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Advanced Networking for Nuclear Education and Training and Transfer of Expertise

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Report on the participation of fusion professionals in nuclear training activities

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ABSTRACT:

This report deals with the pilot run of nuclear fusion training courses developed within WP6 of the ANNETTE project. Based on the material developed for these specific courses as presented in report D6.3, the training courses were implemented. This report describes the feedback provided by the participants, and the conclusions and recommendations based on it.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS 4
1. INTRODUCTION 5
2. ANNETTE NUCLEAR TRAINING OFFER FOR FUSION PROFESSIONALS 8
3. A-NF-01 *FUNDAMENTAL KNOWLEDGE ON FUSION AND NUCLEAR ASPECTS* 9
4. A-NF-02 *REGULATION AND ITS APPLICATION IN NUCLEAR PROJECTS* 11
5. A-NF-03 *NUCLEAR SAFETY CULTURE IN THE ITER PROJECT – THE SUPPLY CHAIN* 13
6. GENERAL CONCLUSIONS AND RECOMMENDATIONS 16
7. REFERENCES 17
ANNEX 1: TRAINING DESCRIPTION A-NF-01 18
ANNEX 2: TRAINING DESCRIPTION A-NF-02 21
ANNEX 3: TRAINING DESCRIPTION A-NF-03 25

List of abbreviations

ANNETTE	Advanced Networking for Nuclear Education, Training and Transfer of Expertise
CPD	Continuous professional development
C&S	Codes and Standards
ENEN	European Nuclear Education Network Association
F4E	Fusion for Energy
FUSENET	European Fusion Education Network Association
IAEA	International Atomic Energy Agency
IO	ITER Organization
ITER	International Thermal Experimental Reactor
MOOC	Massive Open Online Course
SAT	Systematic Approach to Training
WP6	Work Package 6 of the ANNETTE project: COORDINATING THE NUCLEARIZATION OF FUSION

1. INTRODUCTION

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

Considering the attractiveness of fusion as a potential sustainable, low carbon source of electricity contributing effectively to a secure mix of different energy sources, the EU created a coherent, ambitious but pragmatic fusion program aiming, via a comprehensive, integrated science, technology and engineering program, to provide electricity to the grid by the middle of the 21st century[1].

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

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

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

Consequently, the objectives of WP6 include

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

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

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

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

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

Considering the current time frame for design, construction and operation of fusion facilities like ITER and DEMO[2], one will have to put the activities of WP6 and its outcomes into this context. What are the current and near term main activities of the involved human resources in the ITER and DEMO projects?

Although basic design already has been completed for ITER, detailed design activities are still ongoing, either within the ITER Organization, or within the various sub-contractors involved with their supplies and services. Furthermore, manufacturing as well as assembly and construction activities are conducted, either on the sub-contractors' or on the ITER construction site. As for DEMO, the conceptual design phase most probably will be performed in the 2020s, basic design activities in the 2030s, and detailed design as well as manufacturing, assembly and construction activities most probably in the 2040s. In parallel, research and development are ongoing (primarily through the EUROfusion consortium) to prepare the operational phase of ITER, and to contribute to resolving diverse technical challenges connected to DEMO.

Consequently, it may be expected that the size of the workforce involved will grow in the 2020s mostly relating to construction, assembly, commissioning and operation of ITER, to be possibly reduced subsequently during the DEMO basic design activities, while mostly kept constant for research and development activities. This certainly will have an impact on the required competences in the work force, with implications on the long-term importance of the courses that are adapted or newly developed within WP6.

Obviously, under this perspective one may conclude that these courses should have a sustainable impact not only on the nuclear awareness of the manufacturing, assembly and construction work force (short-term time frame), but also on the nuclear expertise of engineers and scientists (middle to long-term perspective), and thus on the involved industry and research and development institutions. Furthermore, it may be expected that on the long-run this may lead to a related adaptation of fusion education curricula, e.g. on Bachelor or Master level.

The current report builds on how the result of sub-task T6.2, namely the training material for three training courses that have been selected for training development as documented in reports D6.2 and D6.3 (see [2] and [3]), were deployed for implementing pilot courses.

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[2] See, e.g. http://fusionforenergy.europa.eu/mediacorner/newsview.aspx?content=1140

These are:

1. A-NF-01 *Fundamental Knowledge on Fusion and Nuclear Aspects*
   (implemented during the ANNETTE Summer School in Turku, Finland, June 25th – 29th, 2018)
2. A-NF-02 *Regulation and its Application in Nuclear Projects*
   (implemented by ANNETTE project partner Framatome in Karlstein, Germany, February 11th – 12th 2019)
3. A-NF-03 *Nuclear Safety Culture in the ITER Project – The Supply Chain*
   (implemented by ANNETTE project partner UNED, Madrid, Spain, March 11th – April 30th, 2019)

The feedback and evaluation from the pilot training were used for course improvements and further offering of fusion specific training courses. Consequently, activities within the sub-task T6.4 of the work package WP6 dealt with offering further editions of the three courses, how these nuclear training opportunities were made public to the fusion community, how this contributed to training attended by the fusion community, and which means were applied to ensure sustainability of the training initiatives beyond the end of the project.

