



**Fuel Recycle and Experimentally Demonstrated  
Manufacturing of Advanced Nuclear Solutions for Safety**

**Project Number: 101060800**

**DELIVERABLE D5.1**

**INITIAL TRAINING PROGRAMME**

Lead Beneficiary: RATEN

Authors	Due date:	31/12/22
Daniela Diaconu Francesco Lodi Gabriel Pavel Roberta Cirillo	Actual release date:	27/12/22
	Version:	1.5

Contributors	Approved by AMO	Coordinator
	Petr Kořán, Jana Peroutková	Christian Ekberg

Project start date: 01/09/22

Project duration: 48 months

Dissemination level			
PU	Public	X	
RE	Restricted to specific group		
CO	Confidential (only for FREDMANS partners)		

## Version control table

Version number	Date of issue	Author(s)	Brief description of changes made
1.0	27/12/2022	Daniela Diaconu Francesco Lodi Gabriel Pavel Roberta Cirillo	Draft version released
1.1	02/01/2023	Petr Kořán, Jana Peroutková	AMO check, revisions
1.2	03/01/2023	Daniela Diaconu	Incorporation of the revisions
1.3	10/01/2023	Christian Ekberg	Coordinator's check and approval
1.4	10/01/2023	Teodora R. Vollmer	XRD changed to XRD
1.5	18/01/2023	Daniel Shepherd	Typos corrections

## Project information

Project full title:	Fuel Recycle and Experimentally Demonstrated Manufacturing of Advanced Nuclear Solutions for Safety
Acronym:	FREDMANS
Funding scheme:	RIA
ECGA number:	101060800
Call/topic	HORIZON-EURATOM-2021-NRT-01-02
Coordinator:	Chalmers University of Technology –Christian Ekberg
EC Project Officer:	Renata Bachorzcyk-Nagy
Start date – End date:	01/09/22 – 31/08/26 i.e. 48 months
Coordinator contact:	+46-31-7722801 <a href="mailto:che@chalmers.se">che@chalmers.se</a>
Administrative contact:	+420 245 008 599, <a href="mailto:petr.koran@evalion.cz">petr.koran@evalion.cz</a>
Online contact	<a href="https://enen.eu/index.php/portfolio/fredmans-project/">https://enen.eu/index.php/portfolio/fredmans-project/</a>

## Disclaimer

The document is proprietary of the FREDMANS consortium members. No copying or distributing, in any form or by any means, is allowed without the prior written agreement of the owner of the property rights.

*Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union, European Commission or European Atomic Energy Community. Neither the European Union nor the granting authority can be held responsible for them.*



## CONTENT

EXECUTIVE SUMMARY .....	4
1 INTRODUCTION .....	5
1.1 Main approach of the E&T programme .....	5
2 OBJECTIVES AND SCOPE OF THE E&T PROGRAMME .....	7
2.1 Objectives .....	7
2.2 Scope .....	7
3 INITIAL LIST OF TRAINING COURSES .....	8
3.1 Training on fuel characteristics and performances requested for an LFR reactor.....	8
3.2 Seminar and hands-on training on the basics of nuclear fuel fabrication and characterisation (metalography, SEM, EDS, calorimetry) .....	9
3.3 Hands-on training session on UN manufacturing via dry and wet routes .....	10
3.4 Hands-on training session on UN characterisation in term of SEM, XRD .....	11
3.5 Summer school Actinide Science and Innovative Nuclear Fuel Cycles.....	12
3.6 Support for outside FREDMANS training courses .....	12
4 TRAINEES' SELECTION PROCEDURE .....	13
4.1 List of criteria for trainees' selection.....	13
4.2 Selection process .....	13
4.3 Feedback from trainees.....	14
5 CONCLUSIONS.....	15

## EXECUTIVE SUMMARY

The purpose of this deliverable is to present the initial education and training (E&T) programme proposed to be implemented by the FREDMANS project, with preliminary details on learning objectives and outcomes, target audience, venue, estimated duration and period, and trainee selection.

The document will be used in planning the WP5 activities and their correlation with the activities carried out by other WPs, especially with dissemination actions.

### *Scope of the deliverable*

The report describes:

- Objectives, approach, and scope of the FREDMANS E&T programme
- Training courses planned within FREDMANS
- Trainees' selection procedure

### *Relations with other deliverables*

This deliverable includes input from *M5.1 -Requests on lectures and training collected* and *M5.2 Evaluation criteria for participants selection* and provides the initial content elements for deliverable *D5.3 Report on the series of lectures and training (M48)*.

### *Updating the Training Programme*

The Initial Training Programme will be updated in month 24 and 36, in order to include new requests received from the consortium partners and training events organized by- or in collaboration with other ongoing EU projects, European networks/associations, or international organisations, funded from the FREDMANS Travel Fund.

