Ref. Ares(2017)1227443 - 08/03/2017

HORIZON 2020
The EU Framework Programme for Research and Innovation

Grant Agreement Number: 661910
H2020 – NFRP-2014-2015

ANNETTE PROJECT

Advanced Networking for Nuclear Education and Training and Transfer of Expertise

DELIVERABLE D 6.1
Competence Needs with Respect to Nuclearization of Fusion

Nature of the deliverable		
R	Report	X
P	Prototype	
D	Demonstration	
O	Other	

Author(s) Christian Schoenfelder

Date of issue: 31/12/2016 1st Reporting Period

Start date of project: **01/02/2016** Duration: **48** Months

Project co-funded by the European Commission under the Euratom Research and Training Programme on Nuclear Energy within the H2020 Programme, Call NRFP 2014-2015		
Dissemination Level		
PU	Public	Yes
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the partners of the ANNETTE project	
CO	Confidential, only for partners of the ANNETTE project	

DISTRIBUTION LIST

URL: http://www.enen-assoc.org/en/training/annette.html

Name	Number of copies	Comments
European Commission	Electronic copy via email	
All Partners	Electronic copy via website	

Scope	ANNETTE / WP 6	Version:	1
Type/No.	Deliverable Report 6.1	Total pages	30
Title:	Competence Needs with respect to Nuclearization of Fusion	Chapters:	7
Access:	Restricted	Appendices:	2
Filename:	ANNETTE deliverable 6.1 Competence Needs.PDF	Suppl. pages:	0
Internet	http://www.enen-assoc.org/en/training/annette.html		

RESPONSIBLE BENEFICIARY: ENEN Association

DOCUMENT TRACKING

	Name	Follow-up Email to Coordinator	Date
Prepared by	Christian Schoenfelder	Yes	31/12/2016
Reviewed by Referee(s)	Project partners	Yes Yes	31/12/2016
Quality assurance (QA leader)		Yes	
Approved by Coordinator	Pedro Diéguez Porras	Yes	… /2016

ABSTRACT:

This report deals with the specific competence needs for the transition of fusion to a nuclear technology, thereby providing the important input for the next sub-tasks within WP6. In particular, directions for development of nuclear competences of the fusion work force are presented.

TABLE OF CONTENTS

List of abbreviations

ANNETTE	Advanced Networking for Nuclear Education, Training and Transfer of Expertise
ASME	American Society of Mechanical Engineers
CFD	Computational Fluid Dynamics
CPD	Continuous professional development
C&S	Codes and Standards
DG RTD	Directorate-General for Research & Innovation
DNA	Deoxyribo Nucleic Acid
ECTS	European Credit Transfer System
ECVET	European Credit System for Vocational Education and Training
EHRO-N	European Human Resources Observatory for the Nuclear Sector
ENEN	European Nuclear Education Network Association
EQF	European Qualifications Framework
FEM	Finite Element Method
FUSENET	European Fusion Education Network Association
HVAC	Heat, Ventilation and Air Conditioning
IAEA	International Atomic Energy Agency
I&C	Instrumentation and Control
IEEE	Institute of Electrical and Electronics Engineers
IFMIF	International Fusion Materials Irradiation Facility
IO	ITER Organization
ITER	International Thermal Experimental Reactor
JRC-IET	Joint Research Centre - Institute for Energy and Transport
KSA	Knowledge, skills and attitudes
LO	Learning outcome
LOCA	Loss Of Coolant Accident
MCNP	Monte Carlo N-Particle Transport Code
MELCOR	Engineering-level computer code to model the progression of severe accidents in nuclear power plants
NJT	Nuclear Job Taxonomy
NQF	National qualifications frameworks
NUSHARE	Project for Sharing and Growing Nuclear Safety Culture Competence[1]
PIA	Protection Important Activity
PIC	Protection Important Component
P&ID	Process and Instrumentation Diagrams
PIRT	Phenomena Identification and Ranking Table
PSA	Probabilistic Safety Analysis
RAMI	Reliability, Availability, Maintainability and Inspectability
RCC-M	Règles de conception et de construction des matériels mécaniques des ilôts nucléaires
RCC-MR	Règles de conception et de construction des matériels mécaniques des installations nucléaires hautes températures, expérimentales et de fusion
RELAP	Reactor Excursion and Leak Analysis Program
SAT	Systematic Approach to Training
TCWS	Tokamak Cooling Water System
VET	Vocational education and training

[1] See http://www.enen-assoc.org/en/training/nushare.html

1. INTRODUCTION

The ANNETTE Project (Advanced Networking for Nuclear Education and Training and Transfer of Expertise) is addressing the present situation of nuclear energy in Europe by a continuing effort in the field of education and training. The aim is to assure a qualified work force in the next decades, by consolidating and better exploiting the achievements already reached in the past and by tackling the present challenges in preparing the European workforce in the different nuclear areas. Special attention is paid to continuous professional development, life-long learning and cross border mobility.

Considering the attractiveness of fusion as a potential sustainable, low carbon source of electricity contributing effectively to a secure mix of different energy sources, the EU created a coherent, ambitious but pragmatic fusion program aiming, via a comprehensive, integrated science, technology and engineering program, to provide electricity to the grid by the middle of the 21^{st} century[2].

As noted in the roadmap to the realization of fusion energy (the Fusion Roadmap), the evolution of the fusion program requires a shift from "from pure research to designing, building and operating future facilities like ITER and DEMO. This transition requires strengthening the available engineering resources, with a marked change from non-nuclear to nuclear technologies, and has to be facilitated during Horizon 2020 by specific measures in support of training and education."

Through its Work Package 6 (WP6) the ANNETTE project addresses this particular challenge, dealing in particular with the transition from non-nuclear to nuclear technologies in fusion, as this will have an important impact on the work force active in fusion: the human resources involved in development, design and construction of fusion facilities must possess suitable nuclear related competences.