2. ANNETTE NUCLEAR TRAINING OFFER FOR FUSION PROFESSIONALS

After implementation of the pilot courses and due consideration of the feedback provided by the students, the three training courses were ready for publicly announcing and marketing the use of these courses.

The sub-task T6.3 not only provided the training material for the three courses, but also a training description to specify the courses. These training descriptions were published through the FuseNet Internet site[3]. Additionally, the course offer was made public in the regular ANNETTE Monthly Bulletin which was distributed to a large network of persons that were interested in nuclear education and training, or responsible supervisors in institutions active in fusion related projects. In addition to the courses A-NF-01 – 03, the ANNETTE course offer naturally included all nuclear training provided by the ANNETTE partners. In some cases, this also might be of relevance for fusion institutions, e.g. *Single and Two-Phase Thermal-Hydraulics - for Nuclear Applications*.

To enroll for the courses, the registrations had to be made through the ENEN Internet site related to ANNETTE[4], thereby allowing a follow-up of course registrations, implementations, and evaluations. During registration the applicants were asked to provide some personal information (like their expectations on the course, stored in accordance with the GDPR[5]), which should assist the trainers in course preparation targeting the enrolled students. This should also support an enhanced evaluation of course implementation.

This was the regular approach for all courses offered under the ANNETTE project, but finally conducted somewhat differently for A-NF-01 and A-NF-03, see explained below in the respective chapters.

After concluding a course, the students were regularly asked to complete an evaluation questionnaire, with the aim to identify further areas of improvement for the respective course.

The following chapters describe the results of further training offering and implementation during the year 2019.

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[3] See https://www.fusenet.eu/node/1296, https://www.fusenet.eu/node/1297 and https://www.fusenet.eu/node/1298
[4] See http://www.enen.eu/en/projects/annette/eoi1.html
[5] See, e.g., https://eugdpr.org

3. A-NF-01 *FUNDAMENTAL KNOWLEDGE ON FUSION AND NUCLEAR ASPECTS*

During the execution of the ANNETTE project, namely after start of the second reporting period, it was agreed within WP2 to organize and implement an ANNETTE Summer School at the end of June 2018 (June 25th -June 29th). This Summer School should deal with Nuclear Technology, Nuclear Waste Management and Radiation Protection. Participants should be introduced to the multi-disciplinary present and future challenges in three core topics in present-day nuclear power production, Gen-IV nuclear power production, fusion and medical applications. The aim should be to compare the similarities and differences in the challenges.

The Summer School was targeted to young professionals, master students and doctoral students in these fields, both in industry, government, regulatory bodies, research centers and universities. A prerequisite was a BSc-level degree related with any of the Summer School topics.

Consequently, within WP6 this opportunity was taken to implement the planned training course on *Fundamental Knowledge on Fusion and Nuclear Aspects* (A-NF-01). The related lectures should then be implemented through plenary lectures as well as topic specific lectures and allocated exercises / workshops, as foreseen in the Summer School schedule.

In accordance with the objectives of the Summer School, the schedule was designed in a way to allow for an alternation between plenary lectures (cross-cutting, introductory-level lectures) on Monday and Friday and specialized in-depth lectures and workshops, dealing with the disciplines nuclear technology, nuclear waste management, and radiation protection, thereby A-NF-01 implemented in the discipline *Nuclear Technology*.

The training description is documented in Annex 1, which was also used for presenting this course in the Internet[6]. The detailed fusion specific schedule of the Summer School and the A-NF-01 were harmonized with this training description, see Table 1 *Syllabus of A-NF-01*.

No.	Content
1	The 7 challenges of Fusion and its implications on nuclear safety
2	Design of DEMO: implications of the nuclear aspects
3	The physics basics of a fusion reactor
4	Basics of nuclear regulation and licensing and its impact on licensing and design of nuclear power plants
5	Exercise: how to consider nuclear regulation in design / engineering activities
6	Aspects of tritium: the safety issues, the breeding, the recirculation, the extraction etc.
7	Neutron irradiation: what is the impact on the material properties, neutron stopping, safety issues, production of radioactive waste
8	Exercises to aspects of tritium / neutron irradiation

Table 1 ***Syllabus of A-NF-01***

[6] See e.g. http://www.fusenet.eu/node/1296

As the Summer School was very well rated by the participants, it was recommended implementing this type of course annually. Through targeting young professionals, master students and doctoral students in these fields, both in industry, government, regulatory bodies, research centers and universities, this might thereby contribute substantially to the attractiveness of job positions in the nuclear field.

Additionally, this type of Summer School would provide a broad picture and good overview on the various aspects of nuclear applications, with nuclear technology (including fusion), radiation protection, and nuclear waste management, thereby boosting the looking-out-of-the-box attitude of the participants. For today's challenges related to applications of nuclear, this attitude is indispensable for a successful work in nuclear. And it would certainly support the flexibility of participants in a world with ever changing work boundary conditions, providing a steppingstone to lifelong learning, while relying on networks that could be fostered in this type of Summer School.

