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ABSTRACT:

Application of ECVET system to the professional and trainee profile described in report with deliverable WP1.3 - Safety Engineer – Assessment and Performance Analysis for construction license of a selected site – allowed to break down the profile in three Units constituted of a multitude of Learning Outcomes (knowledge, skills, competencies). The Units programs were detailed as best as possible to better assess their credits. This helped to identify non-nuclear industries that could potentially provide human resources for nuclearization with a good quality/cost ratio. The example of qualification treated in WP1 could be extended to other qualification related to radioactive waste management.

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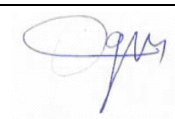
Approved by:	Behrooz Bazargan Sabet		16/11/2015

Document history

Identifier	Date	Short description

Abbreviations

KSC	Knowledge Skills Competencies
LO	Learning Outcomes

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1. Nuclear Energy Demand Scenario in Europe

In 2011, the European Commission (2011) issued the EC Energy Roadmap 2050 and different scenarios are analyzed for the energy production in the EU27 countries. Their reference business as usual scenario leads amongst those scenarios to a high contribution from nuclear energy. However, the EU policy goal in emission reduction will not be realized. Amongst the other scenarios described in this report, the so-called '20% nuclear electricity' (officially called 'Delayed CCS - carbon capture and storage') scenario leads to the highest penetration of nuclear energy and will therefore be most demanding for the current assessment. Therefore, the '20% nuclear electricity' scenario is selected for the current workforce demand extrapolation.
The resulting nuclear energy demand for the period 2000-2050 is seen in Figure 1.

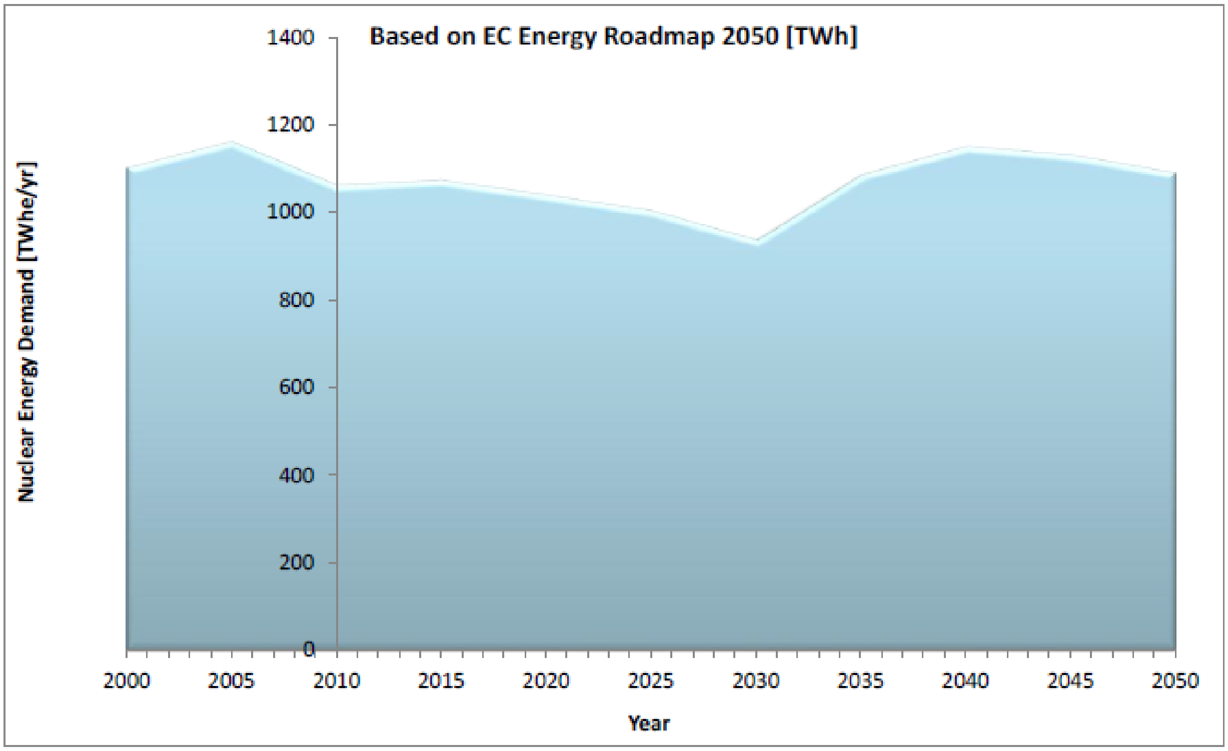

Figure 1: Nuclear Energy Demand based on the EC Energy Roadmap 2050 for EU27 countries including enlargement and integration countries.

