[8], especially at the European level. All national nuclear E&T programmes have links with the international partners at least on the level of students' exchange. These exchanges have a long-term positive aspect as they allow those people who will work in the nuclear field in the future to meet during their studies. Sharing of training facilities and resources brings significant improvement.

The need to keep European R&D on a high level is generally recognized. That was also a conclusion of Symposium on "Benefits and Limitations of nuclear fission for a low-carbon economy"[77]: '*…any nuclear future for Europe must be underpinned by top quality research and development, to ensure that the highest possible public and environmental safety standards are maintained*'. The European Union's Horizon 2020 programme[5] for investment in research and innovation, adopted on 3 December 2013 by the Council of the EU, funds a number of nuclear energy activities and among them - a specific programme for Euratom research and training with a total budget of Euro 1603 million (without ITER).[10] Within its work package "Support the development of nuclear competences at Union level and socio-economic aspects" of spesial interest for nuclear E&T are:
NFRP 10 – 2014 Education and training (Bologna and Copenhagen processes)- 4 mil
NFRP 12 – 2014 Nuclear developments and interaction with society- 2,5 mil
NFRP 13 – 2015 Fostering the network of National Contact Points – 0,4 mil
NFRP 14 – 2014 Regional initiative aiming at nuclear research and training capacity building – 2 mil.
Research efficiency and cooperation under Euratom increased due to the introduction of the technology platforms (SNETP, ESNII, Nugenia, IGD-TP), Melodi association and networks of excellence. Each of them has cooperation on E&T among its objectives and will play an important role in the implementation of Horizon 2020.

Collaboration of E&T providers with industry at all levels is another trend common to the most EU countries. Its aim is to ensure that the most appropriate qualifications, standards, training programmes and other initiatives are in place and that they meet the real needs of the industry. Business companies in the nuclear industry are part of the market, their business planning and approach to recruitment, retention and workforce development is affected by many external drivers, such as government policies concerning nuclear, skills, education, regulator's requirements, international developments, etc., even to the greater extent than the policies of predominantly public funded educational institutions. This awareness of interdependency of nuclear industry and E&T institutions is in the foundations of new strategies and initiatives, regardless of whether they are adopted with the state support or independently.

Industry-academia cooperation is a necessity, as it is very difficult to have practical training without access to the facilities which are mostly of industrial scale and therefore unaffordable for a university (see, however, the thermal loop facility at LUT in Finland and the Dalton Cumbrian Facility at Dalton Nuclear Institute of Manchester University). In many countries there are not enough places available for internships in nuclear sector. There are few training reactors in the world and some of these have just been closed, but efforts are being made to counter this problem in Europe. According to the European Strategy Forum on Research Infrastructures (ESFRI) strategy document[11], '*in the field of nuclear fission, the need for further experimental reactors has been identified.*' Construction of a new training reactor is being considered in Sweden. Many professionals agree that building of their own research reactor can be a very good first step into nuclear industry for the countries which are new to it. Educational and training programmes in many MSs are already coupled to Europe's best research facilities, including national research infrastructures, research institutes' laboratories, industrial technology testing and demonstration facilities. Such cooperation

frameworks with research and industrial infrastructures enhance the overall quality of the E&T system and facilitate innovation developments.

Virtual nuclear reactor development is another interesting effort to make electronic training resources available to everybody (CZ, ES). A distance on-line training on a real reactor operation, developed by the INSTN, FR, is broadcasted via internet to guest institutions, where a real-time display of the reactor's control room is visible for the trainees. The learners can interact with INSTN's on-site personnel via video conference to "conduct experiments" by asking the operators to modify the configuration and observing the real-time reactor changes. In many cases preparing of the e-learning material is left to the responsibility of the teacher, while in other instances audiovisual material for the programmes is prepared by a centralised team, skilled in providing technical support to different types of courses. This appears to be advantageous both in terms of technical quality of the material, as well as allowing the teacher more time for the preparation of the actual work. The majority of the courses in nuclear, as in other scientific fields, are of hybrid or blended type. A part of the course has to be studied at the training provider premises, where labs, models, experimental facilities are situated. Creation of a centralised information source on nuclear education and training courses, a web based platform (NWBP) with publicly available nuclear engineering lectures, education and training materials, supporting documents, books, webinars, etc., is one of the recommendations given in SET-Plan Education and Training Initiative (WG Nuclear Energy) report.[90]