Nevertheless, as the success of the Summer School also was caused by the excellent preparation and implementation of the local organizers, this should be taken care of again. Therefore, future summer schools could be easiest performed once more in Turku, thereby also using the vicinity of Olkiluoto as an opportunity for hands-on presentation of nuclear in real life.

Yet for further summer schools it appeared to be very important to reconsider in more detail the different lectures, and to arrange for an improved well-balanced level. This refers to scope, level of detail, and adaptation to time that is available for presentation and discussions.

Finally, one complicated issue to be considered is the timing of a future summer school: the incompatibility with the semester of the home university may deteriorate the interest to participate. Taking all these issues into account will certainly boost the attractiveness of future summer schools, and their contribution to lifelong learning of the work force in the nuclear field.

In the beginning of 2019, a working group was formed, consisting of different ANNETTE partners as well as further educational institutions, with the aim to prepare, organize, and implement a further edition of the ANNETTE Summer School. However, it soon emerged that timing, budget, organizational capabilities of the working team and location options did not allow for a rerun of the Summer School in 2019. Therefore, the activities of the working group were soon concluded, and in 2019 no further attempt was made to prepare a edition of the Summer School.

As conclusion, although design, specification, and training material (in the format of presentations and video records) of A-NF-01 are available, and will be made accessible through FuseNet, further editions of A-NF-01 will depend on the capabilities (financial as well as human resources) of the fusion community, in particular the FuseNet members. In contact with further fusion stakeholders, like the ITER Organization or Fusion for Europe, the ANNETTE partner FuseNet and the related Third Linked Parties will strive regularly to prepare, organize, and implement a further edition of A-NF-01, when possible also in connection with a Summer School or an equivalent event that may deal with a broad overview and introduction to nuclear issues.

4. A-NF-02 *REGULATION AND ITS APPLICATION IN NUCLEAR PROJECTS*

The specification published in report D6.2 was used to develop a detailed training specification or training description. The result is documented in Annex 2, which was used for offering this course in the Internet[7].

Based on the specification, the training material was developed as already described in report D6.3. In accordance with the specification and the training material, a training program (syllabus) was issued. Finally, the pilot course was implemented by Framatome GmbH in their training center in Karlstein (Germany, close to Frankfurt) on February 11th and 12th.

Based on the written feedback of the course participants, but also on the lively discussions that were held during the course, the following conclusions and recommendations were made:

- Overall, the importance of the course topic (nuclear regulation and how to apply it in nuclear projects) was rated high by the participants.
- Likewise, it was very beneficial to start with an overview of nuclear regulation and codes and standards.
- Next, the expertise of Framatome in nuclear (fission) safety was well received and acknowledged, as this provided the opportunity to illustrate many nuclear safety related issues.
- Furthermore, the use of case studies drawn from Framatome' s expertise greatly helped to recapitulate and apply the theoretical knowledge provided through the lectures.
- However, several comments pointed out that the course should be more focused on fusion related nuclear safety issues.
- And finally, the specifics of French laws, regulations and nuclear codes and how to apply these in the ITER project ought to be presented more extensively, and illustrated with appropriate, practice oriented examples.

These most important recommendations by the participants, namely to focus stronger on the French law/regulations and on fusion aspects, was considered in an update of this training course. In particular, the case studies were re-edited and extended to provide more real-world examples important for dealing with nuclear regulation in design, construction and commissioning of nuclear facilities.

Based on this, another run of A-NF-02 was planned and offered in the fusion community, e.g. through the ANNETTE Monthly Bulletin. The second edition took place in September 2019, see the syllabus in Figure 1.

[7] See e.g. http://www.fusenet.eu/node/1297

framatome

Regulation and its Application in Nuclear Projects
09.09. - 10.09.2019
Location: Framatome Karlstein

Framatome Learning Solutions Training Center

Course day	Weekday	Begin	Duration	Training Topic	Trainer	Comment
1	Monday	09:30	00:30	Welcome and Introduction to Tablet-PC	Baltin	
		10:00	00:45	Introduction and Overview of national / international nuclear law(s), related regulation	Baltin	
		10:45	00:45	Main licensing activities / deliverables / responsibilities	Baltin	
		11:30	01:00	Basic safety principles and Assessment of safety (1)	Baltin	
		12:30	01:00	Lunch		
		13:30	01:00	Basic safety principles and Assessment of safety (2)	Baltin	
		14:30	01:00	Developing Safety Culture	Baltin	
		15:30	01:00	How to integrate nuclear regulation requirements into fusion projects	Baltin	
		16:30		End of the 1st day		
2	Tuesday	09:00	01:00	Recapitulation of 1st Training Day	Baltin	
		10:00	02:00	1. Case Study: Safety Culture	all	
		12:00	01:00	Lunch		
		13:00	02:00	2. Case Study: Nuclear Pressure Equipment compliance with regulatory requirements	all	
		15:00	00:30	Summary and Feedback	Baltin/all	
		15:30		End of the training		

Figure 1. Syllabus of pilot course

Altogether, 8 persons attended the second edition, namely from some European companies active in the ITER supply chain, thereby well representing the expected target group for this course, also with respect to their professional positions and interests in nuclear regulation. Compared to the pilot course in February 2019, the feedback of the participants improved considerably with respect to the content of the course and its implementation, using the training measures, and the overall impression. In particular, the case studies and the related discussions, i.e. the practical or real world examples were highly appreciated by the trainees.