Simonovska & Von Estorff (2012) described the workforce in terms of nuclear skills needed to operate the nuclear plants smaller than 2000 MWe in Figure 2. Clearly, more than 80% of the workforce are either ‘nuclearized’ – 74% or ‘nuclear-aware’ – 10% while only 16% have a true nuclear background in nuclear engineering.

The workforce required to operate a power plant as a function of the reactor size according to Roelofs et al. (2011) can be seen in Figure 3. Hence, for a plant of 1000 MWe, the predicted workforce is in the range of 300 to 500 fte.

The manpower requirements for the construction of one nuclear power plant based on data provided by Mazour (2007) can be seen in Figure 4, which indicates that the largest part of this construction workforce will require no specific nuclear skills (DOE, 2005). Although it is recognized generally, that workers with experience in nuclear projects provide better quality services.

To conclude under long-term operation scenario a large demand is expected for construction workforce at around 2040. However, workforce retirement at 2020 is close to 20%, which makes it important to compensate for the lack of human resources certainly via **nuclearization** of workforce coming from other industrial sectors. This conclusion is also valid in all nuclear energy sectors including radioactive waste management. **This clearly means that ECVET system is supposed to play a major role**.

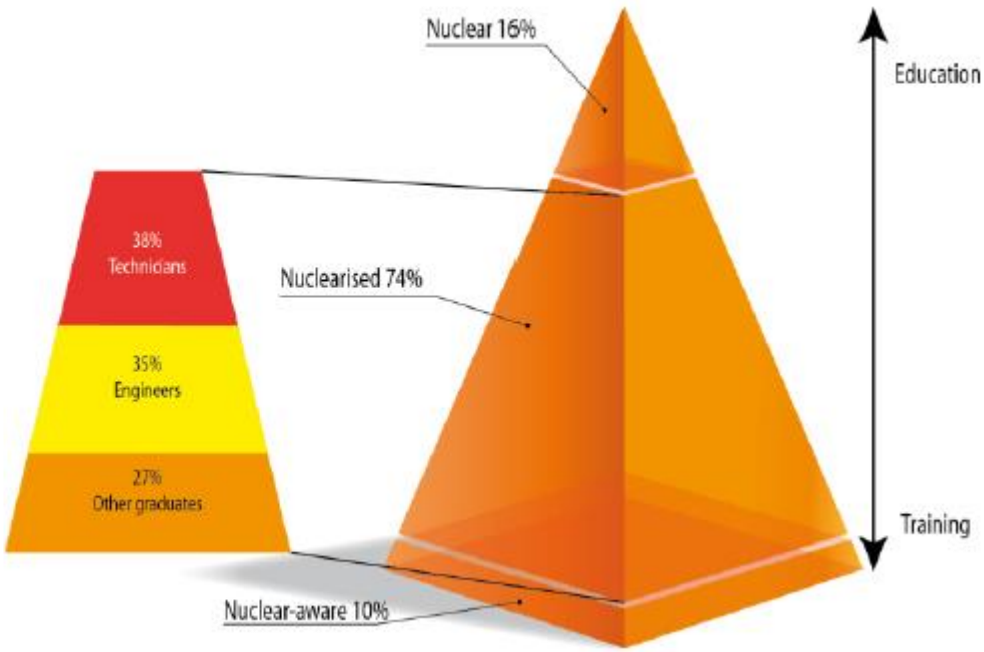

Figure 2: Nuclear Skills Pyramid (Simonovska & Von Estorff, 2012).

