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 3.1

Report on the criteria for selecting the E&T products

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

Author(s) Guillem Cortes, Michèle Coeck, Tom Clarijs, Nele Kesteloot, Lisanne Van Puyvelde, Concetta Fazzio, Gunnar Buckau, Emi Kassim, Dario Manara, Irmgard Niemeyer, Pascal Franco, Filip Tuomisto, Behrooz Bazargan-Sabet, Harry Eccles, Jonathan Francis and Sandeep Kadam

Date of issue: 25/06/2019

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.eu/en/projects/annette.html

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

Scope	ANNETTE / WP 3	Version:	1
Type/No.	Deliverable Report 3.1	Total pages	40
Title:	Report on the criteria for selecting the E&T products	Chapters:	8
Access:	Public	Appendices	1
Filename:	ANNETTE_WP3_Deliverable_D31	Suppl. pages:	0
Internet	http://www.enen.eu/en/projects/annette.html		

RESPONSIBLE BENEFICIARY: UPC

DOCUMENT TRACKING

	Name	Follow-up Email to Coordinator	Date
Prepared by	Guillem Cortés and WP3 partners		10/09/2018
Reviewed by Referee(s)	WP3 partners		30/09/2018
Updated by Referee(s)	WP3 partners		25/06/2019
Quality assurance (QA leader)	Leon Cizelj		
Approved by Coordinator	Pedro Diéguez Porras		

ABSTRACT:
The present report concerns the identification of needs for E&T, aiming to plan the preparation of teaching material adapted to new technologies in the fields of geological disposal, radiation protection, nuclear fuel properties, and nuclear safeguards and security. This represents the first deliverable released in the frame of Work Package 3.

TABLE OF CONTENTS

1. Objective of the work

In the framework of the ANNETTE (**Advanced Networking for Nuclear Education and Training and Transfer of Expertise**) project and as part of the work package on "generational transfer of expertise: promoting knowledge, skills and competencies preservation in front of personnel turnover" (WP 3), UPC led the task 3.1. This task is aimed to identify the needs and the opportunities for the production of new educational material, in the form of books, e-books and multimedia. In particular, the areas of geological disposal, radiation protection, nuclear fuel properties and behaviour, and nuclear safeguards.

2. Description and Objectives of Task 3.1 of ANNETTE project

As given in the project description of objectives [1], the objective 3 is related with the promotion of knowledge preservation in front of personnel turnover by producing teaching material. The aim of this report is to identify the needs for E&T material and to provide some recommendations to prepare teaching material adapted to new technologies in the selected fields.

3. E&T material available

3.1. Topics covered by E&T material

The topics covered by the E&T material to be developed in this project are: geological disposal; radiation protection; nuclear fuel properties and behaviour; nuclear safeguards and security. These topics have been selected from a set of topics taking in account the results presented on deliverables of WP1 and WP2 (see [2] and [3] respectively).

3.2. Description of types of material available

3.2.1. Geological disposal

Works already undertaken by the PETRUS projects identified an adequate framework for addressing Education and Training objectives in the context of underground radioactive waste disposal activities. This initiative has provided means to strengthen European co-operation, for mitigating prospective risks of scarceness of high-educated workers. The first priority was clearly the creation of attractive courses, which arouse students to choose and pursue studies on underground disposal. These courses are targeted for delivery at the final year of Engineering and second year of Master (MS) degree in different disciplines related to the geo-science engineering.

The PETRUS consortium observed that assembling the critical mass in terms of students, teachers and facilities for launching specific waste disposal academic programme is beyond the capability of any individual university. Thereby, not only European universities but also public bodies in charge of radioactive waste management (i.e. national agencies and regulators) and industry must rely on

collaborative effort to meet the challenge of supplying sound curricula in this field. Since adequate human resources are scarce and public funds are rare it is preferable to act and mobilise resources at the European level rather than the national level. Likewise, it is more efficient to join efforts towards building a common curriculum rather than several scattered programmes.

The main idea of a common curriculum development is to share the best human resources and pedagogic materials available at each partner institution. Partners will jointly audit themselves and compare the content of available courses in different allied disciplines that can contribute to the expected content of the educational programme, assess stakeholders' resources that can be included in the programme, study how pooling resources that can be used to gain efficiencies and finally decide the scope of course curriculum.

The consortium also stated that as a wide number of disciplines are extensively used in the field of radioactive waste disposal, providing students with an extensive range of skills across the disciplines must be one of the main objectives of the educational programme. The goal is not to teach exhaustively all concepts to all students, but to provide them with a necessary foundation where they can teach themselves what is needed during their professional life or their future academic research in this expending multidisciplinary area. Thereby, such multidisciplinary lectures must be arranged so that students may attend courses outside their initial area of expertise. Curriculum must be developed in such a way that lectures can be offered from several universities, so that the programme can have the best quality that partners can offer regarding their staff and experiences. For this purpose, live lectures to be simultaneously broadcasted to students at multiple distance sites seem to be efficient. However, the use of multimedia facilities does not have to compromise the effort for students' mobility. Students must be highly encouraged to visit other institutions during their study. This will provide them with a flexible and interesting learning experience and will allow them to become more familiar with technologies, concepts and culture of other countries.

Finally, the consortium stressed that curriculum must have a real impact on boosting academic research. As many scientific subjects related to the radioactive waste disposal still belong to the research domain, the programme must be tailored in such a way to arouse top level students' interest in pursuing radioactive-waste storage studies at PhD level.

3.2.1.1 Planning R&D Programme towards Geological Disposal

Within the objective of continuous professional development, the planning of research and development programs towards a geological disposal has been considered an important area to be addressed in particular for waste management programs that are at an early stage. Indeed, within the IGD-TP and the JOPRAD project it has been agreed that Specific Training for Planning of RD&D Programmes towards Geological Disposal (cf. IGD-TP PLANDIS Guide) needs to be implemented. Since this area will most probably develop over the coming years, the associated training materials is in electronic format. Moreover, this type of knowledge is relevant for different professional profiles, which would need to acquire background knowledge. Therefore, the foreseen training is organised in a two-step approach with each step having its own syllabus and E&T material. The first step has a preparation character addressing general knowledge on Geological Disposal and the associated materials are of e-learning type. The second step addressing the more specific topics related to the planning has its own syllabus and the associated material for the time being is in the

form of presentations. In summary, within this framework the training material prepared is of different type:

- E-learning material (http://elearning.iaea.org/m2/course/index.php?categoryid=60) prepared in collaboration with IAEA. In table 1 the syllabus for the needed background knowledge is presented.
- The e-learning material is complemented with additional information and supporting material, such as the Waste Directive (Official Journal of the European Union, L 199, 2 August 2011 "Council Directive 2011/70/Euratom of 19 July 2011 establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste"), the PLANDIS Guide (T. Beattie, R. Kowe, J. Delay, G. Buckau, D. Diaconu "RD&D Planning Towards Geological Disposal of Radioactive Waste Guidance for less advanced Programmes", IGD-TP, 30th June 2015) and the NAPRO Guide ("Guidelines for the establishment and notification of National Programmes under the Council Directive 2011/70/Euratom of 19 July 2011 on the responsible and safe management of spent fuel and radioactive waste", ENEF Working Group Risk Working Group on National Programmes NAPRO January 2013).
- Classroom lectures material in form of hands-out presentation. This material is archived and publicly available (e.g. http://2016.radioactivewastemanagement.org/index.php). In table 2 the syllabus for planning R&D programmes towards geological disposal is presented.

Table 1: Syllabus for the preparatory course

Disposal	***Basic Concepts of Disposal***
	• Introduction to Basic Concepts • Waste Classification • Multibarrier Disposal System • Waste Forms and Waste Packages
	Planning and Managing Repository Programmes
	• Strategies and Approaches for Selection of Radioactive Waste Disposal Sites
Geological Disposal	***Geological Disposal Concepts***
	Safety Case Development and Safety Assessment
	Geological Facility Siting and Site Characterization
Safety Case Development	***Framework for the Licensing Process***
	• Governmental Responsibilities with Safety • Responsibilities and Functions of the Regulatory Body and Operator: Authorization Process
	Safety Requirements for Safety Assessment and Safety Case
	• General Safety Requirements for Safety Assessment

	Safety Assessment
	• Safety Assessment Part 1 • Safety Assessment Part 2
	Safety Case
	• Role and Development of Safety Case and Components of the Safety Case • Specific Issues to be Considered in the Safety Case • Documentation and Use of Safety Case
	Review Process of the Safety Assessment and Safety Case
	• Management of the Review Process of the Safety Assessment and Safety Case • Conducting and Reporting the Technical Review of the Safety Case and Safety Assessment

Table 2: Syllabus for the Planning R&D Programme towards Geological Disposal.

R&D Planning: Context and Overview
Radioactive Waste Inventory and Disposal Options
Roadmap towards developing a DGR programme
Development of a 'Needs-Driven' RD&D Programme
Key factors influencing DGR development
The use of Scientific Readiness Levels SRLs™ in the Planning of Waste Disposal RD&D
Integrating DGR development in the national front-end and back-end strategy
IMPLEMENTING THE R&D PROGRAM
Safety Case for the Disposal of Radioactive Waste and Spent Fuel
Site investigation – From desktop to in-situ studies
Engineering developments – From generic to site specific
Safety Assessment Tools and Methodologies
GOVERNANCE AND CASE STUDIES FOR R&D PROGRAMMES
Governance: Preparing, informing, and obtaining needed decisions to progress with programme development
National case study: Programme at early siting stage
National case study: Mature programme without active siting
EURATOM RD&D Programme

3.2.2. Radiation protection

Education and training in radiation protection has always been driven by legal obligations in nuclear and radiological safety. The Council Directive 2013/59/Euratom of the European Commission (Basic Safety Standards BSS) describes in Chapter IV several profiles in radiation protection[1] which require specific education and training:

- Radiation workers (including workers potentially exposed to orphan sources)
- Emergency workers
- Medical professionals exposing patients to ionizing radiation
- Occupational health physicians
- Professionals responsible for individual monitoring of radiation workers
- Radiation Protection Officer (RPO)
- Radiation Protection Expert (RPE)
- Medical Physics Expert (MPE)

The education and training for some of these specific profiles were addressed in several European projects, such as:

- RPE & RPO : ENETRAP I, II and III
- MPE: MPE project, EUTEMPE-RX
- Medical professionals exposing patients to ionizing radiation: MEDRAPET

The main outcomes of each of these projects, relative to this task within ANNETTE WP3 are briefly discussed.