Enhancing nuclear education attractiveness for a young generation is another important task for the nuclear community. Current enrolment of students, having had a nuclear energy related subject, covers only up to 70% of the demand.[51] The challenge is pretty similar in all MSs. This is due to the fact that today young people from different European countries are very much more alike, than before. And this Millennial Generation has a different perception and way of doing things than generation whose task is to introduce them to the nuclear knowledge and teach them nuclear skills. The nuclear sector's message to this generation first of all must be credible and honest. Research shows that many young people are not willing to work for the industry regarded as having negative impact on the environment. But the awareness of issues such as CO2 emissions and climate change, the concept of sustainable development and the need for security of supply is increasing. Due to the European uncertainty about the future of nuclear programmes many are not convinced that this career is a secure choice. They have to be shown that there are new technological challenges in nuclear field, including plant life extension, safety and research into ageing issues, decommissioning and waste management. Young generation wants to do something important for the world and they want to do it soon, but career growth in nuclear is slow in comparison with other industries/fields. It takes at least 3 years to develop basic operating competences, and another 10 – to reach a mid-level position, when the employee can finally be given responsibility to run the project. Whereas in other businesses young people manage the projects in their late 20s. To accelerate the careers of its employees, EDF Group created "Campus EDF" and launched "Training Challenge" and "The People Development Programme" in all countries where the group is present. Within these programmes any employee may receive promotional diploma courses, allowing him/her grow professionally and access positions of greater responsibility. The fact that today fewer students are pursuing traditional STEM degrees, not just nuclear engineering and science, makes the problem even more urgent. These issues have to be addressed. Young Generation Network and similar organisations can be effective in persuading school and university students to think seriously about careers in science and technology generally and in nuclear science and technology in particular and should be supported.

It's also important to ensure students' time at university is interesting. Using only traditional methods of learning is no longer sufficient, there has to be interaction between lecturers and

students. Spain, Sweden and UK, for example, demonstrate good progress in attracting good students to the nuclear courses. Aware of the fact that new technologies are a magnet for young people, Tecnatom, ES, has developed new training applications, which can be connected to full scope simulators. In addition the ability to run training scenarios on any display devices appears to be a motivating tool for young engineers. Inspiring young people to study nuclear science and engineering requires, in addition to the highest quality of teaching, offering an international perspective for innovative developments. And this is where the EC, European initiatives and research projects play an important role.

Excellent background of future nuclear graduates in basic sciences and avoiding specialization on too early stages is beneficial for both parties – students, because it leaves them with the wide choice and they do not feel trapped in the nuclear industry; and nuclear industry, because fundamental sciences are absolutely crucial in the training of efficient and adaptable engineers and managers. Industrial companies today are not satisfied with the graduates specializing at the cost of adaptability and vision. The "Ingénierie Physique des Énergies" Master's degree course at Paris-Diderot University aims to attract physicists to engineering positions in the field of energy. Strong core curriculum allows to address the issues of a power plant, so the future engineers will be able to adjust to any kind of production activity, with further specialisation in one of the currently growing areas (wind energy, solar energy, etc.) or nuclear energy. This flexibility is seen by the students as a real asset, as well as is the social and human sciences approach. Nuclear specialists must be able to put energy issues into context, including their environmental or political dimension. The challenge is to ensure that university educated nuclear engineers have the skills suitable to a commercial environment (example – nuclear law course, FR), as well as that the nuclear industry is able to attract non-engineers and non-scientists (e.g. new social and human sciences Master's degree "Energy, Ecology and Society", starting in September 2014 in Paris-Diderot University).

Several countries and organisations put a lot of efforts in the development of tools and instruments which can help to assess, validate and forecast their training needs in nuclear and radiation safety. The purpose of the measures taken by the National Skills Academy for Nuclear, UK, is that competences and training are recorded on a Skills Passport, common and accepted by all nuclear employers, enabling a greater flexibility of the workforce across the sectors and individual employers. Some interest has already been expressed by the European Nuclear Education Network (ENEN) and other forums about this concept being rolled out on a pan-European basis.

Special attention has to be further dedicated to building competences and high-level expertise in radiological protection, safety and security, decommissioning and waste disposal, reinforcement regulation and legal control. European Commission is funding a European Master course in radiobiology, when about 15 students per year follow courses in 5 specialised centres throughout Europe. Within the European Radiation Protection Education and Training (ERPET) framework, the European Commission has funded for almost a decade now several tens of training courses for professionals in different areas of radiation protection such as emergency management, medical applications, dosimetry and radiation-ecology.