Relying on the existing initiatives and institutions in Europe that are providing education and training to build up nuclear (fission) related competences, and that have decided to cooperate within the ANNETTE project, the inclusion of WP6 within the ANNETTE project is an effective contribution to meeting one important objective of the Fusion Roadmap.

Consequently, the objectives of WP6 include

- To facilitate adaptation of existing education and training curricula to or the development of new curricula for the specific nuclear related competence needs of the work force in design and construction of fusion facilities (e.g. ITER, DEMO),
- To provide suitable training courses or other forms of informal or non-formal learning, thereby contributing to the Advanced European Program for CPD and the Summer School with specific courses on Fusion,
- To implement adapted or newly developed courses or other forms of learning,
- To assess the quality and effectiveness of the implemented courses or other forms of learning and discuss the possible means to ensure sustainability of these initiatives beyond the end of the project.

[2] See https://www.euro-fusion.org/eurofusion/the-road-to-fusion-electricity/

To achieve these objectives, WP6 is structured into four different sub-tasks:

- T6.1 Investigate and specify the specific competence needs for the transition of fusion to a nuclear technology
- T6.2 Design and development of fusion specific training addressing the competence needs as specified In T6.1
- T6.3 Implement and evaluate courses or other forms of learning as designed and developed in T6.2
- T6.4 Support the participation in nuclear training activities

This approach reflects a practical implementation of the Systematic Approach to Training (SAT), which was developed in the nuclear (fission) community under the guidance of the IAEA (see [1]).

The current report documents the results of sub-task T6.1, thereby providing the important input for the next sub-tasks within WP6.

2. PROCEDURE FOR IDENTIFICATION OF COMPETENCE NEEDS

In accordance with SAT, the first step to specify (or design) before starting to develop training is the identification of those competences that shall be imparted by the training, i.e. the competence needs. This is usually conducted either by a job and task analysis, or by a job competency analysis, as explained in detail in [2].

However, in the current case another approach is followed. Here, one should take into account the work already conducted by EHRO-N, the European Human Resources Observatory for the Nuclear Sector. One of its main objective is to implement the European Credit System for Vocational Education and Training (ECVET) in the nuclear energy sector in Europe. Hosted by the JRC-IET (Joint Research Centre - Institute for Energy and Transport), EHRO-N has published the results of its activities in multiple reports. Important to mention for WP6 is [3]: *Towards the implementation of the European Credit System for Vocational Education and Training (ECVET) in the nuclear energy sector*.

ECVET adopts an approach based on learning outcomes as key element for the definition and description of qualifications. Learning outcomes are defined in terms of competences and can be the result of a learning process of any nature, i.e. formal, non-formal, informal or incidental. Learning outcomes are synonymous to the concept of training objectives.

On its road to the implementation of ECVET, EHRO-N conducted several workshops to prepare a Nuclear Job Taxonomy (NJT), which should contribute to the objectives of EHRO-N by providing a harmonized and structured description of standard jobs. Currently the existing NJT (as documented in [3]) covers the jobs within the three life-cycle phases of a Nuclear Power Plant, i.e. New Build, Operation and Decommissioning.

In order to connect the labor market and its requirements on human resources to the education and training institutions, competence is the key concept. Therefore, its interpretation and explanation is the subject of a number of technical documents related to ECVET, but also in the technical documents developed by the IAEA in order to establish world wide a systematic approach to training, see e.g. [1] or [2]. In [3], competence denotes a holistic notion, encompassing cognitive, technical and behavioral aspects.

	Personal	Occupational
Conceptual	Meta-competence (facilitating learning)	Cognitive competence (knowledge)
Operational	Social competence (attitudes and behaviors)	Functional competence (skills)

Table 1 The competence components (from [3])

Table 1 The competence components (from [3]) illustrates the nature of competence's components. These components find a direct correlation with the definitions given by the European Qualifications Framework[3], leading to the following association:
Knowledge: Cognitive competence (occupational-conceptual)
Skill: Functional competence (occupational-operational)
Attitude: Personal competence (conceptual and operational)

[3] See e.g. http://www.cedefop.europa.eu/en/events-and-projects/projects/european-qualifications-framework-eqf

For EHRO-N, the development of a Nuclear Job Taxonomy (NJT) represented the first step for the creation of ECVET bricks, which shall be used as basic pieces for the construction of nuclear qualifications. In first place, it involved the identification of the jobs that are representative of the typical organization in a nuclear power plant.

During the different NJT related workshops the job profiles were developed by various experts from education and training institutes as well as from nuclear industry. Focus was laid in the exhaustive description of job requirements, defined in terms of knowledge, skills and attitudes, following the competence concept as described above. Additionally, the job profiles contained a (functional and occupational) categorization of the jobs, as well as a description of the areas of responsibility in terms of a list of tasks / functions associated with the job.

Based on the results achieved by EHRO-N during NJT development, the following approach will be taken in order to finally identify the specific nuclear related competence needs of the work force in design and construction of fusion facilities (e.g. ITER, DEMO):

1. Stakeholders that are active either in in design and construction (including manufacturing, qualification and licensing) of fusion facilities will be contacted and asked for their support,
2. So that based on their experiences job positions can be identified that require nuclear competences (to be illustrated by some job profiles taken from the NJT),
3. As well as tasks / functions that require nuclear competences,
4. So that finally the required nuclear competences in fusion projects and their links to job positions and tasks / functions can be specified.

Steps 2 to 4 have been undertaken in the format of a workshop, which was held on November 10th and 11th 2016 at the Eindhoven University of Technology. The results of this workshop are documented in the following chapters 3 to 6, and are based on written input from participants, but also on results of the discussions performed during the workshop.