Further implementations of A-NF-02 will be considered continuously by the Framatome Training Center, as amongst others this course will be posted and offered on their Internet site. Additionally, as already communicated to ITER Organization, Framatome is ready to provide the course also at other locations, e.g. at the ITER Academy, details to be agreed directly with Framatome.

After the end of the ANNETTE project, FuseNet and the related Linked Third Parties will strive to inform the fusion community regularly about the availability of A-NF-02, and the benefits for fusion stakeholders of having attended this training course by their employees active in design, construction and commissioning of nuclear facilities.

5. A-NF-03 *NUCLEAR SAFETY CULTURE IN THE ITER PROJECT – THE SUPPLY CHAIN*

After having conducted the stakeholders' workshop in November 2016 it emerged that in the ITER project there was a need for fostering a nuclear safety culture within the ITER supply chain. The supply chain consists of different sub-contractors that are active in manufacturing, construction, and assembly of ITER. This issue of nuclear safety culture is specifically important for artisans, technicians, or related supervisors and management staff. Thereby, the target group may extend to several hundred or more persons, when all responsible staff in the complete supply chain on all levels must be addressed. Because of this high number, and the necessity to train people concurrently, best at various locations easily accessible for the target group, it was decided to offer the training as an online training course, designed for flexible and autonomous learning. Participants reach learning outcomes by working through contents explained in videos by a native English speaker, and self-evaluation tests that let participants test their knowledge acquisition.

Based on the specification made in report D6.2 and the considerations above, a detailed training specification, or training description was developed. The result is documented in Annex 3, which is also used for publishing the course in the Internet[8].

Next, the development of training material was conducted according to this training specification (documented in report D6.3). Subsequently the material (i.e. slides and text to be talked by the presenter) was reviewed by the Nuclear Safety Division of the ITER Organization and approved for implementation.

In the next step, the presentation of the course (subdivided in 6 chapters, see figure 2) was recorded and programmed in UNED CEMAV polymedia studio. When accessing the course through *UNED Abierta*[9] in the Internet, the trainees may view slide by slide through watching the video lectures, allowing them to focus on the content. Viewing all videos by a trainee will require a duration of about one hour.

No.	Title of video	Appr. Duration [min]	Synopsis
1	Introduction and Overview	4	Provides an introduction into the course, and an overview of its content, as well as its training objectives
2	Basics of Fusion	22	Delivers some technical content that is a basis for the rest of the course, namely an introduction to ITER and its main characteristics and equipment (tokamak, magnets, tritium, heating, fuel cycle, heat extraction)
3	Why Nuclear is different!	6	Explains the notion of risk and the specifics of nuclear: ionizing radiation, and its impact on people, hence the ITER safety equipment and their safety functions are introduced
4	Safety objectives and functions at ITER	5	Nuclear safety is the top priority in the ITER project, so ITER safety functions are explained to achieve nuclear safety
5	Contribution of a safety culture to achieving safety objectives	8	To ensure nuclear safety, a safety culture must be implemented. Safety culture is explained, the stakeholders

[8] See, e.g., http://www.fusenet.eu/node/1298
[9] See https://iedra.uned.es/

No.	Title of video	Appr. Duration [min]	Synopsis
			involved are presented, and how to achieve safety objectives through safety culture
6	Nuclear Safety Culture: management /individual commitment	10	As nuclear safety is a collective responsibility, the commitment of managers and individuals to safety culture is introduced and explained. Expectations on attitude and behavior of course students are presented.

Figure 2. Chapters (videos) of course A-NF-03

Finally, after Fusion for Energy had selected persons from sub-contractors that should participate in a pilot run of this course, these persons were invited by UNED to access the course in *UNED Abierta*. The work of these persons with the course was tracked, in particular the grades of the examination at the end of the course.

The pilot run of the course was attended by 23 trainees (with 29 enrollments), and 22 trainees successfully passed the final examination. The feedback of the trainees (reported in deliverable D6.4) in summary showed a high satisfaction with the course, i.e. in the overall rating of the course and its importance for the trainees, in rating the training material and especially the trainer, as well as in evaluating course access and support during the course. Based on the feedback from the participants in the pilot run, some minor modifications only were made in the course material, specifically in the set of examination (test) questions. Therefore, as conclusion we recommended the (unmodified) course for further use in the ITER supply chain, as it provides in a compact way the important basic knowledge that is necessary for developing and fostering nuclear safety culture in the ITER project.