To what extend the EC has to be involved and have an influence on the national strategy for the retaining competences in the nuclear and radiation safety? What is the right correlation between the measures at the European and national levels? Nuclear safety and therefore the quality of the nuclear workforce can be considered only in a European context. The long-term common European strategy on nuclear E&T and common instruments for its implementation allow consolidation of the efforts of all interested stakeholders. '*It is now time for all the governments of Europe to agree what the European Commission has been proposing for some years. It is to have a truly European energy policy,* '- said the EC President Barroso on the June European Council, 2014.[17]

7.2 Recommendations

The current state of the nuclear workforce's supply and demand gives this issue very high priority on national and European political and technical agendas. Education and training systems in nuclear safety, as well as nuclear policies, differ significantly in the EU Member States. This makes the efforts to retain key competences in nuclear safety especially challenging. To address the challenge a long-term nuclear energy education and training strategy has to be adopted on the national and European levels. Such strategy has to provide a clear legal and physical framework - basis for the development of detailed plans and actions. It has to be developed by the competent body designated by the national government and facilitated by the regulator-academia-industry-research fora.

Strategy is a plan of actions. To develop a plan the objectives have to be identified. That has been done in many studies and legal documents, dedicated to the situation in education and training in the nuclear energy field in the European Union. The remaining questions are – By what means and on which level? How already existing measures, organisations, practices can be put together and fulfilled with new initiatives to form a well coordinated system to implement these objectives?

The goal of this chapter is, based on the analysis of the existing and planned best practices in European and national nuclear E&T systems, to propose the actions and to outline possible ways of implementation of the future strategy. Following conclusions and recommendations are based on many sources, namely - SET-plan Roadmap on Education and Training[90, 93], EC Situational Reports on E&T in te nuclear energy field in te EU[1], materials of interdisciplinary symposium on HORIZON 2020[77], SNETP recommendations[60], conclusions of the WS on retaining nuclear competences, organised by I2EN, Action plans of the UK NSA for Nuclear and Cogent SSC [70], interviews with experts.

- <u>EU common energy policy</u> is necessary in order to face a double challenge – energy security and 2030 climate targets – and as a basis for the structured developments in all areas, which have to do with its implementation. '*Government interventions that affect this market framework* (internal market for energy)*, such as national decisions on renewable energy or efficiency targets, decisions to support investment in (or decommissioning of) nuclear generation, or decisions to support key infrastructure projects need to be discussed at European and/or regional level to ensure that decisions in one Member State do not undermine security of supply in another Member State. A real European Energy Security Strategy requires that enforcement tools are preceded by a strategic discussion at EU level, not just at national level.*'[6]

    - National laws and regulations and Euratom directives should play more important role in the organisation of nuclear E&T;
    - future funding efforts in nuclear E&T should be policy driven. In addition to Euratom funds, innovative financing instruments such as loan guarantees, EIB credits and structural funds, could support E&T strategies;
    - setting up '*a common education and training fund jointly managed by the European Commission and Member States and financed by a mandatory levy on nuclear generators based on nuclear MWh produced*' (D'Haeseleer)[77].

- <u>Strategic role of governments:</u>

    - foster links between the nuclear industry and national government;
    - put the issue of availability of nuclear workforce on the political agenda's on national and European levels;

- promote long-term comprehensive national strategy against incidental or individual approaches[77];
- support students and provide adequate financial resources for nuclear R&D programmes.

- Reinforcement of the organisational mechanisms, harmonisation of regulations by further involvement of the European Nuclear Safety Regulators Group (ENSREG), Multidisciplinary European Low Dose Initiative (MELODI), te association of the Heads of European Radiological Protection Competent Authorities (HERCA), as well as the existing nuclear industry platforms – SNETP, ESNII, Nugenia, IGD-TP.

- Development and enhancement of a common nuclear safety culture, harmonisation of regulations across the EU.

- Promote nuclear as a career choice. Enhance sector attractiveness:

    - enhance visibility of nuclear industry, show its breadth and opportunities, including international;
    - inform about the opportunities for nuclear education and training at European level;
    - enhance the attractiveness of nuclear education programmes to foreign talent[93];
    - create and implement for each employee career development plan;
    - increase scholarships for the students, choosing nuclear degrees at the universities;
    - support the Yong Generation Network and similar.

- Forecast of the workforce supply/demand, analyse resources and needs of society and industry and identify gaps in knowledge, skills and competences in nuclear sector:

    - develop credible labour market intelligence to be able to project skills gaps;
    - quntify the imbalance in supply vs. demand of nuclear specialists per areas;
    - define in cooperation critical areas of nuclear competence;
    - cover in the surveys also socioeconomic and managerial skills gaps in nuclear sector[77];
    - regularly perform national and European labour markets surveys. EHRO-N has to play a leading role in these.