# 1 INTRODUCTION

Developing nuclear energy programmes need excellent scientists able to shape the future changes needed for a net-zero energy system, innovative engineers able to design new nuclear reactor concepts and fuel cycles, and technicians able to build the infrastructure for sustainable economy.

Excellence in science is closely related to excellence in education. For this reason, FREDMANS aims to implement an ambitious and coherent education and training programme, focused on development and stimulation of the talents of students and young researchers and engineers through a wide range of dedicated activities.

Today, many research centers and nuclear installations are facing major changes in the age profile of the staff, dominated by young employees with limited experience, which requires intensive education and training. The efforts made in each of these institutions are joined by numerous other initiatives, on a national, European and international level.

The FREDMANS project joins these efforts and proposes the implementation of an education and training programme in the field of nuclear fuels (with focus on uranium nitrides, UN) that complements the research-development activities it addresses. Young scientists with relevant theoretical and, above all, practical knowledge will be trained in the E&T programme answering the needs for skills and abilities in the field of nuclear fuels, combining theoretical courses with hands-on training sessions, thus ensuring the transfer of the valuable experience gained by the specialists with outstanding competencies in this field, who with time become rarer.

## 1.1 MAIN APPROACH OF THE E&T PROGRAMME

The education and training activities carried out in the FREDMANS project are based on the main characteristics recognized as necessary for excellence in an educational process:

- *Appropriate level of entry competence and motivation of students/young researchers* – ensured through the selection process of trainees;
- *Excellent teachers* – selected from among the renowned specialists in the field of nuclear fuel, with extensive experience and competence in the field of nuclear fuel manufacturing technologies, characterization and recycling;
- *Adequate framework and organization* – designed to stimulate learning and develop new skills and abilities.

All these aspects will synergistically contribute to effective transfer of knowledge to the new generation of nuclear scientists, preparing them for their future work in the development of nuclear fuels for innovative reactor systems.

In order to gain an in-depth understanding of nuclear fuel manufacturing technologies as well as a more holistic view of the many different types of nuclear fuel and associated fuel cycles,

the FREDMANS E&T activities will be linked to other training programmes either from European projects and networks, or international organizations (IAEA, NEA/OECD).

Therefore, during the implementation of the project, joint training and education events will be organized with other ongoing projects (for example, A-CINCH, ENEN2plus, etc.), using the capacity of the European Network on Nuclear and Radiochemistry Education and Training (NRC Network) which brings together 27 institutions, including many FREDMANS partners. This will maximize the impact of nuclear fuel training activities at European level.

The series of courses proposed to be held within FREDMANS have been designed to meet the beneficiaries' needs. This bottom-up approach was implemented from the very initial stage when a number of topics of great interest was identified. The same approach will be applied during the implementation of the project to collect new requests, arising from the continuous developments of the human resource in the nuclear sector, thus responding to the most urgent and acute needs in the field of advanced nuclear fuels.

## 2 OBJECTIVES AND SCOPE OF THE E&T PROGRAMME

### 2.1 OBJECTIVES

The education and training programme envisaged in the FREDMANS project primarily addresses the quality of the learning process and the ability of the trainees to perform at a high level, combining theoretical aspects with practical training in the most advanced laboratories, centers of excellence in nuclear fuel research (of e.g., CHALMERS, KTH, NNL, PSI, FZJ).

The high quality of education and training will be ensured by:

- The quality of the curriculum proposed for all training activities (lecture series and training courses, the summer school);
- The high-level learning objectives set for each education and training activity, the ambitious learning outcomes and the expected skills developed as practical activity in the laboratories.

The topics proposed to be addressed in this programme reflect the challenges posed by innovative reactor systems in terms of nuclear fuel design and the associated fuel cycle. The topics of lectures and courses, as well as the programme of the summer school, have been selected to attract and stimulate the interest of students and young scientists, and to improve their understanding and knowledge.

### 2.2 SCOPE

To ensure an effective transfer of existing and newly created knowledge on UN manufacturing, the education and training programme carried out in the FREDMANS project aims to cover at least the following topics addressed by the project:

- UN manufacturing routes
- Advanced manufacturing technology
- Characterization techniques
- Recycling of spent fuel.

The topics, methods and activities proposed by the FREDMANS E&T programme are designed to spark learners' interest and include learning by doing as part of an excellent learning environment provided by the best European specialists, teams and laboratories in nuclear fuel research.

To reach its objective, the E&T programme has been designed to provide theoretical and practical training sessions provided by the FREDMANS partners, to support participation in training events outside FREDMANS, to facilitate the mobility of specialists for internal assistance on request, and to organize a summer school on *Actinide Science and Innovative Nuclear Fuel Cycles*.