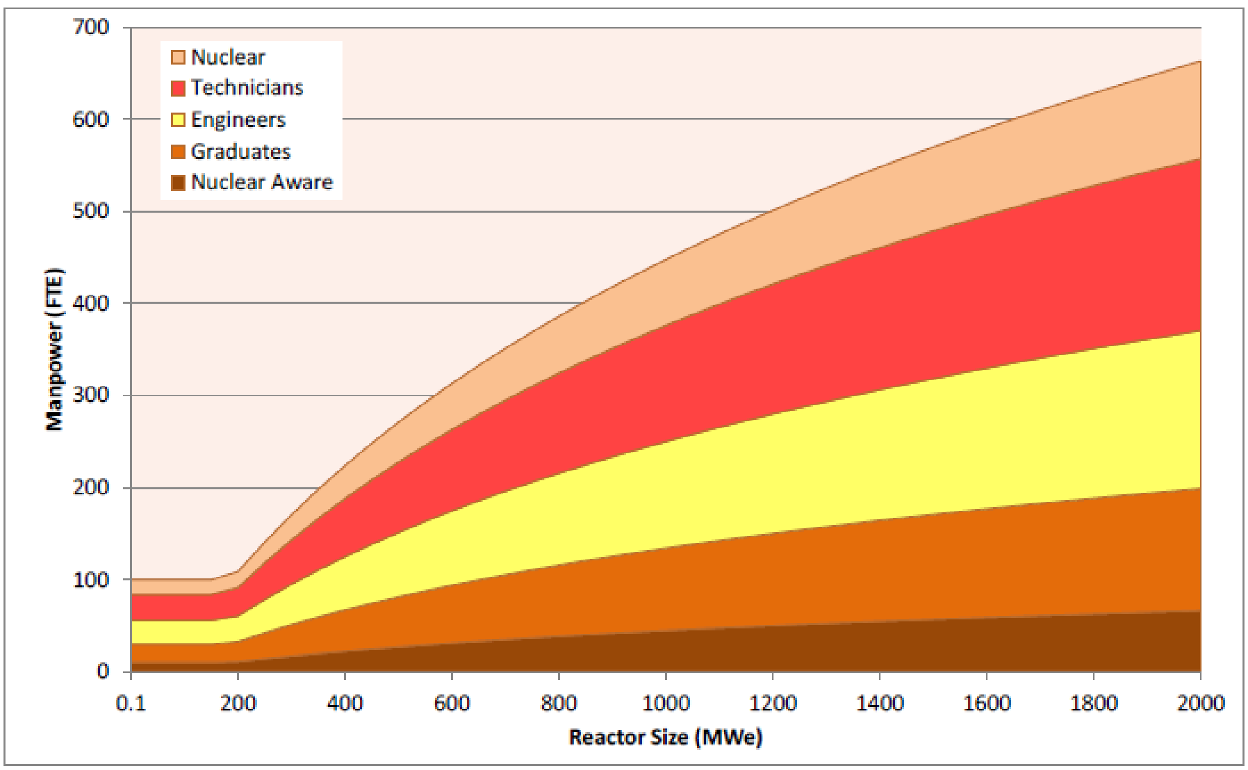

Figure 3: Graphical representation of the manpower required for different sizes of nuclear reactors based on the model described by Roelofs et al. (2011).