ENETRAP training scheme

In the framework of the European Network on Education and Training in Radiation Protection (ENETRAP), a European Reference Training Scheme was developed for the Radiation Protection Expert (RPE), as shown in Figure 1. This reference scheme contains several training modules which can be followed to obtain a licence as radiation protection expert. Each module consists of a number of training courses. These are linked to specific competences and activities that a Radiation Protection Expert requires in compliance with Council Directive 2013/59/Euratom (BSS).

[1] The requirements for professionals involved in radioactive transport are described in international legislation, such as the ADR treaty. This target group is out of the scope of this document.

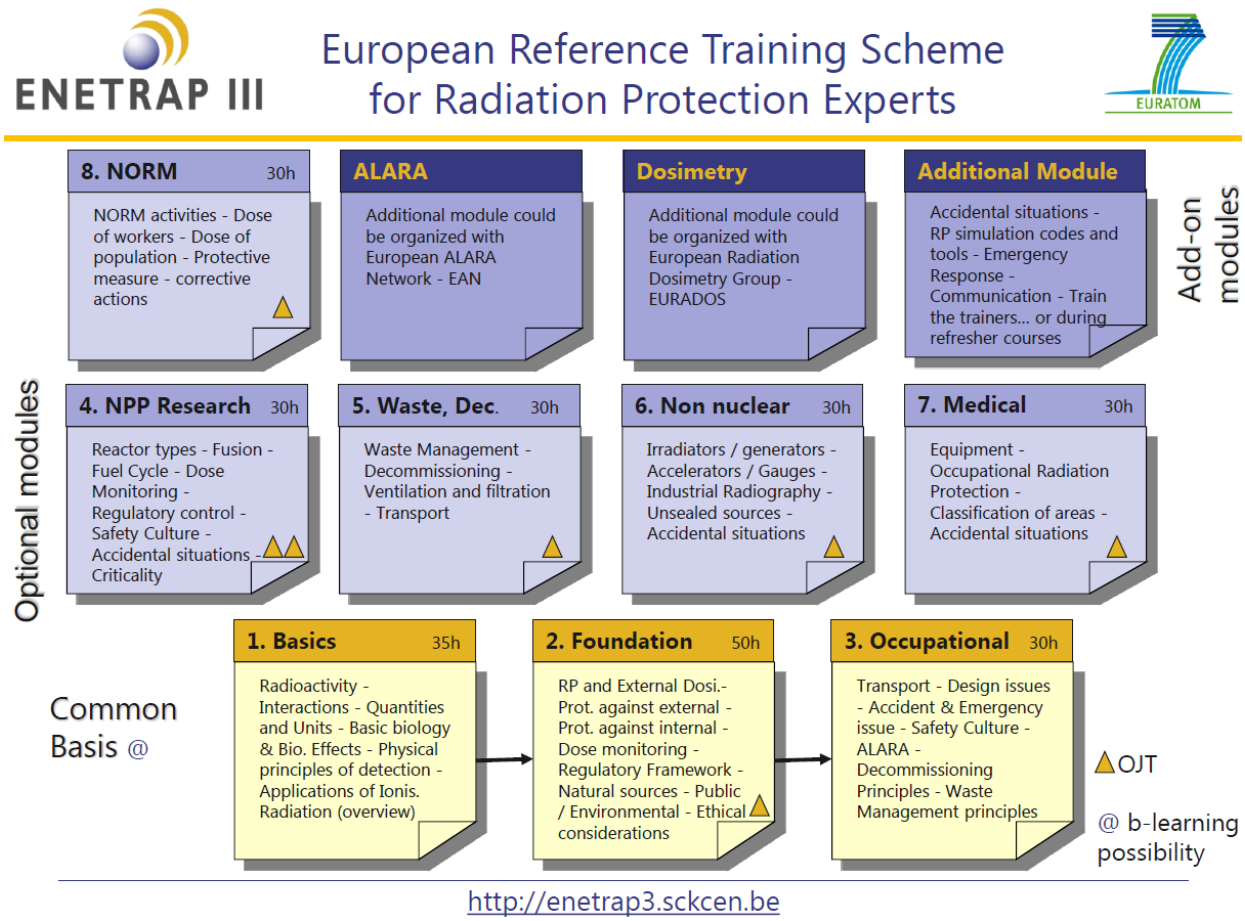


Figure 1: European Reference Training Scheme for Radiation Protection Experts, developed in the frame of the ENETRAP III project.

The training scheme consists of three basic modules:

1. Basics of radiation protection
2. Foundation of radiation protection
3. Occupational radiation protection

Next to that, five advanced modules are defined, of which pilot courses of three modules have been organized by the ENETRAP III partners at different locations in Europe:

1. Nuclear power plants & Research reactors
2. Medical applications
3. Geological disposal

A specialised module “Train-the-trainer” was designed for trainers who have to instruct and coach Radiation Protection Experts (RPEs) and/or Radiation Protection Officers (RPOs). It aims to provide various and innovative teaching methods and introduce the ECVET approaches.

Several pilot courses of the basic modules as well as the advanced modules were run during the ENETRAP project series.

A book was developed by the partners of the ENETRAP II project which contains the basics of the European Radiation Protection Course. This book is also available as e-book[2].

In the ENETRAP III project, an online radiation protection knowledge management system was created to allow further capacity building in radiation protection. The website of the EUTERP Foundation (http://www.euterp.eu) was used as a basis and serves today as a knowledge platform where information on educational resources can be found, as well as professional information for the radiation protection professionals. Examples are the library section where references that are useful for E&T in Radiation Protection in various domains can be downloaded. Further information on international legislation, reference documents, and e-learning, as well as links to relevant projects in radiation protection can be found.

A specific feature of this platform is the link to the online database http://euterpdb.org, which acts as a main point of information for (training) courses, academic education, internships, PhD and postdoc opportunities, on-the-job training, job opportunities, workshops, conferences, symposia and E&T organizations in the field of radiation protection in Europe.

European Master in Radiation Protection (EMRP)

The Master in Radiation Protection from the University of Grenoble 1 (UJF) and CEA/INSTN offers a one-year specialized professionalizing training in the second year of the Master Health Engineering and Medicine. Since 2008, under the leadership of the European project ENETRAP, the degree became a European Master in Radiation Protection in combination with other European universities (CTU in Czech Republic and UHI / NHC in Scotland).

This unique professionalizing degree in France follows the Diploma of Specialized Higher Education in Radiation Protection, which since 1995 has trained two hundred professionals in radiation protection.

The EMRP is a one-year study programme of 60 ECTS, containing the following courses:

1. Fundaments on ionizing radiations – 3 ECTS
2. Biological effects of ionizing radiations – 3 ECTS
3. Radiation detection and measurements, applied dosimetry – 3 ECTS
4. Management of radiological risk and regulatory basis – 3 ECTS
5. Radiation protection in the professional environment – 6 ECTS
6. Public exposure – 3 ECTS
7. Safety / Radiation protection interface, Accident situations – 3 ECTS
8. Medical exposure – 3 ECTS
9. Standard security, non-ionizing radiations – 3 ECTS
10. Internship (6 months) – 30 ECTS

[2] Philippe Massiot, Christine Jimonet - European Radiation Protection Course: Basics https://books.google.es/books?id=o2n0AwAAQBAJ&hl=en&source=gbs_slider_cls_metadata_9_mylibrary

MEDRAPET

The MEDRAPET project aimed to provide an update of the education and training requirements for medical professionals exposing patients to ionizing radiation. The final deliverable of this project was the EC publication Radiation Protection 175[3], which represented an update of Radiation Protection 116, and consisted of (core and specific) learning outcomes for various medical professionals. These learning outcomes are formulated in terms of knowledge (facts, principles, theories and practices), skills (cognitive and practical) and competences (responsibility and autonomy) following the ECVET principles.

MPE project

The MPE project addresses the various aspects related to competences of the medical physics expert (MPE): the role, mission and activities; the qualification and E&T curriculum frameworks; the approach for national recognition; and the staffing levels. The main deliverable of this project was published as Radiation Protection 174[4].

EUTEMPE-RX (http://www.eutempe-rx.eu/)

The MPE is an expert in radiation protection with a focus on the radiation protection of the patient. Due to the nature of the tasks and responsibilities of this profile, combined with the rapid changing challenges in medical imaging and therapy, the knowledge, skills and competences/attitudes are estimated to be on EQF level 8. In order to reach and maintain this level, specialised training courses were developed in the EUTEMPE-RX project for medical physics experts active in medical imaging.

Other E&T initiatives in radiation protection

For the remaining profiles no dedicated E&T European projects were initiated within Euratom, although some training courses for professionals active in nuclear emergencies were developed by NERIS. Most of the professionals in radiation protection are trained on a local or national level. Few to no international reference guidance documents exist to address the training needs, recommend training content, format and evaluation, with exception of the documents and training courses of IAEA. For example, the IAEA postgraduate educational courses (PGEC), which are organised in regional training centres around the world.

Several education and training initiatives in radiation protection are organized by different national and international training providers. For example, the SCK•CEN Academy for Nuclear Science and Technology organizes multiple basic training courses and training courses for Continuous

[3] https://ec.europa.eu/energy/sites/ener/files/documents/175.pdf
[4] https://ec.europa.eu/energy/sites/ener/files/documents/174.pdf

Professional Development (CPD) for professionals in radiation protection. The offer of courses can be found on http://academy.sckcen.be/en/Customised_trainings/Calendar.