After having reported these recommendations in deliverable D6.4, several communication initiatives were launched to offer the course to the ITER Organization (IO) or bodies related to it for a continuous implementation. Thereby it was pointed out that the course naturally will not constitute a complete nuclear safety culture training or even replace one but could easily be deployed e.g. as a first (introductory) module in a nuclear safety culture training curriculum, delivering basic facts about nuclear safety culture in the ITER project. Now the course is ready to be deployed immediately, its implementation will require only marginal costs for hosting the course and providing controlled access to it via the Internet. However, by now this suggestion has not yet been seized by IO senior managers.

In parallel to the communication initiatives, learning with the course was offered through the ANNETTE Monthly Bulletin. Enrollments could be made from July onwards through the ANNETTE form[10], training with the course should be possible in September. However, finally starting the course was delayed until the end of October. Since then only 14 persons registered for the course, and by now only 3 persons completed the course, also passing the final examination successfully.

For sure this small number of enrolled persons may be explained by the fact that the ANNETTE Monthly Bulletin mainly was distributed within the education and training community, depending on the contacts available for the ANNETTE partners, i.e. definitely not within the intended target group of this course (i.e. the ITER supply chain). In contrast to that, an online training course (also called MOOC, total training time about thirty hours) on (general) nuclear safety culture developed

[10] http://www.enen.eu/en/projects/annette/eoi1.html

and offered through ANNETTE WP5 encouraged a considerably larger number of persons to register for this course. In this case, mostly students enrolled, probably also attracted by the fact that after successful completion of the course they would receive (ECTS) credits from UNED that they could use in their nuclear studies.

As conclusion: to what extent A-NF-03 will be used in the future will depend on several factors. First, of course, whether and to which degree the various companies in the ITER supply chain will be required to train their personnel on nuclear safety culture. It is important to realize that this will also have an impact on the related budget of contracts awarded to companies in the ITER supply chain, namely on the working hours of the personnel that are required for learning with the course (or for attending further training on nuclear safety culture). Considering the complete supply chain, the number of persons targeted (and their required working hours for training) may easily reach some thousands, with a noticeable effect in total on the required budget for supply chain contracts.

Next, the ease through which the employees of the different supply chain companies will have access to online courses in the Internet (and their experiences with online training) will play a crucial role for acceptance of the course. The course should be hosted preferably by UNED, as its *UNED Abierta* platform provides an easy access that can also be simply managed.

It may certainly also be beneficial to deploy the course (e.g.) when setting up a nuclear safety culture campaign at the ITER site, and when introducing personnel face-to-face at the ITER site to the site specifics in connection with an induction to occupational health and safety.

In summary, the course and its access through the Internet offer an enormous potential for reaching a large target group effectively, providing a short and concise as well as motivating introduction to nuclear safety culture, thereby contributing essentially to developing and fostering this culture.

To what extent this potential will be made use of, will depend crucially on how related senior manager in the ITER project will be made aware of it, and to what extent budget (for hosting and controlling the access to it) will be provided to implement the course on a large scale.

6. GENERAL CONCLUSIONS AND RECOMMENDATIONS

As has become apparent during the ANNETTE project, there is a clear need to raise the nuclear awareness in fusion projects. The systematic approach to training that was applied in WP6 allowed to focus on the most important topics where an urgent competence demand was identified. It could be met through the three training courses that were developed, and that by now were implemented in pilot as well as some further runs.

To support spreading the information about the outcome of WP6 during its contract period, several conferences were attended to present the work conducted in ANNETTE, namely

1. *ANNETTE Project: Contributing to The Nuclearization of Fusion*, ANIMMA 2017[11]
2. *ANNETTE Project: Assure a Qualified Nuclear Work Force in the Next Decades*, 43rd Annual Meeting of the Spanish Nuclear Society, Malaga / Spain 2017[12]
3. *The ANNETTE Summer School: A Significant Contribution to Professional Development*, 44th Annual Meeting of the Spanish Nuclear Society, Ávila / Spain 2018
4. *Nuclear Safety Culture in the ITER Supply Chain: Successful Implementation of Online Training*, 45th Annual Meeting of the Spanish Nuclear Society, Vigo / Spain 2019
5. *SPOCs[13] for innovating education in the nuclear sector*, OOFHEC2019[14]: the Online, Open and Flexible Higher Education Conference, Madrid / Spain 2019

However, despite using additionally various frequent communication channels during 2019 (mainly through the ANNETTE Monthly Bulletin), it apparently has not yet been possible to address the large target group of the WP6 training courses comprehensibly, and to initiate the implementation of further editions of the developed WP6 training.

Consequently, we conclude that to ensure the sustainable effect of the results achieved in WP6 after closing the ANNETTE project, the ANNETTE partner FuseNet should conduct as main recurrent tasks the following:

- Informing regularly the fusion community and stakeholders, i.e. fusion students, the fusion education and training institutions, the related research and development organizations, related industry, fusion project partners like IO, F4E and their supply chain, about the outcome of ANNETTE WP6,
- Whereupon focusing on senior management in IO, F4E or EUROfusion.