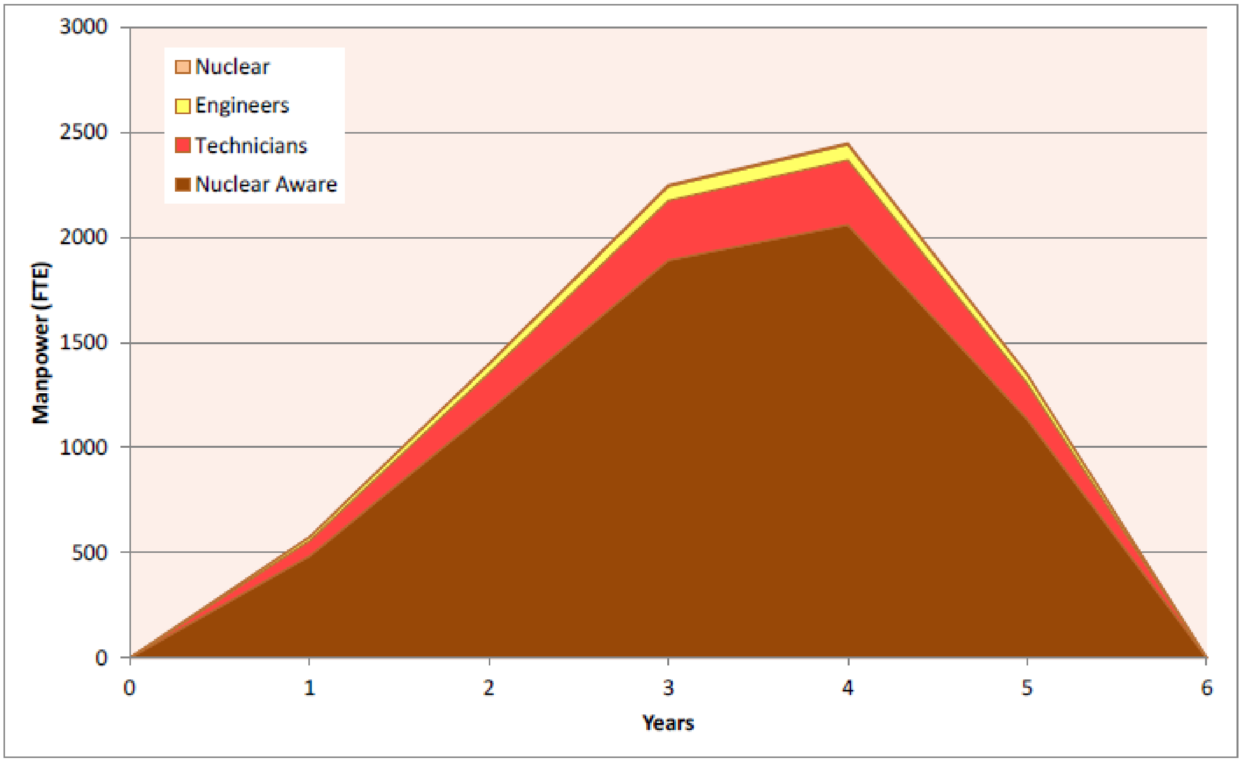

Figure 4: Graphical representation of the manpower required for construction of a nuclear power plant based on data from Mazour (2007).

2. The ECVET system

The European Credit system for Vocational Education and Training (ECVET) is the new European instrument to promote mutual trust and mobility in vocational education and training. Developed by Member States in cooperation with the European Commission, ECVET has now been adopted by the European Parliament and the Council on 18 June 2009. The adoption and implementation of ECVET in the participating countries is voluntary.

ECVET makes qualifications more transparent and understandable for someone who has no nuclear background. This is very crucial in order to remediate to the shortage in human resources expected in the nuclear field in the 2020 horizon. Moreover, ECVET structure of a qualification, allows more flexible pathways to get or to improve a qualification (all Training & Education systems are accepted: formal, informal and non-formal) (Figure 5).