Part of the courses presented in the Nuclear Fuel Schools organised by CEA and JRC mentioned in the following section were devoted to the essential principles and applications of radiation protection. Moreover, some JRC hot laboratories were visited, and students could practice, under the supervision of specialised JRC staff, with the use of training glove boxes, tele-manipulators, radiation detectors etc. In addition, they were guided through a detailed visit of KIT contamination medicine and de-contamination laboratories.

3.2.3. Nuclear fuel properties and behaviour

Only limited E&T material is available for Nuclear Fuel properties and behaviour. In the past couple of decades CEA organised comprehensive schools on nuclear fuel properties and behaviour in the context of the "Ecole du Combustible" (proposed also in English as "Plutonium School"). These schools lasted one to three weeks, depending on the category of attendees. The organisation of these schools has been taken over by ISTN in the last couple of years. More recently, an inter-semester on this topic course was jointly organised by JRC and CEA within the GENTLE project. The following topics were addressed, based on the previous CEA experience:

- Nuclear Fuel Cycle Overview
- Fuel Fabrication Processes
- Fuel Handling Risks and Medical Follow-up
- Fuel Characterisation and Properties
- Accidental scenarios
- Fuel Industrial Reprocessing-Waste Management
- Laboratory visits (JRC and KIT)
- Introduction to safety and criticality
- Practical Work in training glove box

This inter-semester course had an important hands-on training component, much appreciated by the students. Moreover, within GENTLE a MOOC was prepared and launched on the EdX platform (https://www.edx.org/course/understanding-nuclear-energy-delftx-nuclear01x-0). This MOOC had a one session dedicated to Nuclear Fuels.

A supporting text for a course on this topic must thus cover most of the above subjects at an undergraduate level. However, nuclear fuel properties and behaviour is a broad field, encompassing chemistry, physics and materials science. Thus, a classical text book addressing basic in nuclear fuel is not available. However, hereafter there is a list of reference books that are useful for indicating to students a reading path. D. Olander's "Fundamental aspects of nuclear reactor fuel elements" [4] remains a good and comprehensive work on fundamental properties and applications of Nuclear Fuels from a physical/material science point of view. First edited in 1976, this book has been updated and re-edited recently. D. Olander also published an interesting review paper on recent nuclear materials a few years ago [5]. Relevant information on nuclear fuel can be found also in the

"Comprehensive Nuclear Materials" Encyclopaedia, published in 2012 by Elsevier under the supervision of R.J.M. Konings [6]. The latter addresses in a comprehensive way conventional fuels as well as the so-called “advanced” nuclear fuels (metals, carbides, nitrides, molten salts), most of which are planned to be used in Generation IV Systems. Chapters are written by different authors, with specific approach needed for the topic (chemical, physical, ...). More details on advanced fuels can be found in Hj. Matzke’s work "Science of advanced LMFBR fuels", North Holland (1986) [7]. As part of the e-den series, CEA has issued a monograph on Nuclear fuels, in both French and English language, written by specialists from the organisation. It has a low-entry level, and it extremely well suited for non-specialists and wider public (ISBN-2-281-11346-4). A new book called " Advances in Nuclear Fuel Chemistry" under the editorship of M. Piro is currently under preparation, which covers basic and applied aspects related to nuclear fuel. Finally, it is worth mentioning also the behaviour of nuclear fuels under accidental conditions, a topic which has sadly come back to fashion after the Fukushima Daiichi disaster (2011). In this field, a comprehensive work with the title: ”Nuclear Power Reactor Core Melt Accidents: Current State of Knowledge”, was published in 2015 in the IRSN Science and Technology Series, under the co-ordination of D. Jacquemain [8].

In our opinion, the available material is thus sufficient to support training courses on Nuclear Fuels for various levels and backgrounds, using texts from different sources.

3.2.4. Nuclear safeguards

There are typically three types of nuclear safeguards E&T material already developed: i) that which is used in safeguards E&T and which is accessible to anyone; ii) that which is used in safeguards E&T and which is accessible to course participants, and iii) nuclear safeguards training of IAEA inspectors by the IAEA.

Only very limited amounts of E&T material is available under i). One course, “Introduction to Safeguards” (http://elearning.iaea.org/m2/course/view.php?id=169) has been developed by the IAEA as an e-learning course, but its development proved to be very challenging due of the sensitivity of legal wording and it does not seem likely to expect more courses of the same type to be developed by the IAEA. The safeguards course and its video material with associated knowledge checks is accessible to anyone who registers a NUCLEUS account at the IAEA website. The safeguards course covers the topics of “The nuclear non-proliferation regime”, “IAEA safeguards”, and “The main obligations for States under the NPT”.

One other open safeguards course, the “Nuclear Safeguards and Non-proliferation” course, is offered by the ESARDA (European Safeguards Research and Development Association) though JRC Ispra. JRC Ispra facilitates and administers the course and offers it free of charge to approximately 50-60 participants. This course is targeting master students in nuclear engineering as well as to young professionals and international relations/law students. The course is at least annually given at JRC Ispra, and occasionally also at other locations inside and outside Europe (Uppsala, Sweden; Kuala Lumpur, Malaysia). The course offers a comprehensive overview of the safeguards field and it aims at stimulating the participant’s interest. Within the scope of this course, a textbook with the same

name as the course itself has been developed, and is distributed to the course participants. The book is also publicly available at the ESARDA course site https://esarda.jrc.ec.europa.eu/images/files/ESARDA_Course/nuclear_safeguards_and_non-proliferation%20final.pdf. The course also contains practical exercises, which are conducted at the JRC Ispra. During the execution of the course, the lecturers in many cases present power point material, which also becomes available to the course participants in connection to the course.

A Nuclear non-proliferation and safeguards course is also given at the RWTH Aachen University in Germany as part the M.Sc. programme "Nuclear safety engineering". The course material consists of presentation slides, which after translation and amendment to the overall ANNETTE course structure could be made available. Similarly, classes have been given at the IAEA on "Statistical Concepts for Safeguards" and "Game Theory". Both courses are available in English, and can be made available to ANNETTE after slight modifications.

With respect to ii) the European Committee offers a nuclear safeguards training course to member states (https://ec.europa.eu/energy/sites/ener/files/documents/flyer2017.pdf). The purpose is to give a general understanding of the EURATOM Treaty and nuclear safeguards in the EU, and to familiarize course participants with the legislative framework for implementing EURATOM nuclear safeguards. The course material is available only to course participants and includes power point material, case studies, journal publications etc. There are also occasional videos on e.g. how to use particular instruments during inspections. But it all concerns tailor-made EURATOM instruments and it is for internal use only. There are also other nuclear safeguards courses which are open for non-nuclear safeguards inspector applicants. Two examples are the GENTLE safeguards course and an intensive summer course in the policy aspects of nuclear safeguards. In both cases, the course material in this course is available to course participants. The GENTLE project offers a course called Nuclear Safeguards and Security course (http://gentleproject.eu/courses/nuclear-safeguards-and-security-course/). This course is given at SCK·CEN in Belgium. This course targets Master and PhD students coming from the GENTLE partners. The course is similar to the ESARDA course and offers both fundamental safeguards information as well as advanced such with the inclusion of exercises as well as workshops. The course material in this course is open to course participants only and consists mainly of power point material and exercise material. With respect to nuclear policy, an intensive summer course in nuclear safeguards is offered by the Middlebury Institute of International Studies at Monterey (MIIS) in conjunction with the Lawrence Livermore National Laboratory (LLNL), and sponsored by the National Nuclear Security Administration (NNSA) (http://www.nonproliferation.org/education/courses/international-nuclear-safeguards/). The course content covers international safeguards, its concepts and evolution as well as state-level safeguards analysis and case-studies. It also contains an introduction to the technical measures applied in nuclear safeguards.

On the topic if iii), there is substantial nuclear safeguards training ongoing within different IAEA support programs. This training is however targeting mainly IAEA inspectors or other participants which are proposed by their States; thus these courses are not open for application. The training material of these courses needs to be presented by an instructor due to the sensitivity of legal wording and risk of misunderstanding. Examples of other courses offered by the IAEA on the topic of safeguards typically target different equipment or challenges. Examples of such courses are for

instance the course on how to safeguard research reactors and critical assemblies as offered jointly by the Belgian Support Programme for safeguards in collaboration with the US Support Programme, or the Partial defect detection course using the DCVD instrument as offered jointly by the Swedish and Canadian IAEA support programmes. The material disclosed in such courses is only available to the course participants.

3.2.5. Nuclear security

It is known generally that the likes of the IAEA and World Institute for Nuclear Security (WINS) were involved in the provision of workshops, meetings and conferences that involved nuclear security, but not at Masters level and/or with an academic qualification.

The IAEA for example provide international nuclear security awareness programmes but these tend not to lead to qualifications or certification. The Agency in 2009 created the International Network for Nuclear Security Training and Support Centres (NSSC) in an attempt to encourage collaboration and coordination of industry-related training initiatives. A year later, it founded the International Nuclear Security Education Network (INSEN) in conjunction with various academic institutions to promote and support nuclear security education, especially at the academic level.

In an attempt to gauge the needs of nuclear security training etc. WINS Academy conducted a gap analysis across 180 countries from August 2012 to December 2012. This analysis indicated that 'approximately 230,000 professionals have accountability for nuclear security worldwide. Approximately 75% of these are onsite professionals, and approximately 25% are offsite professionals. The majority are employed in medical institutes using radioactive sources. Europe accounts for approximately 59,000 professionals with accountability for nuclear security'. This from UCLan' s perspective (definition of security) appears to be a high number and may include personnel with responsibility of safeguards of nuclear material, i.e. IAEA definition.

The WINS Academy survey did produce: 'As of January 2013, the only certified courses for nuclear security management that could be identified from open sources are those for postgraduate students. The only universities offering certified courses are Kings College and the University of Central Lancashire, both in Great Britain'.