Furthermore, FuseNet should

- also provide access to the (public) deliverables (reports) D6.1 (*Competence Needs for the Nuclearisation of Fusion*), D6.4 (*Implementation of Courses of Nuclear Awareness for Fusion*), and D6.5 (*Participation in the Courses*),
- While hosting and providing access to the training material of courses A-NF-01, A-NF-02, and A-NF-03,
- And encouraging regularly European fusion education and training institutions to deploy the available material for offering and implementing training courses on nuclear awareness in fusion,

[11] See https://www.epj-conferences.org/articles/epjconf/abs/2018/05/epjconf_animma2018_10001/epjconf_animma2018_10001.html
[12] See https://www.reunionanualsne.es/es/
[13] Small and Private Online course
[14] See https://oofhec2019.exordo.com

Thereby contributing considerably to support continuous professional development in the fusion and nuclear sector.

Finally, it is important to mention that the broad training offer from the ANNETTE partners provided many opportunities also for fusion professionals to attend nuclear training. Here we cannot report to what extent fusion professionals used this offer, but the total figure of course applicants and attendees mentioned in deliverable D2.5 (*Evaluation of the pilot European Programme for CPD and the summer courses*) indicates that the course offer and its availability must have had an important impact on professional development in the nuclear sector in Europe. This must have included professionals from the nuclear supply chain, therefore also fusion professionals may have been attracted as well.

7. REFERENCES

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

[2] ANNETTE Deliverable D6.2: Available Nuclear Training Programmes for Fusion and Identification of Gaps, 2017

[3] ANNETTE Deliverable D6.3: Developed Fusion Specific Training Courses, 2018

[4] ANNETTE Deliverable D6.4: Pilot Run of Training Courses on Nuclear Awareness for The Fusion Field, 2019

Annex 1: Training Description A-NF-01
Fundamental Knowledge on Fusion and Nuclear Aspects

Target group of training
The training shall target fusion (industry) professionals, scientists and students to facilitate the further migration of nuclear competences into this group, thereby supporting the current and future research and development activities for the roadmap to fusion energy. Alternatively, the training also targets (industry) professionals, scientists and students from the nuclear/fission field. They have already many of the nuclear competences, but they lack the fusion basics. By providing them with that knowledge they can easier interact with the fusion field and bring in their competence in this field.

Prerequisites of target group
The targeted trainees should have undergone a suitable engineering education, preferably in a technical subject matter important for their actual job position, at an academic level. They shall be able to understand the general engineering and physics principles at a bachelor level. For the specific nuclear knowledge (in case for the fusion students) or the fusion knowledge (for the population from the nuclear field) no prerequisites are needed. The training aims at providing this information in a comprehensive way.

Training objectives
The training should impart knowledge on the specific nuclear aspects of fusion: the issues concerning the neutron irradiation, material damages, tritium breeding, tritium handling and safety, radio-active waste, and nuclear codes and standards. After the training, the trainees shall be able to explain: 1) The impact of neutron radiation on materials 2) How to shield neutrons effectively 3) How to breed tritium 4) What are the safety aspects concerning tritium 5) What are the worst-case scenarios concerning safety for a fusion reactor 6) How the radioactive waste is reduced 7) What implications the nuclear aspects have for the design and licensing of a fusion reactor In addition, the Nuclear community will be able to explain: a) Why the D-T reaction is the exploited in a fusion reactor b) How to breed the tritium c) What the criterion is to achieve fusion and why a temperature of 150 MK is needed d) Why superconducting magnetic fields are needed, and why bigger machines are better e) How to exhaust the power and the particles from a reactor.

Training content
Training will consist of a mix of plenary lectures, group assignments and technical lectures. The following learning content should be dealt with in the training (in the fusion part): 1. Introduction to and overview of the fusion reactor*: details why fusion is nuclear, and the implications on design /construction/ operation of fusion facilities, overview of further important technologies to be mastered when constructing fusion power plants, e.g. plasma/ vacuum/ cryogenic/ electromagnetic/ tritium/material technologies (plenary lecture)* 2. The 7 challenges of the fusion research programme: to give an overview of the state of the art, and how the nuclear aspects play a determining role in this: tritium breeding, material aspects upon neutron irradiation, confinement and control of instabilities etc. (plenary lecture) 3. An interactive session to discuss the implication of the nuclear aspects have on the design of a fusion reactor (group assignment) 4. A dedicated session on tritium: the safety aspects, the breeding, the recirculation, the confinement etc. (technical lecture) 5. A dedicated session on neutron irradiation on materials (technical lecture) In addition, the generic nuclear part of the programme (nuclear technology, rad. waste management and radiation protection) is detailed elsewhere.

Training development
Experts on the topics to be addressed in the training shall develop slides that will be presented in the knowledge-oriented part.

Training method
The training has a mix of activities: plenary lectures discussing the basic ingredients, technical lectures to discuss in an interactive manner with a smaller audience the nuclear issues in more detail. Smaller exercises or assignments will be part of these lecture. Finally, one group assignment (“design a fusion reactor that can deal with the nuclear aspects”) will have to be worked out, so that the students apply the knowledge gained in the lectures.