Stakeholder	Role	Written input	Workshop participation
ITER Organization	Owner and operator of ITER	X	
Culham Centre for Fusion Energy	Owner and operator of JET	X	X
Fusion for Energy	European Procurement Agency for ITER	X	X
Ansaldo Nucleare	Industry, sub-contractor for ITER design and construction	X	(X) remote
AREVA	Industry, sub-contractor for ITER design and construction		X
Ghent University	Education institute	X	X
FuseNet Association	European Fusion Education Network		X

Table 2 Stakeholders participation at workshop in Eindhoven, November 10th and 11th 2016

The advantage of this approach with steps 1 to 4 is that results already developed in the nuclear fission area could be used for adaptation to the fusions specifics, without the need to start from the very beginning by conducting a complete and exhaustive job and task analysis, or by a job competency analysis, as explained in detail in [2]. This is possible, as to some extent, profiles of job positions in the fission and the fusion area are comparable, as well as related job requirements (competences), in particular also nuclear competences.

Important for the application in the current WP6 of the ANNETTE project is the fact that the selection of job profiles is decoupled to some extent from the related nuclear competences: for different job profiles the required nuclear competences may be the same, but also different. Different with respect to the scope of KSAs, but also different with respect to the level of expertise (and thus education level) that is required. The latter has been described in another EHRO-N report (fission related, see figure 34 in [4]) as the nuclear skills pyramid, distinguishing by type of employee between nuclear-aware, nuclearized (i.e. technicians, engineers, other graduates) and nuclear, the latter requiring a more extensive education.

In a next step within the WP6 of the ANNETTE project one may then decide to what extent the target group of fusion work force may be addressed by the training to be developed within WP6. Designing a modularized training structure would allow for dealing with different job positions, maximizing the impact on the fusion work force, while also allowing for a more specialized training of those target groups that need deeper nuclear competences.

3. REPRESENTATIVE FUSION WORK FORCE PROFILES

Annexes 1 and 2 present two examples for detailed job profiles that have been taken from the NJT developed by EHRO-N. As can be seen, the competences listed under *Job Requirements* contain several items that certainly are not allocated to these specific job positions only. Instead, one can expect that they will show up in other job profiles, too. Therefore, it should be sufficient to collect some representative job examples and related nuclear competences, which then certainly will provide the majority of items to be dealt with in the specification of nuclear training for fusion (see sub-task T6.2).

During the Stakeholders' Workshop, the participants provided the following examples of job positions that should be considered:

1. All the positions that are related with the so-called Protection Important Activities, examples:
   a. Design - Directly related to safety analysis:
      i. Nuclear engineers for calculation of releases in design basis accidents
      ii. Nuclear engineers performing safety analysis of accidents
   b. Manufacturing
      i. Mechanical Engineers in charge of welding of first confinement barrier as the vacuum vessel

2. Positions that require nuclear competences are all those concerning responsibility in the Design, Manufacturing and Operation of Nuclear Components, Systems or Facilities, examples:
   a. Risk and Safety Engineer
   b. Mechanical Engineer
   c. System Engineer
   d. Production and Quality Engineer (ensuring compliance with nuclear codes and practice)
   e. Radiation & Radiation Monitoring Engineer
   f. Licensing Expert
   g. Reliability Engineer
   h. Waste and Decommissioning Engineer

3. Job positions with critical gaps, namely
   a. Whole system understanding and deep applied understanding, e.g.
      i. Chief Engineer next generation
      ii. Industrial Architect next generation
   b. Hands-on skilled technicians, e.g.
      i. Design for manufacture
      ii. Effective realization of design/concepts
   c. Understanding of requirements and interfaces, e.g.
      i. Systems engineering
      ii. Integrated design

4. Further examples of job positions
   a. Nuclear Material Specialists, e.g. on IFMIF or Neutron – Material reaction

b. Severe Accidents Specialists, e.g. on using MELCOR or RELAP codes
c. Neutronics experts, e.g. on using MCNP
d. PSA/RAMI Nuclear Experts
e. Experts on application of Nuclear Mechanical / I&C Codes and Standards (e.g. ASME, RCC-M, RCC-MR, IEEE)
f. Classical engineering (non-nuclear): Seismic specialists, structural specialists, High current specialists, Electro Magnetic specialists…

In connection with the above listed job positions, the term Nuclear Component/System/Facility must be explained. It is a component/system/facility which:

- contains a radioactive inventory (radioactivity level higher than a threshold, defined by the nuclear law of the country hosting the facility),
- becomes radioactive during operation,
- is a component/system critical for safety or a safety system.

Very important to note here is that nuclear components or systems have to satisfy not only functional but also safety requirements ones. Examples for fusion facilities:

Component /system	*Functional* requirement	*Safety* Requirement
Vacuum Vessel	Structural resistance and leak tightness in all operating conditions scenario	First barrier to the release of the radioactive inventory contained inside (tritium, activated dust)
Tokamak (Nuclear) Buildings	Structural resistance to all design loads	Barrier to the release of the radioactivity in accident conditions, Radiation shielding to allow presence out of the buildings

Table 3 Functional and safety requirements, examples for fusion facilities

This input provided by the participants of the Stakeholders' Workshop shows that a variety of job profiles should be considered when selecting some for identification of required nuclear competences. This is mainly caused by the fact that – as with nuclear fission – a fusion facility that becomes nuclear must be designed, constructed and operated in a way that people and the environment will be protected against the exposure to radioactivity.

This objective presents a stringent requirement that is set up by law in every country where nuclear energy is produced and used for peaceful use. Its achievement is regulated and supervised by the national nuclear safety authorities, and has far reaching implications on

- codes and standards to be applied during design and construction,
- processes to be applied (e.g. licensing),
- results to be produced, including providing appropriate evidence (i.e. documents) that applicable codes and standards have been observed and safety goals will be achieved,
- the culture to be implemented within organizations and on a personal level: nuclear safety culture with its implications for organizational as well as personal behavior.