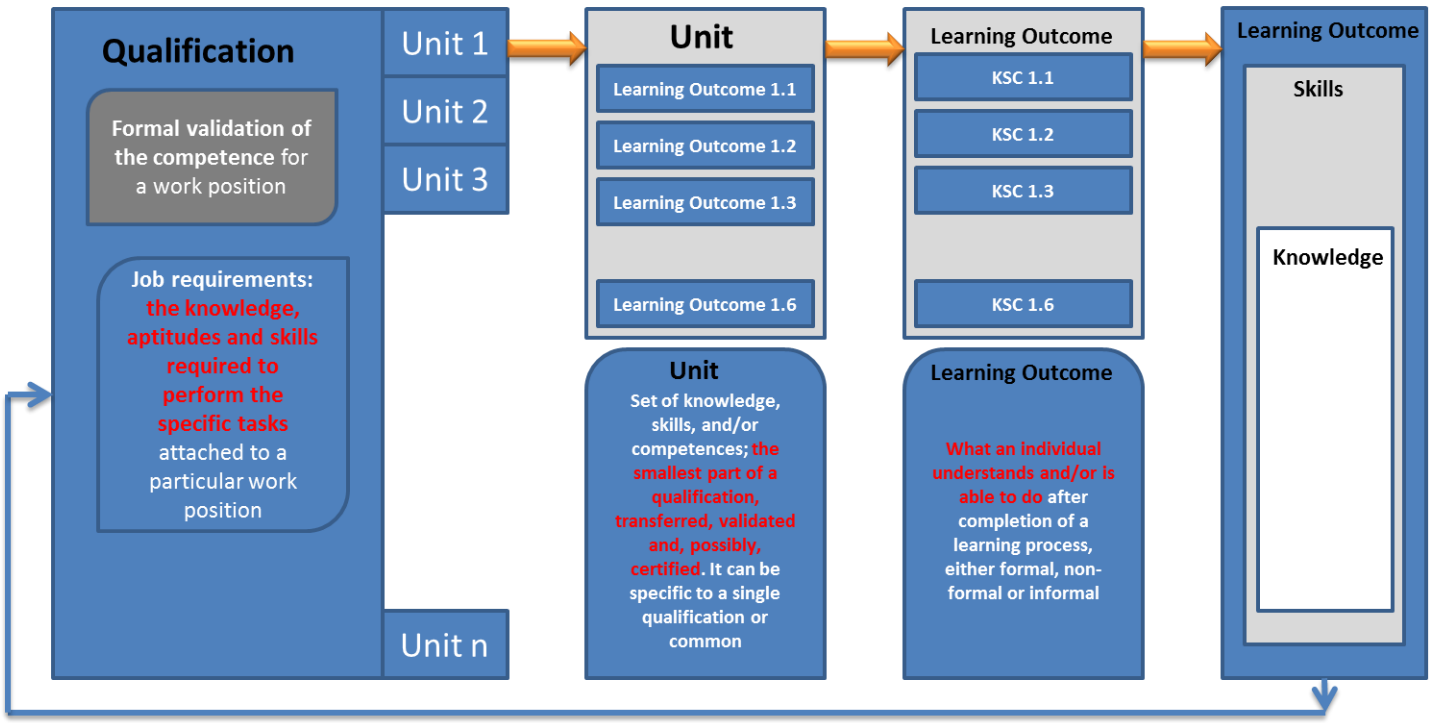

Figure 5: Qualification structure based on ECVET approach.

3. Qualification: professional and trainee profile

In Deliverable: D.1.3 the designed qualification (or job profile) is given in Figure 6, which includes a list of knowledge, skills and competencies required to perform the tasks of assessment and performance analysis for construction licence of a selected site.

<table>
<tr><td>Ref.</td><td>Job Title</td><td>Occupational Category</td></tr>
<tr><td>PETRUS3</td><td>Safety Engineer – Assessment and Performance Analysis for construction license of a selected site</td><td>Professional
(Engineer/Expert)</td></tr>
<tr><td>Phase / Area</td><td>Alternate job title(s) – specialisations</td><td>Functional Category</td></tr>
<tr><td>Radioactive Waste Disposal</td><td>Safety analysis coordinator for transport modelling</td><td>Specialist in hydrogeological modelling</td></tr>
<tr><td colspan="3">Role / Functions</td></tr>
<tr><td colspan="3">The safety engineer specialised in integrating and analysing site specific geochemical and hydrogeological data as an input data for carrying out numerical modelling and calculations for dose estimation under various likely scenarios for the [future] repository.</td></tr>
<tr><td colspan="3">To produce scoping models and perform numerical simulations to provide phenomenological and conceptual description of the behaviour of the repository system and of each repository and geological component during the (evolution of the repository) operating and post-closure periods, in space and time (thermal, hydraulic, chemical, mechanical, gas, radiation and biological processes and the potential release and transfer of radionuclide/toxic substances into biosphere), including related uncertainty analyses.</td></tr>
</table>

JOB REQUIREMENTS	
KNOWLEDGE (Cognitive competence)	EQF level (1-8)
Understand the specific characteristics of the host rock contributing and harming the containment and the isolation of the emplaced waste form/s (understand the requirements contributing to safety and safety functions)	6
Able to understand the impact of the processes (THMCGRB) and their coupling on the evolution of the components and the global repository	5-6
Understand the migratory processes and potential transport paths/routes from the waste container to the biosphere	6
Understand the basis of hydrological processes/groundwater flow, geochemistry including microbial processes and solute chemistry	5-6
Able to carry out simple models for scoping calculations within the current repository context for flows and radionuclide transportation	6
Able to apply the basics of reliability and risk management for a repository system (probabilistic/deterministic approach?)	6
Understand the basic radiation and nuclear safety principles for containment and isolation (ALARA, SAHARA, graded approach, multi-barrier concept, ...).	5
Master the basics of radioactivity and of the nuclear fuel cycle and its safety	4
Understand the physical and radiological characteristics of the waste form and the radionuclides from the waste form/s	4
SKILLS (Technical and functional competence)	EQF level (1-8)
Able to analyse and integrate basic scientific knowledge from various sources (bench-, field experiments) in order to select relevant input data and models for	6