- Address gaps in KSC:
    - encourage new entrants to the nuclear sector, including the intake and re-training of the employees from other industries, offer a well-structured spectrum of "entry points" for people with a different educational or professional background;
    - explore the possible synergies and cooperation on E&T with other energy sectors;
    - identify and improve E&T in the areas with potential and actual skills shortage;
    - establish a flexible framework, which allows quick upgrade, optimisation of current or development of new curricula, teaching materials and methods, and their dissemination and integration by the educational institutions;

- facilitate the development of joint education and training programmes among different academic institutions, encourage the establishment of centres of excellence in specific universities with the necessary critical mass of expertise[77];
- encourage the acquirement of solid background in basic sciences (by avoiding too early specialization), human and social sciences;
- develop a programme of training for professors and lecturers in fields where expertise is scarce;
- promote innovative approaches to teaching and learning, including apprenticeships, internships, hands-on training, e-learning, etc.;
- ensure that all stakeholders within the nuclear industry and its supply chain are aware of the education and training opportunities available on national and international levels.

Virtual learning

- encourage virtual learning, especially for multidisciplinary education, by providing high quality digital courses, development of new approaches, including design of "intelligent games"[22];
- facilitate e-learning in the areas where expertise is available at relatively few universities or training centres;
- provide access via distance learning to remote research infrastructures, test facilities, data banks, and other valuable elements of education and training;
- develop and provide access to new databases, containing valuable learning materials;
- create a centralised publicly available information source on nulear education and training courses [93];
- develop quality assurance methods and increase comparability of e-learning and traditional courses.

- Reinforce the <u>collaboration between education and training providers, industry & research institutions</u>:
  - prepare the mechanism, which ensures industry leadership at the level of decision making;
  - encourage early contact between students and industry;
  - support the existing and encourage development of new fora and partnerships for relevant nuclear stakeholders from academia, research and industry;
  - facilitate mobility, practical experience and knowledge exchange for business/research and teaching staff, create conditions for business and research staff to teach at higher education and training institutions;
  - increase the interaction and mobility between research institutions and higher education institutions across Europe via joint research projects and programmes;
  - stimulate high-quality fundamental and applied scientific research at the universities.

- Facilitate access for education and training purposes to research <u>infrastructure facilities:</u>
  - establish necessary agreements to provide access to students and teaching staff to national research infrastructures;
  - create conditions providing access to learners to large international nuclear facilities in the nuclear fission and fusion energy field, including Generation IV experimental reactors and demonstrators for nuclear fission, e.g. MYRRHA

(Multipurpose hYbrid Research Reactor for High-technology Applications), JHR (Jules Horowitz Reactor Infrastructure); JET (Joint European Torus) and ITER (International Thermonuclear Experimental Reactor), IFMIF (International Fusion Materials Irradiation Facility) and others;

- cooperate with the European Strategy Forum on Research Infrastructures.

- Identify the ways to transfer radiological protection techniques and knowledge about the low-dose effects from the nuclear energy community to the applications in other industrial areas (medicine, environmental protection, water use, etc.) and promote creation of joint programmes.

- Enable mutual recognition through common instruments and techniques for lifelong learning and cross-border mobility of nuclear professionals:
    - establish the European certification/accreditation body in NES

KSC & Qualifications. Training standards

- ensure a common understanding on the definitions of knowledge, skill and competence;
- develop and widely use tools and techniques that support the achievement and demonstration of competence;
- ensure clear routes between vocational education and training and higher education through the use of learning outcomes for defining and describing qualifications and consistent application of EQF levels;
- strengthen mutual recognition of qualifications;
- introduce mechanisms for quality assurance, which involves reviews and regular feedback from relevant stakeholders, develop mechanisms to assist the deployment of common training standards;
- capture all forms of formal and informal learning and reflect it in the standards;
- take account of the qualifications and training standards developed for other industries to enable transferability of KSC;
- introduce compulsory accreditation of training providers;
- establish and maintain national networks of quality training providers.

Implementation of ECVET. Nuclear Job Taxonomy

- accelerate the process of ECVET implementation in nuclear sector at the national level;
- encourage transnational mobility via Erasmus and Marie Curie type programmes;
- create commonly recognized and shared job taxonomy as portfolios of learning outcomes;
- establish network of National bodies in charge of certification of learning outcomes [93];
- support the establishment of a community of practice on ECVET implementation in nuclear sector;
- implement nuclear ECVET pilot project;
- establish EHRO-N National Contact points in the MSs, closely connected with the existing Euratom National Contact Points.[90]

- International collaboration is to be further enhanced.