The key questions UCLan' s survey raise are:

Why such a low number of academic institutions involved with Masters courses?

1. How many nuclear security professionals does the industry need?
2. Is a Master's degree necessary for professional status or can it be provided by on the job training?

The results of UCLan's survey may provide some answers to these questions which are presented in appendix.

4. Needs of E&T material

4.1. Geological disposal

The assessment of available courses on radioactive waste management and disposal had been undertaken by CETRAD European project funded under the FP6. The Petrus consortium updated this survey through large consultation of stakeholders across Europe and extended the work to the evaluation of the current and prospective needs in terms of Education and Training by carefully questioning industrials, waste management organisations (WMO) and technical support organisations (TSO) on the issue. The participants were asked to fill out an on-line questionnaire. The results were then discussed with the participants, misunderstandings were addressed and information was restructured.

From this collection the consortium concluded that for most of the topics for which organizations expressed needs, courses are available albeit under some minor modifications. The topic of waste conditioning in relation to disposal was seen as marginally treated as well as the topic of waste acceptance that was not covered by any dedicated courses.

In order to create appropriate materials for a common programme, the collaborative work undertaken by the consortium has led to the identification of the following items, which constitute the Petrus syllabus:

Overview of Nuclear Power
– Radiation fundamentals
– Nuclear Plants
– Nuclear fuel cycle

Radioactive Wastes
– General background
– Sources of nuclear waste
– Principles of nuclear waste management
– Treatments
– Nuclear waste transportation, storage and disposal

Geological Disposal
– Concepts of geologic disposal
– Selection of waste disposal sites
– Geological disposal performance
– Natural Analogues
– Case study

Social issues
– The Energy Debate, nuclear power and radioactive waste disposal
– Public concerns
– Communication and transparency

Safety Assessment
– Objectives and scope of the safety assessment
– Safety assessment methodology
– Reliability of the safety assessment
– Probabilistic safety assessment (PSA) in the context of geological disposal
– Sensitivity and uncertainty analysis

Safety assessment practices in radioactive waste management
– International rules and principles applicable to the radioactive waste disposals
– Safety requirements and performance assessment of a radioactive waste disposal
– Risk analysis

4.1.1 Planning R&D Program towards Geological Disposal

In view of the long lead-times and operational time-spans for radioactive waste management programs, including disposal, it needs to be ensured that Knowledge is preserved and kept available. Therefore, within the JOPRAD Project (Towards a Joint Programming on Radioactive Waste Disposal) it has been proposed to establish an Integrated Knowledge Management System (IKMS). Research, development and demonstration (RD&D) for the safe long-term management of radioactive waste is carried out since several decades and as part of the EURATOM Research and Training Programme. In the case of Geological Disposal, that start of operation for the first facilities will take place within the next decade, and their operation should last several hundred years. In the meantime, the generation of scientists involved since the early phase of these programmes are retiring. Because of the long duration of the programs, management of the acquired Knowledge, including transfer between generations, becomes absolutely critical.

The overall objectives of the IKMS are to establish, maintain and make accessible Knowledge in the field of radioactive waste management at the European level. The central activity is documenting and keeping up-to-date the state of Knowledge in the different identified topical domains. Knowledge is based on Data and Information but is also the basis for developing Competence and Skills that reside with experts and their experience. The IKMS is designed to collect, generate, share, and distribute Knowledge by assigning meaning to information and data. It is then used to build Competencies and Skills, and creating intellectual capital.
There are several types of activities that feed and update Knowledge and there are activities aiming at using the Knowledge, as well as making it useful for different users. Such activities are:

- Education for generating a competence base for present and future needs,
- Training in support of generating, developing and maintaining specific expertise and competence,
- Strategic Studies developing specific topics, including the needs for developing further Knowledge,
- Guidance on selected topics making the Knowledge accessible for specific purposes and applications,

- Mechanisms for transfer of pre-existing Knowledge between different national Programs of different competence levels, but also with respect to different implementation time schedules, and
- Dissemination and exchange of the Knowledge to the expert community and potentially other interested parties.

4.2. Radiation protection

As stated in 3.2.1, several profiles are identified in legislation on radiation protection which require specific education and training:

- Radiation workers (including workers potentially exposed to orphan sources)
- Emergency workers
- Medical professionals exposing patients to ionizing radiation
- Occupational health physicians
- Professionals responsible for individual monitoring of radiation workers
- Radiation Protection Officer (RPO)
- Radiation Protection Expert (RPE)
- Medical Physics Expert (MPE)
- Professionals involved in radioactive transport

In order to comply with the changing legislative requirements of these profiles, new needs regarding radiation protection training initiatives have arisen over time. The evolution of the qualified expert in radiation protection towards a RPE and RPO introduced a new framework in all European countries. The training needs of the RPE and RPO have been addressed in the ENETRAP project series, and reference documents are published on the website of ENETRAP (http://enetrap3.sckcen.be) and the EUTERP Foundation (http://www.euterp.eu).
The training needs and recommendations for the MPE have been addressed in the Medical Physics Expert project, and have been published in EC publication radiation protection N° 174[5].
The training needs and recommendations of the medical professionals exposing patients to ionising radiation have been addressed in the MEDRAPET project and have been published in EC publication radiation protection N° 175[6].

No up-to-date European reference training standards or training needs are currently available for radiation workers active in different nuclear and radiological domains. For occupational health physicians, emergency workers as well as professionals responsible for individual monitoring of radiation workers, no reference training standards exist, although international documents are available that can be used for E&T purposes (e.g. IAEA documents and training courses, such as the postgraduate educational courses (PGEC)).

[5] https://ec.europa.eu/energy/sites/ener/files/documents/174.pdf
[6] https://ec.europa.eu/energy/sites/ener/files/documents/175.pdf

4.3. Nuclear fuel properties and behaviour

Within the ANNETTE project it was proposed to develop a specialized course on nuclear fuel properties and behavior, largely based on the assessment performed in GENTLE for the organization of an Inter-semester course and a module of the MOOC. According to this proposal, a syllabus was prepared and reported in the table hereafter (table 3):

Table 3: Syllabus for the Inter-semester course

Introduction to the fuel cycle and to different types of nuclear fuels. • Nuclear Fuel Scenario • Nuclear Fuel Cycle • Advanced Fuels
Introduction to materials science of nuclear fuels. • Relation between structure and properties of nuclear fuels. • Nuclear fuel chemistry. • Introduction to materials characterisation methods.
Thermodynamic properties of oxide fuel under normal and extreme conditions • Definition of thermodynamic parameters and relevant applications to nuclear fuels. • Introduction to experimental methods for the measurement of thermodynamic properties. • Phase diagrams and CALPHAD. • Equation of state of the nuclear fuel and thermodynamic description of extreme conditions. • Nuclear fuel behaviour during a core meltdown accident. • Uncertainty analysis.
Nuclear fuel fabrication. • Synthesis of Nuclear Materials • Fuel Pin Preparation • Criticality aspects
Core layout, fuel burn-up and overview on Post Irradiation Examination (PIE). • Description of the nuclear reactor core layout. • Description of the in-pile fuel behaviour. • Post-irradiation examination techniques.
Fuel claddings for Light Water and Fast Reactors. • Different types of fuel cladding. • Impact of irradiation and corrosion on cladding performance.
Radiation effects in oxide fuels. • Introduction to radiation damage and key parameters. • Microstructural evolution and fission gas behaviour. • Introduction to experimental techniques for the investigation of radiation damage in fuel materials.
Thermo-mechanical properties of irradiated fuel and the experimental validation. • Experimental and computational tools for the determination of the fuel thermal conductivity, specific heat, dilatation coefficient, Young modulus, oxygen potential. • Irradiation effects on these properties.

Nuclear Fuel Modelling: An introduction to the TRANSURANUS code. • Overview and main aspects of modelling the neutronic, thermal and mechanical behaviour of fuel rod and fission gas. • Short introduction to the TRANSURANUS code. • Case studies: fuel rod behaviour in normal conditions and under loss of coolant accident condition
Handling of Nuclear Materials: practical radioprotection and medical follow-up. • Practical Radioprotection • Internal and External exposure to radiation sources • Medical Monitoring. • Practical Glove Box and Telemanipulator Exercise.

A first edition of this course or short school has been organised in the second half of 2018, in collaboration of JRC Karlsruhe and KIT. In terms of sustainability of this course, it could be worthwhile to reflect together with the academia and the nuclear industry if such type of specialised courses could take place every year or every second year. Besides the classical classroom training, the proposed course had also a component on practical hands-on trainings on real or simulated hot facilities, which was considered as an highlight of the course (or short school). The appreciation of the course attendants was quite evident and the course providers could conclude that this was due to the fact that hands-on trainings in radiation laboratories can hardly be provided in universities. They have represented, therefore, a real benefit to this initiative.

In conclusion, together with learning material, also hands-on and practical trainings are essential means for the development of students and professionals.

4.4. Nuclear safeguards

It has been noted within the ESARDA organization that many nuclear engineering students do not at all become exposed to nuclear safeguards and are hence poorly aware of what it is and what it means. This of course also applies outside the field of nuclear engineering, where the topic of nuclear safeguards in many fields is completely unheard of. One of the goals with E&T material on nuclear safeguards is therefore to increase the awareness and visibility of the nuclear safeguards field. And although the ESARDA course is already available to nuclear engineering students as well as other students or young professionals, it is not an academic course and participation in the course is voluntary. In addition, participation in the course is limited for practical reasons. In addition, due to the (in many cases) sensitive nature of material on nuclear safeguards it is often not openly shared or publicly distributed, and the E&T material that has been developed often exists in different organizations, research institutions and universities. Against this background, it was suggested to make nuclear safeguards part of the ANNETTE project, and to create a dedicated academic course using traditional as well as e-learning tools.