Consequently, during the Stakeholders' Workshop it was concluded that it would be insufficient to develop only a list of some dedicated job profiles that require nuclear competences. Instead, nuclear competences will be expected in a variety of different job positions that may be distinguished by

a) educational level (i.e. EQF level or craftsmen / technician / bachelor / master / PhD),
b) position within the product or system life cycle (research and development, design, manufacturing, assembly, construction, commissioning, operation, decommissioning),
c) position within an organization or a project team (e.g. senior manager, project manager),
d) position within the design, manufacturing or construction process (e.g. component or system design, design integration, chief engineer, industrial architect),
e) technical specialty (e.g. nuclear material, neutronics, electro magnetics, vacuum, tritium),
f) technical discipline (e.g. mechanical / electrical / automation engineering, physicist).

In order to overcome this complex situation, the participants of the Stakeholders' Workshop proposed another view that should be appropriate for the current work.

Here, one should take into account that the individuals of current work force active in the ongoing fusion projects (ITER, research and development for ITER and DEMO, DEMO) can be classified grossly by two dimensions:

1. the degree to which people have previously been engaged in a nuclear (fission) environment, being either nuclear-aware, nuclearized or nuclear[4],
2. the degree to which people have previously been engaged in a fusion environment, and are aware of fusion specifics (related to main components and systems of a fusion facility).

Consequently, this view does not stick too closely to single job positions; in principle, a finer sub-structure could be set up when taking into account also further job classifications as listed above, a) to f). Nevertheless, it appears the above gross classification will provide largely all the competence needs that will have to be considered when developing training courses on nuclear competences.

Therefore, this approach should allow to target a large fraction of the current fusion work force for nuclear training, but also part of the current fission work force, ensuring a large number of possible course participants, and thereby a high impact on the success and quality of on-going fusion projects.

[4] see figure 34 in [4]

4. TASKS / ACTIVITIES IN FUSION PROJECTS THAT REQUIRE NUCLEAR COMPETENCES

During the Stakeholders' Workshop, the participants provided the following examples of tasks / activities belonging to one or several of the job profiles identified in section 3, that should be considered within the scope of WP6:

1. All the activities defined as Protection Important Activity by the nuclear operator, for example:
   a. Design: Definition of the radioactive inventories, safety analysis, calculation of releases, identification of the pressurized equipment
2. Design, construction, manufacturing, assembly, commissioning, for example:
   a. Manufacturing: Welding of the first confinement barriers
3. minimum to advanced level: Design of any component within the biological shield
4. advanced level: Calculation of Tritium Breeding Ratio for components that affect blanket
5. Integrated design
6. Systems engineering
7. Virtual engineering
8. Safety case development
9. Design and manufacturing of plant components
10. Operation and maintenance of complex components
11. Through-life monitoring and control
12. Risk and Safety analysis
13. Design (e.g. of components, systems, buildings)
14. Quality Control
15. Radiation Protection and Radiation Monitoring
16. Licensing
17. Reliability evaluations
18. Waste and decommissioning
19. MCNP: Nuclear Zoning and Neutronics calculations
20. Safety analysis of severe accidents: MELCOR, RELAP, LOCA, TCWS calculations
21. Material Specialist for neutron interactions
22. Fire specialist HVAC for nuclear installations
23. Application of Codes and Standards, e.g. ASME, RCC-MR, RCC-M

As can be seen from this list, the tasks apparently can be grouped into the following categories:

A. Product life cycle activities, e.g. no. 2, 9, 10, 13
B. Activities related to organization and management (process and responsibilities) of the product life cycle activities, e.g. no. 5, 6, 7, 11, 14
C. Activities directly related to the licensing process of nuclear facilities, i.e. the process itself and related activities like safety analysis, e.g. no. 1, 8, 16, 17, 18, 19, 20
D. Product life cycle activities that are required in addition to non-nuclear activities because of the nuclear nature of the product (i.e. the facility to be constructed), e.g. no. 3, 4, 12, 15, 21, 22, 23

Based on this categorization, one can conclude that scope and level of nuclear competences will grow from category A to category D, i.e. starting with nuclear awareness, finally comprehensive nuclear competences will be required[5].

The implication for the purpose of this report is that the scope of nuclear competences for the work force active in fusion is large, but one has to distinguish between the levels that will be required. Apparently, the largest fraction of the work force will need to become mainly nuclear aware and nuclearized, thus training to be developed within WP6 of ANNETTE should focus on this group, as it will have the largest impact on the nuclearization of fusion.

[5] See also figure 34 in [4]

5. REQUIRED NUCLEAR COMPETENCES OF FUSION WORK FORCE

When considering the job profiles already developed by EHRO-N within the NJT, the degree of expertise or proficiency that is required for job specific knowledge, skills or attitudes is not included in the description of these competences, see annexes 1 and 2. Instead, this degree is provided by a reference to the related EQF level (1-8)[6].

The European Qualifications Framework (EQF) is a common European reference framework. It acts as a translation grid which links countries' qualifications systems/frameworks. It covers qualifications at all levels and in all sub-systems of education and training (general and adult education, vocational education and training as well as higher education). The core of the EQF is its eight reference levels (see table below) defined in terms of learning outcomes, i.e. knowledge, skills and attitudes. Learning outcomes (or training objectives of a training course) express what individuals should know, understand and be able to do at the end of a learning process.