- Establish European Nuclear Sector Education & Training Council in synergy with EHRO-

N.[90] Its aim will be '*to carry out strategic analyses of gaps and shortages on a continuous basis, to provide innovative paths to improve flexibility of the sector workforces and improve learning outcomes and training supply.'* Among its main tasks:

- facilitate services related to job qualifications that are based on portfolios of learning outcomes in view of their recognition across the EU in close cooperation with national and international E&T institutions concerned with assessment, quality assurance, validation, certification and recognition of the proposed portfolios in accordance with the ECVET guidelines;
- carry out detailed gap analysis in nuclear energy at all stages of the nuclear fuel cycle, including future needs of educators and trainers;
- create synergies with relevant sector skill alliances or other industry-academia partnerships at EU level;
- develop coordination with other energy sectors.

- Public involvement. Rebuilding of public confidence. '*The development of societal awareness, through outreach to opinion leaders and policymakers*': [77]

    - develop a platform, which can help to inspire public confidence in the high level of skills of the workforce in the nuclear industry.

Continuous monitoring of the challenges and the ways of addressing them by already existing or planned initiatives has to be further endorsed by the European Commission. This is to ensure timely actions to cover identified gaps and a better coordination of initiatives to maximise their effectiveness.

References

1 Commission Staff Working Document – 2nd Situation report on education and training in the nuclear energy field in the European Union, SWD(2014)299
2 Communication from the Commission - Innovation Union - Turning ideas into jobs, green growth and social progress, COM(2010) 546
3 Communication from the Commission – Towards a resource-efficient, low-carbon economy, COM(2011) 21
4 Communication from the Commission - Rethinking Education: Investing in skills for better socio-economic outcomes, COM(2012)669/3
5 Horizon – 2010 RTD Framework Programme (2014-2020) http://ec.Europa.eu/programmes/horizon2020/en/
6 Communication from the Commission - European Energy Security Strategy, COM(2014)330
7 Treaty establishing the European Atomic Energy Community. Rome, 1957
8 Communication from the Commission - A Reinforced European Research Area Partnership for Excellence and Growth, COM(2012) 392
9 Communication for a policy framework for climate and energy in the period from 2020 to 2030, COM(2014)15
10 Euratom Work Programme 2014 – 2015. European Commission C(2013)8563
11 Prioritisation of Support to ESFRI Projects for Implementation, ESFRI, 2014: http://ec.europa.eu/research/infrastructures/pdf/ESFRI_projects_for_impl_7_april_2014.pdf #view=fit&pagemode=none
12 EU Energy Roadmap 2050, COM(2011) 885
13 Council Directive 2014/87/EURATOM amending Directive 2009/71/EURATOM establishing a Community framework for the nuclear safety of nuclear installations
14 Europe 2020 strategy for Smart, Sustainable and Inclusive Growth: http://ec.Europa.eu/Europe2020/index_en.htm
15 «Erasmus +» programme (DG EAC) - http://ec.Europa.eu/programmes/erasmus-plus/index_en.htm
16 Recommendation of the European Parliament and of the Council of 18 June 2009 on the establishment of a European Credit System for Vocational Education and Training (ECVET) - 2009/C 155/02
17 Speech by President Barroso on the June European Council. European Parliament plenary session. Strasbourg, 2 July 2014
18 Council Directive 2011/70/EURATOM establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste
19 Council Directive laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, COM(2012)242
20 Council Directive 2009/71/EURATOM of 25 June 2009 establishing a Community framework for the nuclear safety of nuclear installations
21 Council recommendation of 20 December 2012 on the validation of non-formal and informal learning. Official Journal of the European Union, C 398, 22.12.2012, pp. 1-5.
22 Opinion of the European Economic and Social Committee on energy education. CESE 1054/2012 - TEN/474, 2012
23 International Atomic Energy Agency, Managing Human Resources in the Field of Nuclear Energy, IAEA Nuclear Energy Series No. NG-G-2.1, IAEA, 2009
24 International Atomic Energy Agency, Status and Trends in Nuclear Education, No. NG-T.6.1, IAEA, 2011
25 International Atomic Energy Agency, A systematic approach to human performance