The proposed course content of the ANNETTE safeguards course thus covers multiple aspects of nuclear safeguards: the history of non-proliferation and safeguards, the legal framework, fuel cycle

and non-proliferation, nuclear material accountancy, probabilistic and statistical methods for nuclear safeguards, export control, the implementation of safeguards, containment and surveillance, non-destructive assay, destructive assay, novel technologies, approaches and methodologies, physical protection, illicit trafficking as well as upcoming challenges. Case studies, exercises and practical work will be included when possible.

4.5. Nuclear security

After extensive internet searches and information provided by other ANNETTE partners only the University of Central Lancashire and Kings College, London in the UK provide a Master degree in nuclear security. It is important to explain why such low number and even more so why these courses attract a comparatively small number of students. To be effective most nuclear employees and contractors need an awareness, but not a Masters level qualification in nuclear security. Consequently, although the total number of nuclear employees is significant worldwide, a large number of these personnel are employed in the Healthcare industry (hospitals). Our report may in part cover these workers. Education is an activity that shares information but effective security relies on the need to know principle. Physical security, transport details, management arrangements are examples of site-specific information that should not be communicated via education. This can result in restrictions on normal educational procedures, hence require, additional teaching techniques.

5. Criteria for selecting E&T material

5.1. Geological disposal

The commitment of the Université de Lorraine as participant in WP3 of the ANNETTE project is to prepare a textbook on Radioactive Waste Disposal for use by Master students. For this purpose, we rely mainly on the works already performed within the Petrus projects and the syllabus presented above. The textbook will be a collection of separate chapters, each one treating a specific issue. The objective is not to have a comprehensive document but to highlight some particular topics that could be of interest for the majority of students. Indeed, the spectrum of the topics in radioactive waste disposal is very large and covers several disciplines. Thereby, it is not possible to produce an “all inclusive” textbook at high scientific level.

The drafting of chapters are untrusted to outstanding Professors and Experts, most of them are external to the ANNETTE consortium. The quality of the work is thereby granted by the proved reputation of the authors very well known in the radioactive waste community.

5.1.1 Planning R&D Program towards Geological Disposal

The Integrated Knowledge Management System for Radioactive Waste Management consists of:

- State-of-Knowledge Handbook
- Education & Training
- Guidance
- Strategic Studies
- Dissemination and Transfer of Knowledge

WEB based State-of-Knowledge Handbook will make available the State-of-Knowledge for the scientific-technical basis of decommissioning, site and facility remediation, and radioactive waste management, including disposal. It serves the purpose of providing the basis for an expert to understand where we are, and were we should go. It thus includes the state-of-the-art (where we are), how we got there, potential conflicting or parallel complementary developments, and identification of potential future direction of scientific and technical work.
The drafting process is based on inclusiveness and involvement of the Member States Actors in order to ensure broad acceptance and support for the outcome. In this context, transparency and visibility are key factors with respect to critical comments and other types of additions (open public WEB page with the possibility to comment and open workshops presenting the documents prior to their publication), as well as transparent review process for dealing with such comments (the external expert group reviewing the comments, publishing their responses and up-dating the State-of-Knowledge, as necessary).
To build the WEB Handbook, experts from consortia working on specific topics (in particular R&D projects) as well as senior experts engaged for the specific purpose of establishing or up-dating the state-of-knowledge for a particular topic are involved.

5.2. Radiation protection

Priority should be given to E&T initiatives that answer to the specific needs that arise from the legislation as described in the Council Directive 2013/59/Euratom (BSS). In this Basic Safety Standard and subsequent national implementation, the job roles, tasks and responsibilities are mentioned for various professional profiles. As different profiles described in the legislation were already addressed in previous European projects, the current priorities are identified with the remaining profiles where few to none European guidance exists:

- Radiation workers (including workers potentially exposed to orphan sources):
In most of the occasions, low-level training material exists on the basics of radiation protection for radiation workers. However, no European references exist on the minimum learning outcomes which need to be achieved by (information) education & training. Due to the diversity of the applications of ionising radiation, specific learning outcomes and training material should be developed to address the practical implementation of the radiation protection system on the work floor.

- Occupational health physicians:
This expert profile requires additional knowledge, skills and competences in radiation protection, complementary to these in occupational medicine. No European reference guidance exists for this target level, although some national training programmes are implemented. In addition, this target audience will benefit if a European approach leads to specific learning outcomes, training course curriculum and E&T material.

- Emergency workers:
Focused small-scale European projects have led to the development of specialised training material for emergency workers (first responders). However, in case of a large-scale incident, various actors at different levels will be involved to manage the radiological/nuclear incident, not only specialised individuals which have been trained. Currently, no European approach nor guidance exists on the learning outcomes and training content for the numerous actors in emergency response, although some national programmes have been developed and implemented. NERIS has organised some training courses on an expert level.

-Professionals responsible for individual monitoring of radiation workers:
The individual monitoring of radiation workers is organised in the majority of European countries by institutes which have been certified by the competent authority. Although the EU BSS clearly mentions that member states should foresee E&T for the professionals responsible for individual monitoring, no European initiatives have been developed so far, with exception to some specialised training courses organised by EURADOS.

As for other key professionals in radiation protection, such as the RPE, RPO and MPE, clear European guidance exists and European training courses have been developed by previous EC funded projects. With the development of training material, as well as the update of existing training material on a national or international level, it must be warranted that it complies with the EU guidance in terms of learning outcomes.

For the professionals working with medical applications, also clear European guidance exists (EC publication Radiation Protection 175). Most of the European countries have developed training material largely in accordance with this guidance document, but not for all target audiences, for example maintenance engineers and maintenance technicians.

5.3. Nuclear fuel properties and behaviour

Based on available reading materials as described in paragraph 3.2.3, in general it can be assessed that a new text book in the field of nuclear fuel behavior would not be needed. Certainly, course providers in the field have to carefully selected the reading material for the students and a unique strategy for this might not be effective. The syllabus indicated in chapter 4.3 can be used as guideline for the topics to be selected in assembling learning materials from the literature. Moreover, as discussed before, in case of nuclear fuel an important learning component is the hands-on training.. Finally, the options of preparing text books or multimedia material as e.g. recording of the lectures and availability of lectures hands-out or to establish a dedicated MOOC on this topic could be viable, given that the QA of the produced material is done by an entity that is accredited for assessing the quality.

5.4. Nuclear safeguards

E&T material on nuclear safeguards will include traditional as well as e-learning material. The material will consist of multiple contributions by several authors in different institutions; each contribution will reflect separate parts of the course content. The material will be prepared by experts in the field, working at nuclear safeguards institutions that are involved in both nuclear safeguards research as well as training and education.

The delivered E&T material is planned to consist of e.g. presentation slides, desk-top exercises, hands-on exercises as well as video material and quizzes. If a dedicated E&T platform is selected and proposed by the ANNETTE consortium, the E&T material as video, quizzes, etc., can be made available there. Based on experience of using e-learning platforms at Uppsala University, video and other material can be included into platforms such as e.g. Scalable Learning (https://www.scalable-learning.com/#/home). In such a platform, the teacher is able to remotely interact with the participants, see how well they do on tests, receive comments and questions from the participants, see where they are confused as well as see whether or not they watch all material and which parts of it that is repeated.

5.5. Nuclear security

E&T material on nuclear security will be developed from existing material that is already in the public domain. With security per se being a sensitive topic it will be a collation of this information which is largely presented as guide lines as each Member State may interpret and apply these guidelines, differently, appropriate to their industry. The material will be prepared by invited experts from across the nuclear industry i.e. largely legislators, operators and educators.

6. Conclusions

This report identifies the needs for the production of new educational material about Nuclear Engineering training. The specific areas analysed are geological disposal, radiation protection, nuclear fuel properties and behaviour, nuclear safeguards, and nuclear security. To do this task the report analyzes the E&T material available in the areas indicated before and, based on the availability, describes the needs of E&T material. I this sense, has been identified a lack of information on many topics as waste conditioning and waste acceptance in the field of Geological Disposal, and a lack of European reference standards in Radiation Protection. Also, about Nuclear Safeguards and Nuclear Security, the E&T material available is scarce, due the sensitive nature and confidentiality of this topics. Additionally, the study has identified that is essential the combination of learning material with hands-on and practical trainings

Based on the needs of E&T material identified, the report describes the criteria to develop the new E&T material in each area of interest. About Geological Disposal, due the diversity of topics related with this area, the decision has been to develop a textbook with a collection of separate chapters elaborated by experts with proved reputation in each field, highlighting interesting topics. About

Radiation Protection, in section 5.2 of this report is described the criteria to elaborate E&T material for radiation workers, occupational health physicians, emergency workers, and professionals responsible for individual monitoring of radiation workers. Related with the area of Nuclear Fuel Properties and Behavior, is recommended to prepare multimedia material as recorded lectures and MOOCS, taking in account that there are already textbooks and reading material available. About nuclear safeguards is recommended to prepare e-learning material, based on presentation slides, desktop exercises, hands-on exercises as well video material, to be included into platforms accessible to nuclear engineering students. Related with Nuclear Security, is recommended to develop material from existing material in the public domain, to be adapted to the regulations of each State.

7. References

[1] Technical Annex – Coordination and Support Actions – ANNETTE Project

[2] Survey on E&T and VET in the nuclear fields in Europe. N. Kesteloot and T. Clarijs. Deliverable D1.1. ANNETTE Project, 07/12/2016

[3] Specific needs for an advanced European Programme for CPD in the nuclear areas. W. Ambrosini and P. Porras. Deliverable D2.1. ANNETTE Project, 09/06/2017

[4] D. Olander, "Fundamental aspects of nuclear reactor fuel elements"

[5] D. Olander, " Nuclear Fuels: Present and Future," Engineering Journal, vol. 13, no. 1, pp. 1-28, 2009. doi:10.4186/ej.2009.13.1.1

[6] R. J. M. Konings (editor), "Comprehensive Nuclear Fuels", Elsevier, 2012

[7] Hj. Matzke, "Science of advanced LMFBR fuels", North Holland (1986)

[8] D. Jacquemain (editor), "Nuclear Power Reactor Core Melt Accidents: Current State of Knowledge", IRSN Science and Technology Series, 2015

8. Appendix

WORK PACKAGE 3

Teaching/training of Nuclear Security in the European Union.