	Knowledge	Skills	Attitude
EQF Level	**In the context of EQF, knowledge is described as *theoretical and/or factual*.**	**In the context of EQF, skills are described as *cognitive* (involving the use of logical, intuitive and creative thinking), and *practical* (involving manual dexterity and the use of methods, materials, tools and instruments)**	**In the context of EQF, attitude is described in terms of *responsibility and autonomy*.**
Level 1	Basic general knowledge	Basic skills required to carry out simple tasks	Work or study under direct supervision in a structured context
Level 2	Basic factual knowledge of a field of work or study	Basic cognitive and practical skills required to use relevant information in order to carry out tasks and to solve routine problems using simple rules and tools	Work or study under supervision with some autonomy
Level 3	Knowledge of facts, principles, processes and general concepts, in a field of work or study	A range of cognitive and practical skills required to accomplish tasks and solve problems by selecting and applying basic methods, tools, materials and information	Take responsibility for completion of tasks in work or study; adapt own behaviour to circumstances in solving problems
Level 4	Factual and theoretical knowledge in broad contexts within a field of work or study	A range of cognitive and practical skills required to generate solutions to specific problems in a field of work or study	Exercise self-management within the guidelines of work or study contexts that are usually predictable, but are subject to change; supervise the routine work of others, taking some responsibility for the evaluation and improvement of work or study activities
Level 5	Comprehensive, specialised, factual and theoretical knowledge within a field of work or study and an awareness of the boundaries of that knowledge	A comprehensive range of cognitive and practical skills required to develop creative solutions to abstract problems	Exercise management and supervision in contexts of work or study activities where there is unpredictable change; review and develop performance of self and others
Level 6	Advanced knowledge of a field of work or study, involving a critical understanding of theories and principles	Advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialised field of work or study	Manage complex technical or professional activities or projects, taking responsibility for decision-making in unpredictable work or study contexts; take responsibility for managing professional development of individuals and groups

[6] See e.g. http://www.cedefop.europa.eu/en/events-and-projects/projects/european-qualifications-framework-eqf

Level 7	Highly specialised knowledge, some of which is at the forefront of knowledge in a field of work or study, as the basis for original thinking and/or research Critical awareness of knowledge issues in a field and at the interface between different fields	Specialised problem-solving skills required in research and/or innovation in order to develop new knowledge and procedures and to integrate knowledge from different fields	Manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches; take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams
Level 8	Knowledge at the most advanced frontier of a field of work or study and at the interface between fields	The most advanced and specialised skills and techniques, including synthesis and evaluation, required to solve critical problems in research and/or innovation and to extend and redefine existing knowledge or professional practice	Demonstrate substantial authority, innovation, autonomy, scholarly and professional integrity and sustained commitment to the development of new ideas or processes at the forefront of work or study contexts including research

Table 4 Eight EQF levels related to knowledge, skills and attitudes

Adapted from https://ec.europa.eu/ploteus/en/content/descriptors-page

The following recommendations are made in [3] for the development of job profiles:

- To improve clarity, some items of knowledge and skills can be grouped, provided they belong to the same field and the EQF level applicable is the same for all of them. The goal is to keep the definitions as concise as possible. It is advised to avoid words redundant with the nature of the items, such as “understanding” for knowledge or “ability” for skills.
- *Knowledge* (cognitive competence) items are those that are referring to concepts and facts that should be distinguished, identified and/or understood, similar to the contents of an academic syllabus.
- *Skills* (technical and functional competences) items are those that are referring to the ability to carry out tasks – physical or intellectual – resulting in a concrete outcome. The skills are typically formulated by a verb (or action word) followed by an object, and may also explicitly mention the resources or tools to employ and the purpose or expected result.
- *Attitudes* – most of the items listed here are in general desirable attributes for every individual; nevertheless those that are crucial for the performance in the concerned position should be identified and mentioned.

They should also be applied here for the intended specification of competences.

During the Stakeholders’ Workshop, the participants provided the following examples of nuclear competences that should be considered within the scope of WP6:

Knowledge:
1. Licensing: licensing process and characteristics
2. Code and standards, required safety factors, impact on regulation or licensing
3. Safety requirements and awareness of them
4. Basic safety principles (single failure, redundancy, defense in depth etc.)
5. Defined Requirements for PIC/SIC components
6. Loads for normal, incident, accident scenarios
7. Risk and Safety: Thermal hydraulic, simulation, simulation tools, CFD, risk methodologies
8. Radiation protection and radiation monitoring: Typical simulation tools, shielding and doses etc.

9. General knowledge of existing tools used by other groups for simulations in support of the licensing process
10. Mechanical design according to nuclear codes (ASME, RCC-MR), FEM, material behavior under irradiation
11. System Engineer:
    a. Systems and components, fluid systems, mechanical standard components (pumps, valves etc.);
    b. Requirements imposed by safety rules (e.g. redundancy, independency)
12. Manufacturing and assembly principles
13. Power plant fundamentals
14. Tokamak, in vessel components, material, pressurized equipment
15. Specific knowledge of fusion waste
16. System knowledge (T/H, electric, control, safety etc.)
17. Other specific aspects of fusion, such as plasma disruption and instability impacts and operating scenarios.
18. Decommissioning process
19. Periodic testing and In-service inspections
20. Waste & decommissioning: waste produced, activated materials
21. Detailed technical requirements
22. Real world vs theory

Skills:
1. System functional design (P&ID etc.)
2. System performance calculation
3. Calculation to verify accidental conditions
4. Analyze objectively the results of simulation
5. Typical solutions for component design
6. Data sheets development
7. Radiation normative aspects
8. Calculation to verify accidental conditions
9. Capability to identify initiator events, PIRT
10. Modelling and simulation (move to predictive/integrated models)
11. Design using advanced computing tools, while being able to criticize advanced computing tools results and ability to judge the credibility of results using lumped, global considerations (see also skill items 13 and 14)
12. Use tools like MCNP, RELAP, MELCOR, Nuclear C&S, e.g. for analysis of structural integrity or material properties
13. To know exactly the capabilities and limits of the simulation tools
14. Assess the reliability of the solution
15. Procurement skills
16. Manufacturability
17. Corrosion and welds problems
18. Identification of critical aspects

19. Ability to understand and manage risk
20. Effective communication – make the complex simple
21. How to collaborate between different organizations, taking into account different national as well as organizational cultures
22. How to innovate within a framework
    a. In design
    b. In realization
    c. In approval and regulation
    d. In operation

Attitudes:

1. Safety and Quality DNA
2. Open mind
3. Team work with input/output from/to other disciplines
4. Collaboration as key to success (no individual has all the answers)
5. Capability to obtain information from different groups
6. Ability to deal with contractors
7. Start with the end in mind – clear scope and plans up front.
8. Drive for results
9. Pragmatism – what we need to know to move on
10. Operate with discipline – do what we say we're going to do
11. Willingness to learn and improve
12. Innovate where it adds value

The input provided during the Stakeholders' Workshop as listed above was only slightly rephrased and regrouped in order to get a better overview on the stakeholders' input. We can summarize the competence needs that came to the table in terms of Knowledge, Skills and Attitudes as follows:

Knowledge:

Most important, knowledge about nuclear licensing:
the applicable regulations, the licensing process with the different responsibilities of involved parties, its impact on product life cycle activities (i.e. design, manufacturing, development, assembling, construction, commissioning, operation, maintenance, decommissioning), the codes and standards to be applied in these, the applicable risk assessment and simulation activities, the tools to be used for these activities.

In order to conduct these activities properly, at least a basic understanding of a fusion facility appears to be absolutely necessary:
the plant layout and its structuring into systems / components, the physical processes that are active during operation (like energy production, fuel production, energy transfer, activation of material under radiation, production and removal of waste, auxiliary support processes e.g. for energy confinement), the main functional as well as safety oriented tasks of systems and components, systems and components interactions, all to be considered from different technical perspectives (like mechanical, electrical, HVAC, I&C).

Apparently, the level of detail of which all these items must be known by the involved personnel clearly depends on their role within the product life cycle activities, and on the impact of these activities on safety of the facility as well as on the economics of operation and maintenance.

In summary, when dealing with nuclear competences in the design and operation of fusion reactors, three different knowledge areas have to be addressed:

i. Licensing of a nuclear facility and its impact on organizational, project and human resources activities,
ii. Basics of a fusion facility (i.e. its design and its operation),
iii. The multi-disciplinary nature of a fusion project.

As for the degree of expertise, depending on the role within the product life cycle activities EQF levels 3 to 6 may be required.

Skills:

Based on the knowledge as presented above, the involved personnel should be able to perform the necessary processes properly, in particular to apply the required codes and standards, to use the necessary tools correctly and efficiently, and to evaluate the results appropriately, while considering the limits of the performed analysis.

Furthermore, the involved personnel should be able to take into account the downstream impact of their activities, and to become also involved in these if necessary, e.g. in procurement, manufacturing.

While being able to understand and manage risk properly, they should also be able to collaborate and to communicate effectively, supported by the skills to introduce innovations in the required framework of their work.

In summary, 3 different skills areas have to be addressed:

i. Implementing nuclear regulation in the product life cycle activities,
ii. Performing the necessary processes and activities within the product life cycle,
iii. Evaluate impacts of design changes/modifications on different fields,
iv. Social skills (collaboration, communication, innovation).

As for the degree of expertise, depending on the role within the product life cycle activities also here EQF levels 3 to 6 may be required.

Attitudes:

The most important attitude prevailing with the involved personnel shall be the incorporation of a safety oriented behavior that emphasizes safety over competing goals to ensure protection of people and the environment.

Having an open mind, people shall operate with discipline, drive for results and quality of their work, shall be willing to learn and to improve, and to innovate where it adds value.

In summary, 2 attitude areas have to be addressed:

i. Nuclear safety culture
ii. Social behavior within a goal oriented team

As for the degree of expertise, depending on the role within the product life cycle activities as well as on their management position, also here EQF levels 3 to 6 may be required.

6. DIRECTIONS FOR DEVELOPMENT OF FUSION WORK FORCE NUCLEAR COMPETENCES

Based on the input received during the Stakeholders' workshop, this chapter presents some directions for how to specify nuclear training that shall be either newly developed, or composed of adapted existing training or modules of training courses. The final specification shall be the result of sub-task T6.2 of ANNETTE WP6, it will have to be used for development of training.

Target group of training
In accordance with the approach presented in chapter 3, the training should target individuals that possess different levels of nuclear or fusion competences. When properly designed, i.e. modularized, part of the training could build up not only basic, but also advanced or expert competences (i.e. EQF levels higher than 4) that will be important for persons that already possess basic competences. This modular approach could ensure a large target group, thereby effectively contributing to a large dissemination of the training. Special attention should be devoted to Nuclear Safety Culture training. As already discussed and implemented within the NUSHARE project[7], in this case a leadership training for CEOs or other senior managers from fusion subcontractors should have a high impact on the implementation of an effective Nuclear Safety Culture. This type of training should be implemented in an easy and effective way, e.g. by e-learning, and could thus become also interesting for other target groups that would like to be introduced to the main issues of nuclear and fusion. In summary, the training should mainly address the fusion work force with higher education levels, not only in industry involved in fusion related contracts, but also within research institutes as well as within operators of fusion facilities, including their procurement agencies.

Prerequisites of target group
The targeted trainees shall possess a suitable academic education (Bachelor level or equivalent), preferably in a technical subject matter.

Training Objectives
After the training, the trainees shall have knowledge on i. Licensing of a nuclear facility and its impact on organizational, project and personal activities, ii. Basics of a fusion facility (i.e. its design and its operation), iii. the multi-disciplinary nature of a fusion project, they shall be able to i. Implement nuclear regulation in their product life cycle activities, ii. Perform the necessary processes and activities within the product life cycle, iii. Evaluate impacts of design changes/modifications on different fields, iv. Collaborate, communicate and innovate within a team,

[7] See e.g. http://www.enen-assoc.org/en/training/nushare.html

they shall exhibit a personal behavior in accordance with

i. Nuclear safety culture,

ii. Social behavior appropriate for a goal oriented team.