improvement in nuclear power plants: Training solutions, IAEA-TECDOC-1204, IAEA, 2001
26 International Atomic Energy Agency, Organisation and Staffing of the Regulatory Body for Nuclear Facilities, IAEA Safety Standards Series No. GS-G-1.1, IAEA, 2002
27 International Atomic Energy Agency, Commissioning of Nuclear Power Plants: Training and Human Resource Considerations, IAEA Nuclear Energy Series No. NG-T-2.2, IAEA, 2008
28 International Atomic Energy Agency, Knowledge Management for Nuclear Industry Operating Organisations, IAEA-TECDOC-1510, IAEA, 2006
29 International Atomic Energy Agency, Human Resource Issues Related to Expanding a Nuclear Power Programme, IAEA-TECDOC-1501, IAEA, 2006
30 International Atomic Energy Agency, Risk Management of Knowledge Loss in Nuclear Industry Organisations, STI/PUB/1248, IAEA, 2006
31 International Atomic Energy Agency, The nuclear power industry's ageing workforce: Transfer of knowledge to the next generation, 2004
32 International Atomic Energy Agency, Managing nuclear knowledge: strategies and human resource development. Summary of the international conference, 2006
33 International Atomic Energy Agency, Knowledge Management for Nuclear Industry Operating Organisations, 2006a
34 International Atomic Energy Agency, Risk Management of Knowledge Loss in Nuclear Industry Organisations, IAEA, 2006
35 International Atomic Energy Agency International conference on knowledge management in nuclear facilities, 2007
36 International Atomic Energy Agency Workforce planning for new nuclear power programmes. IAEA Nuclear energy series. NG-T-3.10, 2011
37 Nuclear Education and Training: Cause for Concern? NEA, OECD, 2000
38 Nuclear Safety Research in OECD countries. Major Facilities and Programmes at Risk, NEA Committee on the Safety of Nuclear Installations, OECD, 2001
39 Nuclear Competence Building, NEA, OECD, 2004
40 Assuring Future Nuclear Safety Competences. Specific Actions, NEA, OECD, 2001
41 Nuclear Education and Training: From Concern to Capability, NEA, OECD, 2012
42 ENS News Special edition on education and training: INTRO, ENS, e-news Issue 31, 2011
43 World Nuclear Association, Public Information Service, Country Briefings
44 Palmu, M., Avolahti, J.M., Hutri, K-L., Markovaara-Koivisto, M., Collaborative training development in nuclear waste management in Finland, NesTet 2013, ENS Conference, Madrid, 17-21 November 2013
45 Salomaa, R., Ala-Hekkila, J., Tuomisto, F., Kyrki-Rajamaki,.R., Palmu, M., Higher level academic nuclear engineering education in Finland – need of post graduates? NesTet 2013, ENS Conference, Madrid, 17-21 November 2013
46 Cogent. A Skills Needs Assessment of the Nuclear Industry. http://www.nuclearliaison.com/pdfs/Cogent_A_Skills_Needs_Assessment_2005.pdf
47 Cummings, J., Teng, B., Transferring R&D knowledge: the key factors affecting knowledge transfer success. Journal of engineering and technology management. 2003, 20, pp. 39-68.
48 Goodfellow, M., Williams, H., Azapagic, A., Nuclear renaissance, public perception and design criteria: An exploratory view. Energy Policy. 2011, 39 pp. 6199-6210
49 Nuclear Industry Association, Education, Skills and Training, 2012 http://www.niauk.org/education-skills-training
50 Safieh, J., De Regge, P., Kusumi, R. ENEN's approaches and initiatives for nuclear education and training. Nuclear Engineering and Design. 2011, 241, pp.3530-3539.
51 Simonovska, V., von Estorff, U., Putting into perspective the supply of and demand for nuclear experts by 2020 within the EU-27 nuclear energy sector. EC. JRC. Institute for Energy and Transport, 2012