Training duration
In total, two days will be an ideal duration to discuss the fusion specific aspects, i.e. all the content as listed above can be addressed in the training. However, the fusion students will also benefit from the generic nuclear training (aimed at the fission-oriented students) and an extra 2-3 days for these topics is advantageous, making the fusion students ‘Nuclear Aware’. Therefore, a duration of one week will be necessary to cover the complete training content in the summer school.

Training material

The slides must not be overloaded with text (if only text on a slide: about 7 lines with 7 words each). The text and associated photos / figures / diagrams shall logically sub structure the content as outlined above. They should be fit for purpose to achieve the training objectives.

It is recommended to develop a training manual that includes all the text that shall be presented by the expert (trainer) when the corresponding slide is shown. Spoken text and slide should correspond, it is recommended to present a slide part by part, in parallel to the talk of the expert. The manual possibly could be used later for the development of an e-learning course.

These slides should be useable for self-study afterwards. If not, the lecturer should provide a concise description of his presentation, or a video recording of the presentation will be made.

Evaluation of training effectiveness

After the training, feedback from the trainees shall be collected to evaluate how the trainees liked the course – with respect to course organization, fulfilment of their expectations, achievement of training objectives, quality of training material, competences of the trainer (i.e. expert as presenter).

Finally, a test (best: a “kahoot –like quiz) shall be passed by the trainees to check whether they have achieved the training objectives.

Annex 2: Training Description A-NF-02
Regulation and its Application in Nuclear Projects

Target group of training

The training shall target engineers that are employed by the ITER Organization, Fusion for Energy, or their sub-contractors in the ITER project (down to the lowest level), and active in ITER related design, procurement, manufacturing, construction, assembly, and commissioning of ITER equipment.

Prerequisites of target group

The targeted trainees should have undergone a suitable technical engineering education, preferably in a technical subject matter important for their actual job position. They shall be able to understand the basic design of a power plant and its systems and components, and the technical basics (physics/chemistry resp. design/operation) of a nuclear (fission or fusion) reactor.

Training objectives

The training should impart specific knowledge on nuclear licensing and the impact of licensing requirements on design as well as on subsequent down-stream activities. Furthermore, it should be complemented by additionally training the skills that are necessary in the nuclear environment of a fission or fusion project like ITER.

After the training, the trainees shall be able to

1. shortly describe some national / international nuclear law(s) and related regulation, and their impact on design/manufacturing/construction/assembly/commissioning activities,
2. list and shortly describe some important Codes and Standards (C&S) and their impact on regulation or licensing,
3. list and shortly describe some basic safety principles and their impact on management / technology / project processes,
4. shortly explain the importance of safety analysis, and their application in licensing, design/manufacturing/construction/assembly/commissioning activities,
5. integrate important nuclear regulation requirements into fission or fusion projects, and perform basic requirements management activities,
6. apply important nuclear regulation requirements in some design / manufacturing / construction / assembly / commissioning activities.

Training content

Training will consist of a knowledge-oriented part, and a skills-oriented part.

The following learning content should be dealt with in the training:

1. Introduction to and overview of national / international nuclear law(s) and related regulation, involved national and international organizations (e.g. ASN, IAEA),

2. Main licensing activities / deliverables / responsibilities,
3. Overview of Codes and Standards (C&S) and introduction to relevant C&S, their impact on regulation or licensing,
4. Introduction to and overview of nuclear risks, safety objectives, and derived requirements,
5. Basic safety principles: management / technology / process oriented (e.g. defense in depth),
6. Introduction to (deterministic and probabilistic) safety analysis and related tools used by different technical disciplines for simulations in support of licensing,
7. How to integrate nuclear regulation requirements into fusion projects, and perform requirements management,
8. How to apply nuclear regulation requirements in design/manufacturing/construction/assembly/commissioning activities.

The knowledge-oriented part shall deal with topics no. 1 to 5, whereas the skills-oriented part shall focus on topics no. 7 and 8. To some extent the content no. 1 to 5. may be known to some participants, but a summary and overview shall be presented, and discussed in the first part of the training. Thereby it shall provide the basis for the second part, which shall develop the skills required to apply important nuclear regulation requirements in design, procurement, manufacturing, construction, assembly, and commissioning of ITER equipment.

Training development

Experts on the topics to be addressed in the training shall develop slides that will be presented in the knowledge-oriented part.

As for the skills part, examples provided by ANNETTE partners from industry or from IO or F4E shall be taken to develop case studies. They must describe a fission/ fusion relevant scenario, e.g. based on their past experiences with contract follow-up, collected e.g. through reports on findings or non-compliances during contract execution, and provide all relevant information thereof. The case study will contain several exercises that must be solved / worked through by the trainees.

Training method

Face-to-face presentation during the knowledge-oriented part, where appropriate slides (altogether about 50 – 60) are shown and explained by topic related experts with good training experiences. During presentation, the trainees shall be animated to discuss the content with the trainer(s).