Training content

Based on the considerations in chapter 5, the following items should be included in training content:

1. applicable regulations and the nuclear licensing process with the different responsibilities of involved parties,
2. its impact on product life cycle activities,
3. the codes and standards to be applied in these,
4. the applicable risk assessment and simulation activities,
5. the tools to be used for these activities,
6. layout and systems / components structure of a fusion facility,
7. main physical processes that are active during fusion facility operation, in particular nuclear aspects that are to be treated differently in fusion reactors compared to fission reactors,
8. main functional as well as safety oriented tasks of systems and components,
9. interfaces and interactions between systems and components,
10. application of codes and standards,
11. use of necessary tools, understand as well as interpret the results while assessing the limits of the analysis performed,
12. multi-disciplinary nature of fusion projects,
13. considering impact of activities on downstream activities, e.g. procurement, manufacturing,
14. impacts of design changes/modifications on different fields,
15. understanding and managing risks,
16. effective collaboration and communication, innovations,
17. nuclear safety culture, and the impact of leadership and organizational culture for its effective implementation,
18. open mind, discipline of work, driving for results and quality, willingness to learn and to improve, and to innovate where it adds value.

In view of the importance of nuclear safety culture, and the importance of leadership for its implementation, existing nuclear fission training, e.g. developed within the NUSHARE project, should be deployed, but should be adapted by fusion specifics.

Training modularization

In order to accommodate for the diverse, sometimes conflicting interests of a large target group, the training course should be properly modularized. This would allow for dealing with the content on different degrees of expertise and in different levels of detail. For example, structuring the course into overview / basics / specialized modules would be ideal, providing also the opportunity to include already existing training, e.g. from the NUSHARE project.

More specific, first an on-line course could provide a basic level training that could be certified as basic nuclear safety training for the ITER project, which is required for all staff of the construction companies. This basic-level training could differentiate in levels EQF1 to EQF3 (each leading to different final online tests). The second part could provide a more detailed one week classroom training/workshop for those that passed the online course, focusing more on the skills and attitudes, and allowing for more detailed knowledge items.

Training development

Before starting to develop new modules, one will have to investigate carefully which existing training courses (or parts of these) can be reused and/or merely adapted, providing suitable modules as convenient. Based on specification of target group, training objectives, training content and suitable modularization, i.e. the training design as to be published in deliverable D6.2 of WP6, gaps will have to be identified that require the adaptation of existing modules, and the development of new course modules.

Existing sources of training that will be investigated could be identified at the fusion stakeholders (see chapter 2), including also EUROfusion and the partners in its consortium, i.e. European fusion research laboratories.

This particular approach with its focus on reusing existing training will allow for an efficient training development.

Training method(s)

Classroom training, i.e. presentations by an instructor should be the prevailing training method, to be supplemented by e-learning if possible, to impart mainly basic knowledge. However, when developing skills, suitable exercises must also be included, ideally supplemented by instructor led discussions between the trainees. Exercises should include case studies, the details of which depend on the respective training module and its content.

When addressing nuclear safety culture and the development of an appropriate attitude as well as motivation of the trainees, group interactions will be necessary.

Training duration

In total, 2 weeks could be an ideal duration, so that all the content as listed above could be addressed in the training, ideally on different levels as made possible by the modularization of training. The duration will depend, of course, on the entry competence level of the trainees, and the extent (i.e. expert level) to which the content listed above will be dealt with in the course.

If feasible, some modules should be conducted by e-learning, ideally before classroom training, so that only a limited time is required for physical presence during the course, or during the implementation of some course modules.

Requirements on training material (and instructor guides)

The training material could consist of slides, possibly supplemented by further, perhaps already existing material for self-study after the end of a course module (e.g. web lectures, lecture notes, worked out exercises). The slides should focus on supporting the presentation of the instructor, possibly containing also some notes. However, the slides shall not contain a comprehensive text that could replace the talk of the instructor. Furthermore, within the limited budget of WP6 the development of a complete training manual that could also be used for self-study without attending the classroom training, will certainly not be possible without a reduced quality.

For exercises that shall complement instructor presentations, case studies or other forms of text based problems that shall be solved will be ideal. However, in this case input from stakeholders is absolutely necessary. They should provide real life problems that will make trainees aware of the challenges they will have to be prepared for.

The training material will have to be complemented by the development of feedback questionnaires or tests if necessary. These will have to be deployed for evaluation of training effectiveness (see below).

Requirements on instructors

For overview and basics training, experienced instructors with suitable pedagogical competences for adult training should be deployed. When details are addressed in the training course on a more detailed level, preferably subject matter experts should be involved in the respective modules. This will also be necessary for conducting instructor led discussions that shall address skills and attitude competences.

Evaluation of training effectiveness

After implementation of training module, feedback from the trainees shall be collected in order to evaluate how the trainees liked the course – with respect to course organization, fulfilment of their expectations, achievement of training objectives, quality of training material, competences of instructors.

Next, for certain modules a test could be prepared to check whether the trainees have learned what they should learn. Of course, without a great effort it will only be possible to check the achievement of knowledge, sometimes also the achievement of some skills related training objectives.

Course design and related test should be presented to and discussed with the fusion stakeholders, with the aim to establish a recognition of the course and its test certificate as a prerequisite for personnel to perform activities within the fusion stakeholders' organizations or their subcontractors.

7. CONCLUSIONS

The valuable input received during the Stakeholders' workshop helped to understand that the most imminent needs in nuclear competences of people active in fusion projects should focus on 3 different areas:

1. Licensing of a nuclear facility and its impact on organizational, project and human resources activities, as well as related processes, tools, and skills of involved human resources,
2. Basics of a fusion facility (i.e. its layout, design and operation) and the related multi-disciplinary nature of a fusion project,
3. Nuclear safety culture and related social behavior within a goal oriented team.

The success of ongoing fusion projects will strongly depend on these nuclear competences of the nuclearized people (in terms of the nuclear skills pyramid, see figure 34 in [4]), that represent the majority of the design and construction work force. Apparently for this target group appropriate education and training measures do not exist that build up systematically the above listed competence areas - a further important conclusion of the Stakeholders' workshop.