applications	
Select, use and improve the appropriate simulation tools and codes for calculations (common codes: Porflow, Feflow, Aster, Comsol, Fluent, PhreeqC, PHAST)	6
Interpret the outcomes of the simulations in support of safety arguments and identify the related uncertainties in the outcomes	6
Physical and numerical conceptualisation of the normal and altered scenarios	5-6
Able to manage all kinds of uncertainties in the models, using deterministic and multi-parametric probabilistic approach	6
Provide solutions to improve the system design and progressive management of disposal operations during the active control period of the repository	5-6
Use complementary information (multiple arguments, performance indicators) to strengthen the outcome interpretation from the modelling	5-6
COMPETENCE (Attitude; behavioural and personal competence)	EQF level (1-8)
Able to work and coordinate interdisciplinary calculation team consisting of own staff and consultants	6
Able to integrate interdisciplinary data and able to synthesize results	5-6
Able to think analytical	5
Willing to take and demonstrate accountability	5
Able to recognise safety culture behaviour	5

DRAFTED BY:	DRAFT EXTENDED IN 1ST REVIEW:	2ND REVIEW:
A. ABDELOUAS	MARJATTA PALMU	GROUP REVIEW
30.09.2014	11.11.2014	23.04.2015

Figure 6: Qualification (job profile) of Safety Engineer – Assessment and Performance Analysis for construction license of a selected site.

Most of the EQF levels (European Qualifications Framework) are 5 to 6 (Figure 7). This implies specialized to advanced knowledge, practical to advanced skills and management competencies for projects and workers.

EQF Level	Knowledge	Skills	Competence
	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, competence is described in terms of responsibility and autonomy.**
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

Figure 7: The European Qualifications Framework.

4. The program units

The qualification 'Safety Engineer – Assessment and Performance Analysis for construction license of a selected site ' is based on three units:

Unit 1: Basics

Unit 2: Foundation for radioactive waste disposal

Unit 3: Safety and performance analysis for radioactive waste disposal

4.1. Unit 1: Basics

This first unit constitutes the basic learning outcomes for a quantitative safety assessment in particular the quantification of the migration of radionuclides. This includes the rock characteristics, water/rock interactions and underground water flow. The content of this basic unit is classically covered in master programs specialized in **hydrogeology**. Thus, nuclearization of professionals with hydrogeology background seems to be adequate for the designed qualification.

Unit 1: Basics – 75 hours

Host rock / site physical and chemical characteristics
Water/rock interaction
Basics of hydrogeology
Hydrogeological and transport modelling

The contents of each outcome of Unit 1 can be detailed as follow and each outcome has been attributed a number of hours in case of a training while a learning outcome could be validated based on a working experience in the field of interest.

Host rock / site physical and chemical characteristics - **12 hours**
Rock geology and site geodynamical history and stability
Rock geochemistry, mineralogy, sedimentology
Rock geo-mechanic

Water/rock interaction - **18 hours**
Rock dissolution / precipitation processes (solubility)
Chemicals aqueous speciation (complexation) and sorption (Kd)
Redox control reactions
Microbial effect

Basics of hydrogeology - **10 hours**
The hydraulic head, porosity, permeability, hydraulic conductivity
The hydrodynamic dispersion, molecular diffusion
The retardation (adsorption, surface complexation)

Hydrogeological and transport modelling - **35 hours**
The natural flow underground (the above and under the host layer)
The transport properties of rocks at small and large levels
The impact of erosion and tectonics on water flow (geological time)

4.2. Unit 2: Foundation for radioactive waste disposal

This second unit includes the fundamental learning outcomes on radioactivity, safety, waste disposal sites, the engineered barrier system (EBS) and site evolution with time. Unit 2 constitutes the core Unit for **nuclearization** of professionals originating from non-nuclear industrial fields.

Unit 2: Foundation for radioactive waste disposal – 60 hours

The phenomenon of radioactivity and fuel cycle
Basics of risk assessment and management
The concept of engineered barrier system (EBS)
Safety requirements for disposal of radioactive waste, Safety assessment and safety case
Situations description and scenarios
Safety functions and indicators
The THMCGRB multi processes

The contents of each outcome of Unit 2 is detailed as follow with a corresponding volume of hours.