52 Chenel Ramos, C., The Preparation of an ECVET-oriented Nuclear Job Taxonomy: Concept and Progress Report, EC. JRC. Institute for Energy and Transport, 2012
53 Lacal Molina, M. A., von Estorff, U., Mapping of Nuclear Education Possibilities and Nuclear Stakeholders in the EU-27, EC. JRC. Institute for Energy and Transport, 2012
54 Braček Lalić, A., Simonovska, V., von Estorff, U., The concept of internationalisation and the inevitability of mobility of highly skilled employees, EC. JRC. Institute for Energy and Transport, 2012
55 Roelofs, F., von Estorff, U., Top-down workforce demand extrapolation from nuclear energy scenarios, EC. JRC. Institute for Energy and Transport, 2013
56 Ceclan, M., Chenel Ramos, C., Towards the implementation of the European Credit System for Vocational Education and Training (ECVET) in the nuclear energy sector, EC. JRC. Institute for Energy and Transport, 2013
57 Fernandez Lopez, M.A., Barboni, M., Distance learning courses in engineering in the EU-27, EC. JRC. Institute for Energy and Transport, 2013
58 Nuclear Fission. Reactor Safety Research in FP7 and future perspectives. European Commission, DG Research & Innovation, 2014
59 Education and Training in Euratom Research in FP7 and future perspectives. European Commission, DG Research & Innovation, 2014
60 Nuclear education and training. Key elements of a sustainable European startegy, SNETP WG on Education, training and knowledge management, 2010
61 Euratom FP7 Research & Training Projects, Vol.2, 2010, ISBN 978-92-79-15516-1, p.38-43
62 The Nuclear Energy Skills Alliance. Next generation: skills for new build nuclear. Renaissance nuclear skills series: 2, Cogent, 2010
63 Kyrki-Rajamäki, R., Koskinen, K., Finnish solution to increased basic professional training needs in nuclear safety, European Nuclear Society, 2008
64 Blomgren, J., Education for the Nuclear Power Industry – Swedish Perspective, European Nuclear Society, 2008
65 Cogent – Power People – The Civil Nuclear Workforce 2009 – 2025, 2009
66 Cogent – Next Generation – Skills for new build nuclear, 2010
67 Cogent – Standards and Qualifications Prospectus, 2014
68 Long-Term Nuclear Energy Strategy, Department of Energy and Climate Change, March 2013: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/168047/bis-13-630-long-term-nuclear-energy-strategy.pdf
69 Capability Model for the UK Nuclear Industry, The National Skills Academy for Nuclear, 2013
70 Nuclear Energy Skills Alliance annual review 2012/2013
71 Spanish Capabilities to face a new nuclear project. CEIDEN, 2011
72 Delgado, J. L., González, J. I., Camarero, J. M.,Training capabilities analysis of the Spanish nuclear industry. CEIDEN, 2012
73 Rey, P., Rivero, N., Gil, E., The Fukushima accident impact on simulation training tools. Tecnatom, 2013
74 Report of the Committee for Nuclear Energy Competence in Finland. Publications of the Ministry of Employment and the Economy, Energy and the Climate, ISBN 978-952-227-599-8, 2012
75 SKC. Annual Report 2013, 2014
76 Wenzel, H., Yliknuussi, N., Hilden, W., Nuclear safety in a situation of Fading Nuclear Experience. Final Report of the Project. EC, DG for Energy and Transport, 2009
77 2012 Interdisciplinary Study. Benefits and Limitations of Nuclear Fission for a Low-Carbon Economy. Synthesis report. Compilation of the experts'reports Background to the synthesis report. Symposium Proceedings, 2013, ISBN 978-92-79-29833-2
78 Phasing out nuclear power safely. Why Germany needs nuclear expertise for decommissioning, reactor safety, ultimate disposal and radiation protection. Acatech's Position Paper, 2011

79 Research for an environmentally sound, reliable and affordable energy supply. 6th Energy Research Programme of the Federal Government, Federal Ministry of Economics and Technology (BMWi), 2011, Berlin: www.bmwi.de
80 Using ECVET for geographical mobility: part II of the ECVET users' guide. Cedefop, 2011
81 Using learning outcomes: European qualifications framework series: Cedefop 2012, Note 4
82 Monitoring ECVET implementation strategies in Europe, Working paper No 18, Cedefop, 2013
83 ECVET for the nuclear sector, ECVET seminar for the Nuclear Energy World, Brussels, 25-26 September 2012
84 Vocational education and training at higher qualification levels. Research paper, No 15, Cedefop, 2011
85 Coeck, M., Sustaining nuclear knowledge through SCK-CEN's Academy for nuclear science and technology, ENC 2012, 9-12 December 2012, Manchester
86 Berkvens, T., Coeck, M., Maintaining a high quality nuclear engineering programme: future challenges for the Belgian Nuclear higher Education Network, ENC 2012, 9-12 December 2012, Manchester
87 Barbalat, C., Figuet, J., Guet, C., Debreuille, M.-F., The importance of knowledge management sustaining a full education & training system all over the career of nuclear engineers. ENC 2012, 9-12 December 2012, Manchester
88 Van Goethem, G., From Knowledge Transfer to Competence Building in Euratom : DG RTD efforts to support and implement ECVET in the nuclear sector, ECVET Seminar for the Nuclear Energy Sector, 25-26 September 2012, Brussels
89 SET-Plan European Energy Education and Training Initiative. WG Nuclear Energy. Final Assessment Report, 2012
90 Strategic Energy Technology (SET) Plan Roadmap on Education and Training. JRC Coordination: A. Georgakaki, U. von Estorff, S.D. Peteves. European Commission. Joint Research Centre. Institute for Energy and Transport, ISBN 978-92-79-36377-1, 2014
91 SNETP. A Vision Report, EC, DG for Research, 2007
92 Proceedings NesTet 2013. ENS Conference. Nuclear Education and Training, ISBN 978-92-95064-19-5, 2013
93 Strategic Energy Technology (SET) Plan Study on Energy Education and Training in Europe. Assessment Reports of the Working Groups. JRC Coordination: A. Georgakaki, U. von Estorff, S.D. Peteves. European Commission. Joint Research Centre. Institute for Energy and Transport, 2014
94 Ceclan, M., von Estorff, U., The JRC road map for ECVET implementation in the nuclear energy sector, ECVET Magazine, June 2014, Bruxelles
95 Van Goethem, G., Synergy between nuclear research, innovation and education in Euratom programmes, with emphasis on safety culture. European Journal of Medical Physics. 2014, 30, Supplemet 1, p.e12