### 3 INITIAL LIST OF TRAINING COURSES

Four topics were identified early on as being of interest to the organizations participating in the project. These topics cover theoretical aspects of new types of nuclear fuels, manufacturing technologies and associated chemical and physical processes, as well as practical activities on fuel fabrication and characterization.

These theoretical and practical training sessions are aimed primarily at the new generation of scientists, who should take over the fuel manufacturing activities, both in research and industry, and orient them towards current and future needs, using the most advanced material manufacturing technologies.

The four topics are:

- Fuel characteristics and performances requested for an LFR reactor (ENEA)
- Basics on nuclear fuel fabrication and characterisation (metalography, SEM, EDS, calorimetry) (RATEN)
- UN manufacturing via dry and wet routes (CHALMERS)
- UN characterisation in term of SEM, XRD (CHALMERS).

These topics will be addressed in 2 training courses that will combine lectures focused on theoretical aspects with hands-on sessions in dedicated laboratories, under the supervision of specialists in this field.

#### 3.1 TRAINING ON FUEL CHARACTERISTICS AND PERFORMANCES REQUESTED FOR AN LFR REACTOR

To understand the need for new nuclear fuel technologies as well as the challenges associated with their manufacturing, use, and ultimate management of waste, it is essential to understand the phenomena relevant to the fuel behavior for typical fast reactor operating conditions. This is the aim of this training course, provided by ENEA Italy, and addressed mainly to master and PhD students.

<b>Fuel characteristics and performances requested for an LFR reactor</b>	
	<b>ENEA</b>
Venue	RATEN ICN, Pitesti-Mioveni, Romania
Tentative period	September 2023
Learning outcomes	Students will understand the main phenomena relevant for the fuel behavior for typical fast reactor operating conditions and some safety-relevant situations. Emphasis will be placed on differences with light water reactor conditions.



	Students will understand the main differences in terms of performances and challenges of oxides and nitrides fuel forms.
Target audience	Master students PhD students
Number of participants	10
Duration	1-day lectures session
Tests, verification	Yes
Credits, diplomas	Yes, diplomas

### 3.2 SEMINAR AND HANDS-ON TRAINING ON THE BASICS OF NUCLEAR FUEL FABRICATION AND CHARACTERISATION (METALLOGRAPHY, SEM, EDS, CALORIMETRY)

This seminar and hands-on training will focus on the fabrication and characterization of oxide and nitride fuels, respectively. The physical and chemical processes that occur along all stages of the technological streams will be presented and discussed, and the associated control and characterization methods will be explained and experienced practically by the trainees, in the fuel manufacturing laboratories of the Institute of Nuclear Research (RATEN ICN) in Romania.

<b>Seminar and hands-on training on the basics of nuclear fuel fabrication and characterisation (metallography, SEM, EDS, calorimetry)</b>	
<b>RATEN</b>	
Venue	RATEN ICN, Pitesti-Mioveni, Romania
Tentative period	September 2023
Learning outcomes	Students will understand and will be able to describe the fabrication flux of oxide and nitride nuclear fuel types and the associated chemical and physical processes.  Students will understand the impact of different technological parameters on the final characteristics of the nuclear fuel.

	Students will be able to describe and apply different methods used in nuclear fuel characterisation, and interpret the resulting images, diagrams and data.
Target audience	Students Master students PhD students
Number of participants	Max 10
Duration	1-day lectures session + 2-day hands-on training
Tests, verification	Yes
Credits, diplomas	Yes, diplomas

### 3.3 HANDS-ON TRAINING SESSION ON UN MANUFACTURING VIA DRY AND WET ROUTES

Hosted by the Chalmers University laboratories and delivered by its specialists in UN manufacturing, this hands-on training session aims to introduce trainees to nitride fuel fabrication technologies and give them the opportunity to experience the fabrication of UN fuels wet and dry fabrication routes.

<b>Hands-on training session on UN manufacturing via dry and wet routes</b>	
<b>CHALMERS</b>	
Venue	CHALMERS, Gothenburg, Sweden
Tentative period	April 2024
Learning outcomes	<p>Trainees will understand the theoretical aspects of the physical and chemical processes involved in the manufacturing of the UN nuclear fuel both for the dry and wet fabrication routes.</p> <p>Trainees will get in-depth understanding of the role of technological parameters control on the UN pellet properties.</p> <p>Trainees will participate to the UN manufacturing via dry, and respectively wet routes and will gain the ability to control the fabrication processes.</p>

Target audience	PhD students Post doc Young researchers
Number of participants	Up to 5
Duration	1 - day lectures session 2- day hands on training session
Tests, verification	Yes
Credits, diplomas	Yes, diplomas

### 3.4 HANDS-ON TRAINING SESSION ON UN CHARACTERISATION IN TERM OF SEM, XRD

Nuclear-fuel characterization is an important activity in establishing manufacturing parameters, and predict future fuel behavior and performances during irradiation. XRD and SEM are the most widely used techniques in checking the fuel chemical composition and its microstructure.