The phenomenon of radioactivity and fuel cycle - **10 hours**
Radioactive decay: radioactive isotopes, radioactive period, activity, decay chains, energy and matter
Radiation / matter interaction
Basics of radiological protection

Describe open and closed fuel cycles

Basics of risk assessment and management - **10 hours**
Risk and hazard classification
Understand the risk, nature and society relationship (perception, relevance, governance)
People and hazards (acceptability, avoidance, mitigation, transfer, management)
Risk management (identification, assessment and prioritisation)
Risk analysis (deterministic vs. probabilistic analysis)

The concept of engineered barrier system (EBS) - **10 hours**
The engineered barrier system (EBS)
The EBS evolution (hydro-chemical, thermal, mechanical, radiological)
The EBS components interactions
The radiological inventory of waste forms (high- and mid-level wastes)
The structure of the waste forms and nuclides distribution
Waste forms behaviour in storage conditions (oxidation, dissolution, radionuclides release / precipitation)
The different waste packages

Safety requirements for disposal of radioactive waste, Safety assessment and safety case - **10 hours**
Safety objectives and criteria
Governmental, legal and regulatory framework (government, regulatory body and operator responsibilities)
Safety approach (Importance of safety in the process of development and operation of a disposal facility, Passive means for the safety of the disposal facility, Understanding of a disposal facility and confidence in safety – Safety demonstration)
Design concept for safety (Multiple safety functions, Containment and isolation of radioactive waste, Surveillance and control of passive safety features)
Framework for disposal of radioactive waste (by step development and evaluation of disposal facilities)
The safety case and safety assessment (Preparation, approval and use of the safety case and safety assessment for a disposal facility, Scope of the safety case and safety assessment, Documentation of the safety case and safety assessment)
Steps in the development, operation and closure of a disposal facility (Site characterization for a disposal facility, Design of a disposal facility, Construction of a disposal facility, Operation of a disposal facility, Closure of a disposal facility)
Assurance of safety (Waste acceptance in a disposal facility, Monitoring programmes at a disposal facility, The period after closure and institutional controls, Consideration of the State system of accounting for, and control of nuclear material, Requirements in respect of nuclear security measures, Management systems)

Situations description and scenarios - **6 hours**
Disposal site scenario (events leading to the transfer of radionuclides to the biosphere)
Normal and altered scenarios (Seal failure, waste package failure, intrusive borehole, worst case)
Scenarios associated risks

Safety functions and indicators - **6 hours**
The choice of site and favourable properties to limit the water flow
The storage architecture design to limit the water flow
The indicators (Peclet number, radionuclide distribution in near- and far-field)
The geochemical processes to limit release and migration of radionuclides within disposal (radionuclides retention in the waste package, role of containers)
The radionuclides retention (adsorption) on solid phases of host rock to delay and limit radionuclides migration
The indicators (attenuation and delay)

The THMCGRB multi processes - **8 hours**
The heat load of exothermic wastes (e.g. nuclear glass, spent fuel)
Site water desaturation and saturation (role of hydrogen)
The mechanical behaviour of waste package and near field
Site chemical evolution (redox, corrosion, hydrogen production, concrete degradation, clay degradation, glass dissolution, spent fuel dissolution, radiolysis effect)
Describe role of microbial activity (waste degradation, redox control, organic and inorganic by-products formation)

4.3. Unit 3: Safety and performance analysis for radioactive waste disposal

This third Unit is based on the learning outcomes of Unit 1 and Unit 2 including data gathering and management, mathematical and numerical modelling, uncertainties and quality management.

Unit 3: Safety and performance analysis for radioactive waste disposal – 90 hours

Data gathering and management
Physical, mathematical and numerical models for assessment of the performance of a repository
Uncertainties management
Quality management strategies and procedures

The contents of each outcome of Unit 3 is detailed as follow with a corresponding volume of hours.