Professor Harry Eccles
Dr Jonathan Francis
Dr Sandeep Kadam

University of Central Lancashire

May 2018

Executive Summary

This report addresses nuclear security teaching/training at Masters level and courses currently provided by academic establishments across the EU. After extensive internet searches and information provided by other ANNETTE partners only the University of Central Lancashire and Kings College, London in the UK provide a Master degree in nuclear security. It is important to explain why such low number and even more so why these courses attract a comparatively small number of students. To be effective most nuclear employees and contractors need an awareness, but not a Masters level qualification in nuclear security. Consequently, although the total number of nuclear employees is significant worldwide, a large number of these personnel are employed in the Healthcare industry (hospitals). Our report may in part cover these workers. Education is an activity that shares information but effective security relies on the need to know principle. Physical security, transport details, management arrangements are examples of site-specific information that should not be communicated via education. This can result in restrictions on normal educational procedures, hence require, additional teaching techniques.

Content

1. Introduction

This report addresses the teaching/training of scientists/engineers in the art of nuclear security at various institutions, largely academic establishments, within the European Union. This report is primary concerned with provision of Master level degree. Its preparation is in response to the one of the deliverables of Work Package 3,

Work Package 3: GENERATIONAL TRANSFER OF EXPERTISE: PROMOTING KNOWLEDGE, SKILL AND COMPETENCIES PRESERVATION IN FRONT OF PERSONNEL TURNOVER.

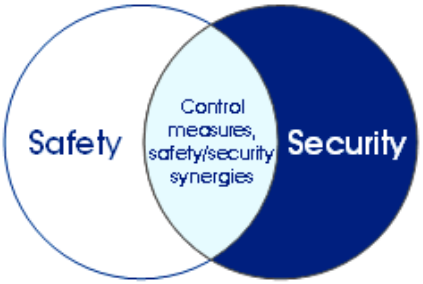
which required the University of Central Lancashire (UCLan) to consider courses/modules on offer within the EU. The remit of this report encompasses only that security associated with civil nuclear facilities. In the international arena, nuclear security is largely concerned with nuclear power plant sites, but not exclusively so, as others such as mining, uranium conversion, reprocessing etc. have to comply with regulatory regimes. The report is divided into two further sections; the first describes the background to nuclear security, while the second identifies those establishments currently engaged in providing nuclear security courses/modules.

2 Nuclear Security

The International Atomic Energy Agency defines nuclear security as:
The prevention and detection of, and response to, theft, sabotage, unauthorized access, illegal transfer or other malicious acts involving nuclear material, other radioactive substances or their associated facilities. (IAEA 2012)

The above definition arguably encompasses safeguarding of nuclear materials as 'illegal transfer' includes diversion of materials. IAEA argues that 'safety' and 'security' are distinct, but overlapping.

This definition is far too broad and extensive, for this report; but safety and safe guards are covered by other Work Packages in the ANNETTE project.



Nuclear safety and nuclear security have many common elements. Both have the same purpose, which is to protect the people, society and infrastructures from the hazards associated with the nuclear industry. The aim of nuclear security is essentially to prevent theft of nuclear/radioactive materials and the sabotage of nuclear facilities. This is achieved by a hierarchal system starting with a legal and regulatory framework, set up by *National Government (NG)*. The framework places the prime responsibility for security with the *NG*, then with the designated *Regulatory Authority(ies) [RAs]*, and finally with the *Nuclear Operators (NO)*. In this report it differs from nuclear safety but necessarily so because unlike safety risks, security threats do not necessarily arise from within the nuclear plant/organisation.

The *National Government* is responsible for designating the *RA* with the power, ability, and the resources (both financial and human) necessary to accomplish its tasks. In addition, the *NG* is responsible for regulations that govern how nuclear security and safety at nuclear facilities is maintained, as well as means to reduce radiation risks, including emergency response and recovery actions, to monitor releases of radioactive substances to the environment and to regulate the safe decommissioning of facilities and disposal of radioactive waste. The *Regulatory Authority* is typically an independent body responsible for conducting the regulatory process including issuing authorisations and undertaking inspections and enforcement. The *Authority* works independently of the *Nuclear Operator*, which is the first line of defence against theft or sabotage. The *Operators* are responsible for translating national security legislation into facility and material-specific plans and policies and implementing on-site systems that put these policies into practice.

Nuclear Operators must design a security system capable of defending a target against realistic threats which, to be effective must be able to detect, assess, report/communicate, delay and/or defeat intrusions. To meet these objectives, the defence-in-depth (DiD) principle is employed. Although DiD has been around for more than 50 years a technical consensus on what it means in the context of specific designs has not been achieved and for this report the IAEA definition has been used, namely,

1. Prevent deviations from normal operation
2. Detect and control deviations
3. Incorporate safety features, safety systems and procedures to prevent core damage
4. Mitigate the consequences of accidents
5. Mitigate radiological consequences

This DiD approach was developed for nuclear safety purposes but provides one possible framework for ensuring security too.
This report addresses three common elements of nuclear security that apply for all nuclear sites:

1. Physical
2. Information
3. Personnel

There is a fourth strand; cyber security. This is also considered but not in detail, as it is a generic problem that has little particular nuclear aspect. That is to say, it is in any way less problematic or less important but, the other three demand that the particular nature of nuclear hazards, nuclear site transport implications for nuclear materials and staffing of nuclear sites be considered.

1.1 2.1 Physical

The attacks of 11 September 2001 resulted in the nuclear industry reviewing its security measures, in particular their vulnerability to deliberate attacks of terrorism. Physical protection (i.e. physical security) includes a variety of measures to protect, from not only terrorist attacks, but also these days from cyber and other external influences. Nuclear facilities and materials need protection

against sabotage, theft, diversion, and other malicious acts. Nuclear facilities that require physical protection include mining, uranium conversion and enrichment facilities, nuclear reactors, reprocessing and spent fuel storage and disposal facilities, currently in operation and undergoing decommissioning. The protection does not solely rest with the facility owner/operator but will be an intrinsic part of the design of plant and equipment, the supply chain and other third parties. Physical segregation and barriers, along with controlled access are also important for protecting against the insider threat, where rogue staff members seek to act in an unconscionable manner.

2.1.1 Site security

EU Member States will have regulations that require operators of civil licensed nuclear sites that hold nuclear material or other radioactive material to have site security plans (SSPs). These plans will/should describe the standards, procedures and arrangements that enable duty holders to maintain and conduct their business in compliance with their legal obligations and demands of a regulatory authority. When tenancy is involved, the tenants should have their own approved SSP.
SSPs are 'living' documents that by necessity require change, upgrading etc. and therefore require the duty holder to obtain approval from the appropriate regulatory authority.

Depending on the site categorisation, the regulatory authority will require periodic inspection and assessments of the various components of the SSP to ensure compliance and continued effectiveness. These inspections/assessments will involve the site security personnel and are key elements of the SSP, which could include annual counter terrorist exercises to test the security elements, evaluates the site's security regime and staff awareness of security.

A non-regulatory process but one now adopted by most new build projects, in particular nuclear power plants, is a pre-project generic assessment, for example in the UK, the Generic Design Assessment (GDA). It involves appropriate agencies to ensure the safety, security and environmental implications of new nuclear reactor designs. These are assessed prior to permission is granted to build that appropriate design at a particular site. It provides a level of assurance prior to committing to design the plant at a particular site.

The GDA is not a mandatory process but has a number of benefits such as:

- It enables the regulators to get involved with designers at an early stage, where they can have maximum influence.
- It is a step-wise process, with the assessments getting increasingly detailed.
- It separates generic design issues from specific site-related issues, improving the overall efficiency of the regulatory process.
- It is open and transparent. The public can view detailed design information on the internet and comment on it.

Sites on which major decommissioning of plant and equipment is to be undertaken, will have their site security arrangements reviewed and at some stage, likely downgraded. A shutdown and de-

fuelled reactor site, or a reprocessing plant undergoing Post Operation Clean Out (POCO) will represent a considerably reduced hazard compared with an at-power reactor site or operational reprocessing plant. Revisions to the site security plans are a stage wise approach, downgrading when likely events have been removed.

2.2 Information security

Information is knowledge, irrespective of its form of existence or expression and covers a broad spectrum such as ideas, concepts, events, processes, thoughts, and facts. Information can be; recorded, copied, stored etc. on material such as paper, film, magnetic or optical media, or held in electronic systems. Information security, involves systems, procedures in place to ensure the confidentiality, integrity and availability of information in any form. At a minimum, it includes:
(a) Security of information in physical forms (e.g. paper and electronic media);
(b) Security of computer systems, sometimes referred to as computer security, information technology (IT) security or cybersecurity (addressed later);
(c) Security of information assets (e.g. information storage and processing equipment, communication systems and networks);
(d) Security of information about facility employees and third parties (e.g. contractors and vendors) that could compromise the security of the above;
(e) Security of intangible information (e.g. knowledge).

All organizations' site security plan (section 2.1) will include a detailed section dealing specifically with the security of sensitive information. Generally, the *National Government* will have developed a national framework for information security that covers:

(a) The responsibility of the State;
(b) A legal and regulatory framework;
(c) National guidance;
(d) Security policies;
(e) Classification schemes.

It is essential that the relevant requirements of the security plan are communicated to employees and contractors working for the organization and that each understand their responsibilities. However, this does not mean all those employees and contractors need Master's level training or education in nuclear security. Rather they need awareness to act in accordance with the expected culture, policies and procedures at their place of work it is for others to make sure these policing procedures and the culture within the organisation protects that organisation, its employees, contractors and assets effectively.