Consequently, there is a competence gap that needs to be closed by the WP6 of the ANNETTE project. In this way, the result of this WP6 can contribute strongly to the success of future fusion projects.

8. REFERENCES

[1] IAEA Technical Reports Series No. 380: Nuclear Power Plant Personnel Training and its Evaluation, International Atomic Energy Agency, Vienna / Austria, 1996

[2] IAEA TECDOC No. 1170: Analysis Phase of Systematic Approach to Training (SAT) for Nuclear Plant Personnel, International Atomic Energy Agency, Vienna / Austria, 2000

[3] JRC Scientific and Policy Reports No. EUR 26443 EN, Towards the implementation of the European Credit System for Vocational Education and Training (ECVET) in the nuclear energy sector, European Commission, Joint Research Centre, Institute for Energy and Transport, Luxembourg: Publications Office of the European Union, 2013

[4] Simonovska V., Estorff U. von, 2012. Putting into Perspective the Supply of and Demand for Nuclear Experts by 2020 within the EU-27 Nuclear Energy Sector. Report EUR 25291 EN, Petten, Netherlands

[5] JRC Scientific and Policy Reports No. EUR 25644 EN, The Preparation of an ECVET-oriented Nuclear Job Taxonomy, European Commission, Joint Research Centre, Institute for Energy and Transport, Luxembourg: Publications Office of the European Union, 2012

Annex 1: Job Profile of Safety Design Engineer
(Taken from [5])

1.2.10	Job Title	Category
NPP – N Design	**Safety Design Engineer** Safety Analysis Engineer	Professional
Responsible for the safety analysis of different NPP systems within specific rules and guidelines		Entry level qualification ISCED 7

Roles / Functions

- Analyse and review the studies on the theoretical and practical safety issues linked to the design of NPPs
- Compilation of relevant input data for the construction of safety analyses (transient analyses,
  probabilistic analyses, accident severity, radiation protection, etc...) for NPPs
- Implementation, evaluation, appraisal and documentation of the appropriate analyses using
  computer programs (for example RELAP, MNCP, CATHARE)
- Compilation of licensing documentation for submitting to regulators and expert organizations

JOB REQUIREMENTS

KNOWLEDGE (Cognitive competence)	EQF level (1-8)
Applied Nuclear Physics	6
Reactor Analysis and Design	6
Reactor Dynamics and Control	6
Heat generation and removal in reactor systems	6
Confinement of radioactive material	6
Radioactive waste management	6
Radiation protection	6
Accident analysis	7
Fundamentals of nuclear safety	7
Nuclear safety methods	7
Nuclear thermal-hydraulics	7
Reactor Thermal hydraulics	7
Nuclear engineering design	5
National and international regulations	7
SKILLS (Technical competence, abilities)	**EQF level (1-8)**
Use computer tools for safety analysis	7
Perform Probabilistic safety analysis	7
Perform Deterministic safety analysis	7
Identification of safety requirements	7
Analyse and interpret the results of safety tests	7
Use and interpret engineering data and documentation	6
Produce nuclear safety documentation	6
Ensuring compliance with statutory regulations and organisational safety requirements	6
Comply with complex regulations and procedures	6

37

Communicate effectively with other project members and stakeholders	6
Assist in performing safety critical experiments on small-scale installations	5
COMPETENCE (Attitude, behavioural and personal competence)	EQF level (1-8)
Analytical thinking	7
Accountability	7
Critical analysis	7
Eye for detail/accuracy	6
Communication – capacity to communicate technical or specialised information	6
Team working	5

NOTES

DRAFTED BY:	1ST REVIEW:	2ND REVIEW:
T. BERKENS		
24.10.2012		

38

Annex 2: Job Profile of HVAC Design Engineer

(Taken from [3][5])

Ref.	Job Title	Occupational Category
1.2.12	**HVAC Design Engineer**	Professional
Phase / Area	Alternate job title(s) – specialisations	Functional Category
NPP N Design	-----	Specialist
Role / Functions		
Responsible for the design of HVAC systems, within specified rules and guidelines.		
• Carry out and/or coordinate the conceptual/detailed design of NPP HVAC, ensuring compliance with regulatory and quality standards, preparing the necessary documentation and reporting. • Define size and select HVAC systems and equipments. • Ensure compliance with applicable codes, standards, licenses, permits, and permissions governing the design, engineering, construction and operation of nuclear power plant. • Distribute tasks to the design technicians. • Interfacing with other disciplines as required.		

JOB REQUIREMENTS	
KNOWLEDGE (Cognitive competence)	EQF level (1-8)
Engineering data and documentation.	6
HVAC engineering and standards	6
Design Standards and regulatory requirements	6
Radiation Protection and ALARA principles.	5
Safety Culture principles.	5
ICT literacy.	5
NPP Systems and main components description (primary and secondary circuit, auxiliary systems and power supply/distribution systems).	3
Reactor Theory.	3
Industrial Safety.	3
Operating Experience.	3
Human Error Prevention Techniques.	3
SKILLS (Technical and functional competence)	EQF level (1-8)
Preparation of conceptual and detailed layout designs of HVAC.	6

Nuclear Job Taxonomy
1.2.12 v. 08.01.2014 80

Technical writing, presentation and communication.	5
Updating existing designs based on other projects and existing standards.	5
Interpret technical specifications (HVAC) to translate them into designs	5
Allocate tasks and organize/plan work.	3
Participation of safety analysis.	3
COMPETENCE (Attitude; behavioural and personal competence)	EQF level (1-8)
Accountability	5
Analytical Thinking.	5
Problems solving.	5
Conscientiousness.	5
Dealing with difficult situations (interpersonal conflicts).	5
Team working.	4
Pragmatism	4
Ability to work in proactive and autonomous way.	4
Punctuality.	4

NOTES

DRAFTED BY:	1ST REVIEW:	2ND REVIEW:
O. DERUELLE/C. D'AGOSTINO		
15.05.2013		