Data gathering and management - **10 hours**
Field and bench data gathering
Literature data gathering
Engineered barrier system data gathering
Waste data gathering
Data processing (extrapolation, interpolation, empirical data)
Planning of data traceability, documentation, record keeping and quality management
Records of all relevant information over the lifetime of the repository
Site descriptive model (SDM)

Physical, mathematical and numerical models for assessment of the performance of a repository - **50 hours**
The physical processes governing solute transport (advection, diffusion, dispersion)
The mathematical equations used in safety calculations [continuity equation, Darcy equation, transfer of solute (radionuclides) in saturated porous media, retardation coefficient (adsorption), solubility limit (precipitation), flux calculations (diffusive, advective), travel time calculations (advection, diffusion, dispersion), Peclet number (local, global)]
Numerical tools and features to solve physical and mathematical problems (mathematical resolution of equations, numerical resolution, parameters associated to models: adequation input data / objective, representativity, grid/mesh, boundary conditions)
Different steps to be performed to assess and quantify scenario (selection of calculation tools for each scenario/compartment, selection of numerical parameters for best compromise with physics and safety objectives, benchmark)
Conceptual model calculations (package, disposal cell, repository, geological environment, biosphere)

Uncertainties management - **20 hours**
Uncertainty (distribution/variability) and sensitivity (rank data critical to uncertainty of result) analysis using deterministic, Monte Carlo probabilistic and ANOVA methods
Uncertainty analysis (distribution/variability of different PA/SA indicators)
Sensitivity analysis (quantification and ranking input data critical to uncertainty of result)
Monte Carlo techniques, deterministic, ANOVA methods…
Uncertainty and sensitivity analysis results: feed-back on R&D, improvement of repository understanding and design…)

Quality management strategies and procedures - 10 hours
Quality management strategies and procedures
Quality management procedures (planning, control, quality assurance)
Quality management tools and techniques, records, reporting

5. The learning Outcomes

According to ECVET scheme described in Figure 5 the learning outcomes declined in terms of knowledge, skills and competencies are given for each Unit.

Unit 1: Learning outcomes (KSL)	
Knowledge	Give the main caracteristics of rock (mineralogy, geochemistry, geo-mechanics,…)
	Give the main hydro-geological caracteristics of rock (porosity, permeability, diffusion, convection, adsorption…)
Skills	Perform hydrogeological and transport modelling using conventional tools (Poreflow, Feflow, Comsol,…)
Competencies	Able to integrate interdisciplinary data and able to synthesize results Analytical thinking

Unit 2: Learning outcomes (KSL)	
Knowledge	Define the notions of activity, intensity of radiation, half-life
	Define risk and hazard
	Define the safety approach and legal framework
	Describe waste inventory, waste forms, waste packages and overall the EBS
Skills	Perform risk analysis (deterministic vs. probabilistic analysis)
	Build a disposal site scenario (normal, altered scenario) with associated risks
	Describe the safety functions and indicators
	Give THMCGRB multi processes
	Build a safety case and perform safety assessment
Competencies	Critical and analytical thinking Safety culture Decisiveness

Unit 3: Learning outcomes (KSL)	
Knowledge	Describe and use a site descriptive model (SDM)
	Give a safety calculations architecure
Skills	Select and use the physical processes and mathematical equations for safety calculations
	Select and use the numerical tools for safety calculations
	Establish the conceptual model calculations
	Perform uncertainty and sensitivity analysis
Competencies	Apply quality management strategies, procedures, tools and techniques, records and reporting Problem solving Stress tolerance

6. Conclusions

We applied the ECVET system to design a qualification in the field of safety analysis and performance related to radioactive waste geological disposal. The qualification (job profile) was broken into three Units constituted of a set of Learning Outcomes (knowledge, skills, competencies) that could be easily assessed. The Units were designed to easily allow the nuclearization of human resources from non-nuclear industry. Thus, Unit 1 concerns professionals from earth sciences fields including hydrogeology, geology, geochemistry….Unit 2 is meant for nuclearization of non-nuclear human resources in the field of geological disposal of radioactive waste. Finally, Unit 3 is based on Learning Outcomes from Unit 1 and Unit 2 in addition to specific Leaning Outcomes including quality management and procedures.

The qualification described in this report is a key example in the field of geological disposal where a multitude of knowledge, skills and competencies are required to achieve the required tasks. Thus, classical education and training models (university degrees) may not be adequate to provide trainees with multi-disciplinary profiles. In this case ECVET will play a fundamental for human resources development in the field of radioactive waste management. The outcome of WP1 can be used to design different qualifications related to radioactive waste management.

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