2.2.1 Paper based information

Protecting paper-based material can be initially controlled by its classification. Many of the IAEA Member States use a four-level system, to indicate the level of sensitivity, namely:

1. Top Secret
2. Secret,
3. Confidential
4. Restricted

Until relatively recently, this was the classification used in the UK. For the civil nuclear sector 2, 3 and 4, apply, as it is unlikely that information in these categories would attract top-secret classification. However, the design base threat against which the site must deliver a credible defence will be derived from top-secret information. A fifth classification could be imposed by for example operators to cover commercially sensitive information. Storage, control and distribution of paper documents to organisations, individuals depending on their content/classification would be based on 'needs to know' principal. Commercial property could be covered by a legal binding confidentiality agreement.

2.2.2 Computer based information

Cyber-attacks are a growing threat worldwide, and specific events targeting nuclear installations have brought attention to the importance of robust information and cyber security. The cyber security risk is growing as nuclear facilities become increasingly reliant on digital systems and making use of 'off the shelf' software. The USA, Department of Homeland Security (DHS) has recorded a growing number of cyber-attacks, several against nuclear facilities, over the past few years.
Cyber security is the protection of digital computer and communications systems and networks against cyber-attacks that could enable the theft of material or sabotage of a facility.
National organisations and the IAEA have recommended a series of measures to transform the industry's approach to cyber security, ranging from cyber resilience (ability to detect, contain, mitigate the effects and recover), to continuing improvement in capability and capacity through training and education, at all levels.

2.3 Personnel security

Many, if not all Member States' civil nuclear regulations require that all employees and contractors must be vetted to a level of clearance commensurate with their access to nuclear material and information. In the UK the lowest level of clearance is the Baseline Personnel Security Standard rising to Developed Vetting Security Clearance (DV). The Cabinet Office as the National Security Authority for the United Kingdom determines the Baseline Personnel Security Standard (BPSS) and National Security Vetting (NSV) policy.

Baseline is the minimum requirement for unescorted access to civil nuclear premises and to information on a 'need to know' basis. A Counter-terrorist Check (CTC) is clearance required for anyone who works in close proximity to sensitive materials or information that may be vulnerable to a terrorist attack. It is required for unescorted access to a vital area, unless the category of any associated nuclear material holdings dictates that a higher level of security clearance is required.
Higher levels of vetting (Security Check and Developed Vetting (DV)) are necessary for regular access to more highly sensitive information / areas and for those whose knowledge extends to the more

detailed workings of a civil nuclear facility, especially those aspects directly associated with the safety / security of nuclear materials and the operation of the security regime.

The Regulatory Authority security team is responsible for providing a vetting service to the civil nuclear industry. In processing applications and granting clearances, it will apply to agreed standards and processes in accordance with the National Government's security vetting policies. At prescribe intervals security clearances are re-validated.

3 Key Nuclear Security documents on the web

IAEA Nuclear Security Series No. 23-G, *Security of Nuclear Information, Implementing Guide, 2015.*

IAEA–EU JOINT Action, Partnership in Improving Nuclear Security, 2013

EU efforts to strengthen nuclear security, Joint Staff Working Document – *SWD 70, 2012.*

Caroline Baylon with Roger Brunt and David Livingstone, Chatham House Report, *Cyber Security at Civil Nuclear Facilities Understanding the Risks*, September 2015.

Ian Anthony, *The Role of the European Union in Strengthening Nuclear Security,* EU Non-Proliferation Consortium, The European Network of Independent Non-Proliferation Think Tanks, Non-Proliferation Papers, *No 32, Nov. 2013.*

4 UCLan's survey of EU nuclear security courses

4.1 Background

One of the deliverables of Work Package 3, required the University of Central Lancashire (UCLan) to consider courses/modules on offer within the EU.

Work Package 3: GENERATIONAL TRANSFER OF EXPERTISE: PROMOTING KNOWLEDGE, SKILL AND COMPETENCIES PRESERVATION IN FRONT OF PERSONNEL TURNOVER.

The results of UCLan' s survey, carried out from January to April 2018, which largely involved both web searches and information provided by other ANNETTE members, are reported later. Even before the survey, it was known generally that the likes of the IAEA and World Institute for Nuclear Security (WINS) were involved in the provision of workshops, meetings and conferences that involved nuclear security, but not at Masters level and/or with an academic qualification.

The IAEA for example provide international nuclear security awareness programmes but these tend not to lead to qualifications or certification. The Agency in 2009 created the International Network for Nuclear Security Training and Support Centres (NSSC) in an attempt to encourage collaboration and coordination of industry-related training initiatives. A year later, it founded the International Nuclear Security Education Network (INSEN) in conjunction with various academic institutions to promote and support nuclear security education, especially at the academic level.

In an attempt to gauge the needs of nuclear security training etc. WINS Academy conducted a gap analysis across 180 countries from August 2012 to December 2012. This analysis indicated that '*approximately 230,000 professionals have accountability for nuclear security worldwide. Approximately 75% of these are onsite professionals, and approximately 25% are offsite professionals.* The majority are employed in medical institutes using radioactive sources. Europe accounts for approximately 59,000 professionals with accountability for nuclear security'. This from UCLan' s perspective (definition of security) appears to be a high number and may include personnel with responsibility of safeguards of nuclear material, i.e. IAEA definition.

The WINS Academy survey did produce: 'As of January 2013, the only certified courses for nuclear security management that could be identified from open sources are those for postgraduate students. The only universities offering certified courses are Kings College and the University of Central Lancashire, both in Great Britain'.

The key questions UCLan' s survey raise are:

Why such a low number of academic institutions involved with Masters courses?

1. How many nuclear security professionals does the industry need?
2. Is a Master's degree necessary for professional status or can it be provided by on the job training?

The results of UCLan's survey may provide some answers to these questions.

4.2 Web searches

Our first search revealed that in the EU there are 16 Member States with operational nuclear power stations; of these 16, 11 are involved in ANNETTE.
The following have been identified to date via internet searches, the list however is unlikely to be comprehensive and further searches are therefore necessary:

4.2.1 Master in Nuclear Security (MiNS) at the Brandenburg University of Applied Sciences.

The Master's program spans over three terms, which usually takes 18 months and covers various courses, such as nuclear security management, physical protection or cyber security.
After successful completion of the program, participants receive an internationally recognized Master of Science (M.Sc.) degree in Nuclear Security from the Brandenburg University of Applied Sciences. The program structure and content are based on the results of the internal revision process of the IAEA Nuclear Security Series No. 12 (NSS 12 and the teaching materials of the International Nuclear Security Education Network (INSEN).
Credits: 90 ECTS.
Mode of study: distance learning
Program duration: 3 terms (full-time) or 5 terms (part-time),
Tuition fees: 16,958 EUR (incl. VAT)
Curriculum:

Module	Course	ECTS
Security management	Nuclear Security Management National Security and Counterterrorism	12
International Law and Risk Assessment	Threat Assessment and Planning International Cooperation, Legal Framework and Governance	12
Fundamentals of Mathematics and Technology	Physical Protection Computer Security	12
Nuclear Security	Nuclear Security in Transport and Storage Detection and Response to Nuclear and Other Radioactive Material out of Regulatory Control	12
Compulsory Facultative Courses (= electives)	CFC I, II, III	9
Research and Academic Working	Research Paper Project	12
Master Thesis		21

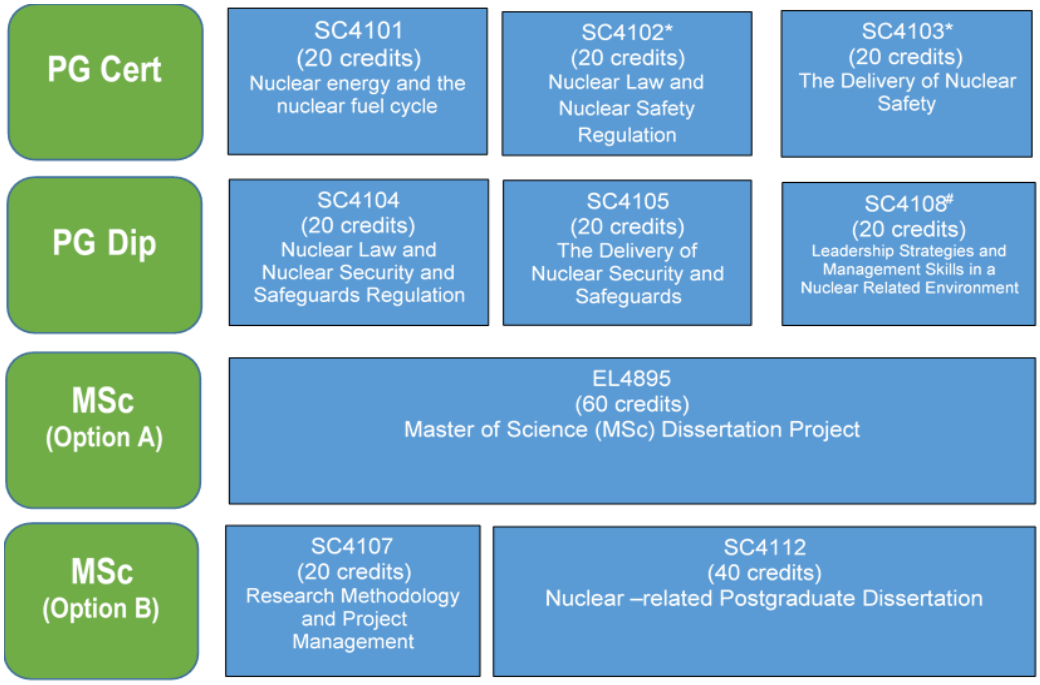
4.2.2 Master's in Nuclear Security at the University of Sofia, Bulgaria.