Principally, the first (knowledge oriented) part could be transformed into an e-learning course. However, the current restrictions of the ANNETTE budget will only allow for the development of slides and possibly also a training manual. In a next step, this material could be used to develop the e-learning course.

Case studies will have to be used that shall be worked through by the course participants during the skills-oriented part.

Training duration

In total, two days will be an ideal duration, so that all the content as listed above can be addressed in the training. The first part (knowledge related) should last for one day, the second part (skills related) should also last for one day.

Training material

The slides must not be overloaded with text (if only text on a slide: about 7 lines with 7 words each). The text and associated photos / figures / diagrams shall logically sub structure the content as outlined above. They should be fit for purpose to achieve the training objectives.

It is recommended to develop a training manual that includes all the text that shall be presented by the expert (trainer) when the corresponding slide is shown. Spoken text and slide should correspond, it is recommended to present a slide part by part, in parallel to the talk of the expert. The manual could be used later for the development of an e-learning course.

Evaluation of training effectiveness

After the training, feedback from the trainees shall be collected to evaluate how the trainees liked the course – with respect to course organization, fulfilment of their expectations, achievement of training objectives, quality of training material, competences of the trainer (i.e. expert as presenter).

Finally, a test (best: a set of about 5 multiple choice questions / one correct answer) shall be passed by the trainees to check whether they have achieved the training objectives.

Annex 3: Training Description A-NF-03
Nuclear Safety Culture in the ITER Project – The Supply Chain

Target group of training
The training shall target workers that are employed by sub-contractors of the ITER project (down to the lowest level), and active in ITER related manufacturing, construction, assembly, and commissioning of ITER equipment.

Prerequisites of target group
The targeted trainees should have undergone a suitable vocational training, preferably in a technical subject matter important for their actual job position. They shall be able to understand basic technical descriptions (including schematics) of a power plant and its systems and components.

Training objectives
After the training, the trainees shall be able to 1. shortly describe the main mission of ITER, 2. shortly explain why ITER is a nuclear facility, and what are the resulting risks that must be handled during its operation, 3. list some measures to protect the ITER machine, the ITER staff and the environment from the radiation, 4. describe the main elements of a nuclear safety culture, 5. list some responsibilities of managers regarding nuclear safety culture, 6. list some responsibilities of individuals regarding nuclear safety culture, 7. list important personal behavior that reinforces nuclear safety culture, 8. describe how this can contribute to a healthy nuclear safety culture.

Training content
Training shall be implemented as e-learning, where appropriate slides are shown and explained by an expert on nuclear safety culture for ITER (see below). The following learning content should be dealt with in the training: 1. Basics of ITER: its mission, layout, nuclear reaction (about 5 slides) 2. Why nuclear is different to other high-risk industries: nuclear risks and entailed safety objectives, and the resulting implications on licensing, design, manufacturing, construction, assembly, and commissioning *(about 3 slides)* 3. ITER design and the safety functions that shall achieve safety objectives *(about 4 slides)*

4. Contribution of a safety culture to achieving safety objectives, and its main elements as well as actors *(about 4 slides)*
5. Traits of a healthy nuclear safety culture: management commitment *(about 2 slides)*
6. Traits of a healthy nuclear safety culture: individual commitment *(about 2 slides)*
7. Implications for behavior of personnel that is active in manufacturing, construction, assembly, and commissioning of ITER components, either at manufacturers' sites, or at ITER construction and assembly site *(about 5 slides)*

No. 5 and 6 and consequently also no. 7 could rely on the INPO document Traits of a Healthy Nuclear Safety Culture *(INPO 12-012, April 2013).*

Training development

Experts on the topics to addressed in the training shall develop slides that will be presented in an e-learning course. The slides will be reviewed by representatives of IO or F4E to ensure that the IO safety policy is implemented in the training. The slides will also be reviewed by the ANNETTE WP6 team to ensure that they are fit for purpose to train the target group.

Training method

e-learning, where appropriate slides (altogether about 20 – 30) are shown and explained by an expert on nuclear safety culture for ITER. The trainees shall be invited to access and work through the e-learning via the Internet.

Training duration

In total, 1 hour could be an ideal duration, so that all the content as listed above can be addressed in the training.

Training material

The slides must not be overloaded with text (if only text on a slide: about 7 lines with 7 words each). The text and associated photos / figures / diagrams shall logically sub structure the content as outlined above. They should be fit for purpose to achieve the training objectives.

As the training shall be delivered as e-learning, where an expert presents and talks about the slides, it is recommended to also develop a training manual that includes all the text that shall be spoken by the expert when the corresponding slide is shown. Spoken text and slide should correspond, it is recommended to present a slide part by part, in parallel to the talk of the expert.

Evaluation of training effectiveness

After having worked through the e-learning, feedback from the trainees shall be collected to evaluate how the trainees liked the course – with respect to course organization, fulfilment of their expectations, achievement of training objectives, quality of training material, competences of the trainer (i.e. expert as presenter).

Finally, a test (best: a set of about 5 multiple choice questions / one correct answer) shall be passed by the trainees to check whether they have achieved the training objectives.