Websites

Nuclear energy skills alliance – DECC: www.decc.gov.uk/en/content/cms/meeting_energy /nuclear/new/supply_skills/nesa/nesa.aspx
The National Skills Academy for Nuclear: www.nuclear.nsacademy.co.uk
Cogent: www.Cogent-ssc.com
Office for Nuclear Development: www.decc.gov.uk/en/content/cms/meeting_energy/nuclear/ new/office/office.aspx
SNE-TP: "Sustainable Nuclear Energy Technology Platform" - http://www.snetp.eu/
IGD-TP: "Implementing Geological Disposal of Radwaste TP" - http://www.igdtp.eu/
ENEF: "European Nuclear Forum Energy" -
http://ec.Europa.eu/energy/nuclear/forum/forum_en.htm
NUGENIA: NUclear GENeration II & III Association - http://www.nugenia.org/

NERIS: “European Platform on Preparedness for Nuclear and Radiological Emergency Response and Recovery” http://www.eu-neris.net/
EurADOS: European Radiation Dosimetry Group in medical and industrial applications http://www.Eurados.org/en
ENSREG: “European Nuclear Safety Regulators Group” http://ec.Europa.eu/energy/nuclear/ensreg/ensreg_en.htm
WENRA: Western European Nuclear Regulators Association/ - http://www.wenra.org/
HERCA: “Heads of European Radiological protection Competent Authorities Association” http://www.herca.org/index.asp
MELODI: "Multidisciplinary European Low Dose Initiative" - http://www.melodi-online.eu/
EHRO-N: http://ehron.jrc.ec.Europa.eu/
European Nuclear Education Network (ENEN): http://www.enen-assoc.org
ECVET: http://ec.europa.eu/education/lifelong-learningpolicy/ecvet_en.htm
EQF: http://ec.europa.eu/eqf
EQF: http://ec.europa.eu/education/lifelong-learningpolicy/eqf_en.htm
Cedefop: http://www.cedefop.europa.eu/EN/understandingqualifications/index.aspx
Education, Audiovisual and Culture Executive Agency (EACEA): http://eacea.ec.europa.eu
ECVET pilot projects: http://www.ecvet-projects.eu
FP7 projects, ENEN: http://www.enen-assoc.org/en/training/for-nuclear-community/efts-fp7.html
ENETRAP: http://enetrap2.sckcen.be/
TRANUSAFE: http://www.trasnusafe.eu/
CINCH: http://www.cinch-project.eu/
CORONA: http://www.cvrez.cz/en/trainings-education/projects/corona/
SETIS: http://setis.ec.europa
European Foundation for the energies of tomorrow http://www.energiesdedemain.com/
I2EN: www.i2en.fr
International WS, Paris, I2EN: http://nkm2012paris.wordpress.com/about/
NIA: http://www.nuclearsupplychain.com/skills-education-and-training
Career Pathways http://www.career-pathways.com/
Nuclear Skills Passport http://www.nuclearskillspassport.co.uk/
National Skills Academy for Nuclear https://www.nsan.co.uk/
Nuclear AMRC http://namrc.co.uk/
Idaho National Laboratory https://inlportal.inl.gov/portal/server.pt/community/home/255
AMEC http://www.amec.com/

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