The structure of the Master's Programme in Nuclear Security consists of a set of 12 compulsory courses. These provide solid knowledge in the fundamental areas (such as the legal framework,

nuclear technologies and applications, radiation protection) and in-depth expertise in the main nuclear security areas (prevention, detection and response), together with more advanced know-how in 10 elective courses that could be selected by students to obtain a specialization in certain areas of nuclear security.
Program duration: 2 years (four semesters)
Tuition fees:
Bulgarian and EU Students = 3 600 BGN (Annual fees), 1 800 BGN (Semester fees)
Students from non-EU Countries = 4 000 EUR (Annual fees), 2 000 EUR (Semester fees)

4.2.3 MSc in Nuclear safety, security and safeguards course offered by the University of Central Lancashire (UCLAN)

UCLan has seven taught modules of 20 credits and one 40-credit dissertation. The course may be studied as a full-time student or by part-time attendance. The course is uniquely designed and is delivered from an UCLan campus, offering employees already working within the sector and assisting employer led provisions, a flexible programme to fit in around their work patterns. This is achieved using intensive delivery of the majority of the teaching sessions on each taught module within a one-week period.
Tuition Fee: 6,500 GBP/year.
Curriculum:



4.2.4 European Masters in Nuclear Security at the Delft University of Technology.

The pilot phase of this course was launched in April 2013 at the Reactor Institute of the Delft University of Technology in the Netherlands. This programme is supported by the IAEA and five other European universities, namely the University of Oslo, the Technical University of Vienna, the Brandenburg University of Applied Sciences, the National Centre for Scientific Research "Demokritos" in Greece, and the University of Manchester Dalton Nuclear Institute.

4.2.5 Other certificate courses,

a. The Triple Bar Nuclear Security (TBNS) Nuclear Security is offered by National Skills Academy Nuclear (NSAN) in the UK, delivered as three online modules. This course is designed to provide industry wide eLearning to transfer fundamental nuclear security knowledge to a broad, global audience covering topics in nuclear security such as threats and nuclear security, the nuclear security legal framework, the role of the IAEA, facilities and methods of prevention, detection and response relating to nuclear security breaches and other key nuclear security elements. The course is available for £50.00 plus VAT via NSAN's e-Learning Portal, the Nuclear Training Network.

b. The European Nuclear Security Training Centre (EUSECTRA) based in the European Commission Joint Research Centre (JRC) in Karlsruhe and ISPRA may not offer official training/teaching modules but could be a key player.

c. Joint ICTP-IAEA International School on Nuclear Security | (sir 3194) at ICTP, Kastler Lecture Hall (AGH), Strada Costiera, 11, I - 34151 Trieste (Italy). From 9 Apr 2018 - 20 Apr 2018

This two-week school was designed for young professionals with specific interest and knowledge of nuclear security from developing countries. Candidates ideally with 1-3 years of experience, working at a relevant institution in their home country, with a scientific or technical background in a discipline of relevance to nuclear security, such as nuclear physics, nuclear engineering or political science, and in related fields were encouraged to apply.
Curriculum topics covered:

- International legal framework supporting nuclear security
- Identification of, and measures to address, threats against nuclear material, facilities, and activities
- Instruments and methods for physical protection of associated facilities
- Threat and risk assessment, detection architecture, and response plan for material out of regulatory control
- Radiation detection instruments and detection strategies and techniques
- Transport security for nuclear and other radioactive material
- Nuclear forensics and radiological crime scene management

- Nuclear security culture, computer and information security, and security at major public events
- Measures for systematic nuclear security human resource development at the national level.

Although most of the above have been found on the internet, it is unclear how many are still live. Identifying other courses is proving to be a more challenging task, even after contacting other established routes (NNL, WINS, IAEA INESN), a response from some of these is still awaited.
Other Master courses listed below deliver generic security/International security education with few sessions dedicated to nuclear security and safeguards

- M.A. in International Security, at Sciences Po, Paris France, focuses on the radical changes in international security issues in the 21st century in the international environment covering remodelling of the geopolitical system, new forms of crisis and conflict, controversial military interventions, international terrorism, nuclear proliferation, cyber warfare, etc. Programme duration Full-time duration for 2 years. Credits: 120 ECTS. Fees: £12,437 for international students. Free for EU/EEA students

Programme Structure
- Foundations of Strategic Thinking
- American Military Power in the World Today
- Global Issues and Leadership: A joint transatlantic course with the Nunn School of International Affairs, Georgia Tech
- EU Approaches to Security: Global Strategy and Regional Issues
- New Combination of Hard and Soft Power: Case study of Contemporary Russia
- Diplomacy and Negotiation
- Understanding The Use of Force in World Politics

- M.A. Science and Security, at King's College London, is designed to understand and analyse the security implications of scientific and technological developments, while utilising knowledge and tools of analysis from the hard sciences, political science, history, philosophy and sociology. Credits 90 ECTS, 180 alternative credits. Tuition Fee: 11,550 GBP/year

Programme Structure
- The Science & Security of Nuclear & Biological Weapons
- Current Issues in Science & Security
- Dissertation
- Armchair Intelligence – Open Sources & Online Investigation
- Chemical, Biological, Radiological & Nuclear (CBRN) Terrorism
- Cyber Security

- Proliferation & International Security
- Risk & Uncertainty in Global Politics
- Contemporary British Defence Policy

- MA in Non-Proliferation and International Security, at King College London, focuses on current and historical developments in weapons proliferation and the effectiveness of the policy tools, the evolution and effectiveness of the international non-proliferation regime, and the way in which proliferation influences other key issues in international relations. Duration: full time 1 year. Credits: 90 ECTS. Tuition fees: £ 11550 /year.

Programme Structure

- Current Issues in Science & Security
- East Asian Security
- International Politics of the Middle East
- The Science & Security of Nuclear & Biological Weapons
- National Security Studies
- Armchair Intelligence – Open Sources & Online Investigation

4.3 Survey conducted within ANNETTE consortium members

Our web searches identified only a hand full of institutions who are involved or were previously involved in delivering nuclear security education and training. The team at UCLan was somewhat sceptical that this reflects the actual picture. To ascertain that we covered all eventualities; a survey was conducted within ANNETTE consortium in the form of questionnaires, which had two question, both required written answers from respondents. The questions that were asked are stated below:

Q1. Has your institutions courses/modules that address nuclear security?

Q2. Are you aware of other academic establishments in your country that are likely to be involved in nuclear security?

Table below provides the response received from consortium members:

Response from ANNETTE consortium partners			
		Responses to	
		Q1	Q2
1	Respondent 1	No modules or courses on nuclear security in Barcelona	
2	Respondent 2	• Few modules in nuclear security, mostly combined with safeguards courses. • Not a officially "academic" course since SCK.CEN is not a university. • Offered this course in the frame of the GENTLE project	• EUSECTRA initiative of the EC. • NSSCs of the IAEA offer a lot of training modules and e-learning • WINS offers the full package.
3	Respondent 3	No module or course on nuclear security in nuclear academic education in Slovenia	
4	Respondent 4	• Second level master after master in Nuclear Safety and Security, started in 2010. Discontinued due to low student numbers. • This Masters was in collaboration with Iter Consult; Nuclear Ansaldo; BNEN - Belgian nuclear higher education network; SCK-CEN - Belgian Nuclear Research Center; CIRTEN, the interuniversity consortium for nuclear technology research founded by the University of Pisa, University of Padua, University of Palermo, University of Rome "La Sapienza", Polytechnic of Milan, Polytechnic of Turin. • Duration: One year and issues. Credits: 60 credits/ECTS.	

		• Delivery: 470 hours in the classroom and 90 hours in the laboratory. • Course content: The legislative and regulatory framework, the international instruments, the licensing requirements, the principles of safety of nuclear facilities and their design elements, analysis of accidents and consequences of radiation, immediate response to emergencies, management, transport, precautions, safety and physical protection of radioactive materials. • Programme details here	
5	Respondent 5	No, however we contribute to Nuclear security education as a member of INSEN	• In Germany, the Brandenburg University of Applied Sciences offers a Master programme in Nuclear Security (MiNS): full programme here • In terms of ESARDA, which I am also representing in ANNETTE, the one-week ESARDA course on nuclear safeguards and non-proliferation includes also some lectures on nuclear security, please find the

			full programme here
6	Respondent 6	A new short module (3 ECTS) entitled "Energy Security" • The concept of energy security: Definitions and variables. • Energy resources and overpopulation. The culture of energy security. • Global geopolitical scenario of energy. • Diversification and energy mix. • Globalization and energy demand. • Global energy security: Challenges and vulnerabilities. • Nuclear energy: current status and future development. • Renewable energies and nuclear fusion: current state and technological challenges • Nuclear Safeguards. The International Atomic Energy Agency (IAEA). Resolutions 1373 and 1540 of the Security Council of the United Nations. • Security of radioactive material. Transportation, export and import. • Illicit trafficking of radioactive materials. The Incident Trafficking and Database (ITDB). Orphan sources. • The European Atomic Energy Community (EURATOM). • Exports of dual-use products: Wassenaar Arrangement, Australia Group, International Initiatives against nuclear	

		proliferation. • Codes of conduct and global nuclear security regime.	
7	Respondent 7	Doesn't offer course or modules on nuclear security	In France such courses can be found at INSTN (CEA) http://www-instn.cea.fr / or at ENSTTI (IRSN) http://enstti.eu/
8	Respondent 8	Doesn't offer course or modules on nuclear security	Not aware of academic institutions in Sweden offering courses on N. Sec
9	Respondent 9	Master programme in Nuclear Energy 13 courses (4 ECTS each) summed together in 42 ECTS. One of the courses is called: Reactor Safety I: Fundamentals.	
10	Respondent 10	No specific nuclear security module on the NTEC programme	
11	Respondent 11	We delivery courses in safety for all Masters in Nuclear engineering (in particular 4 of them). However, security – in terms of proliferation risk analysis, arms control and ensuring the peaceful use of nuclear energy is not yet developed.	

Acknowledgements
The authors are grateful to other ANNETTE partners for their cooperation and provision of information/details of courses on offer in academic institutions in their Member State countries.