This practical training session will complement the UN manufacturing course, and will investigate the characteristics of the UN fuel pellets.

<b>Hands-on training session on UN characterisation in term of SEM, XRD</b>	
<b>CHALMERS</b>	
Venue	CHALMERS, Gothenburg, Sweden
Tentative period	April 2024
Learning outcomes	Students will gain the ability to use SEM and XRD techniques in the characterization of the UN fuels, and to interpret the experimental images and data.
Target audience	PhD students Post doc Young researchers
Number of participants	Up to 5
Duration	2-day hands on training session

Tests, verification	Yes
Credits, diplomas	Yes, diplomas

### **3.5 SUMMER SCHOOL ACTINIDE SCIENCE AND INNOVATIVE NUCLEAR FUEL CYCLES**

The Summer School on *Actinide Science and Innovative Nuclear Fuel Cycles* is intended to provide PhD and MSc students and young researchers lectures on innovative fuels and recycling options for a sustainable nuclear-fuel cycle.

International experts from leading research organizations will teach students the science of actinides and innovative nuclear-fuel cycles, from the basics to the latest scientific achievements developed by the FREDMANS project in fuel manufacturing, recycling and waste treatment techniques.

Prior to the Summer School, participants will have to pass an individual preparatory study based on e-learning modules developed in advance by the project partners.

The knowledge acquired during the Summer School will be evaluated and a number of credits (either ECTS or ECVET) will be awarded according to the internal regulations of the university.

The Summer School is planned as a 5-day educational event. The programme of the Summer School will be coordinated with other ongoing EURATOM projects, seeking, if possible, the organization of a joint event.

### **3.6 SUPPORT OF PARTICIPATION AT OUTSIDE FREDMANS TRAINING COURSES**

Throughout the implementation of FREDMANS, there will be a continuous screening of training events in the field of nuclear fuels organized by other EU projects, European associations or international organizations (IAEA, NEA/OECD). These events will be disseminated through the ENEN websites and several participation applications from students, young researchers and engineers will be supported from the dedicated FREDMANS Travel Fund.

For example, an event of interest could be the *NuFuel 2023* workshop series dedicated to nuclear-fuel research in Europe, organized by EERA – JPNM, with the aim of providing a forum to foster dialogue between experts and to provide students and young scientists with the opportunity to present their work and discuss with experts in the field.

This event is intended for the first half of November 2023.

## 4 TRAINEES' SELECTION PROCEDURE

The trainees will be selected based on their applications submitted to the Call for Applications which will be launched 6 (six) months in advance of an event. Since the number of participants is limited, the trainees will be selected based on a set of criteria intended to ensure the highest level of entry competence of the participants and the best use of the training.

The courses and Call for Applications will be announced and disseminated on:

- the ENEN webpage
- the webpage of other Euratom on-going projects.

The Call for Application shall be open for minimum 2 (two) months, and the evaluation results shall be available three months in advance of the event.

A lump sum between 750 EUR for an up to 3-day training event and 1000 EUR for an up to 5-day training event will be granted by FREDMANS for travel and subsistence costs. These grants will be managed by ENEN.

### 4.1 LIST OF CRITERIA FOR TRAINEES' SELECTION

General criteria listed below in the **decreasing order of importance** will be considered in the evaluation of the applications:

1. Compliance of the request with the objectives of the FREDMANS project (for training events outside FREDMANS project).
2. Existing background and experience in the scope of the course.
3. Training motivation, benefits, and impact of the mobility action on the nuclear career of the applicant.
4. Benefits for the EU workforce.
5. Proposed timeline and feasibility of the work plan and the requested duration of the mobility action (for training events outside FREDMANS project).

Only complete applications will be considered.

### 4.2 SELECTION PROCESS

Trainees will be selected by a group of evaluators based on the general evaluation criteria, supplemented by specific criteria defined and announced within each Call.

The evaluation will pay particular attention to the level of existing knowledge, motivation, benefits and impact on careers, as well as benefits for the EU workforce.

For the training sessions organized by FREDMANS, the evaluators will be appointed by the course organizer(s), from among the project partners.

For applications to the training events outside FREDMANS, ad hoc reviewer groups will be nominated by the WP5 leader and ENEN.

The reasons for non-acceptance will NOT be disclosed, and the decisions will be final. The results of the selection is not intended to be publicly justified.

### **4.3 FEEDBACK FROM TRAINEES**

At the end of each training event, each participant will elaborate and submit to the WP5 leader a short feedback report on the efficiency and usefulness of the training programme for her/his individual professional development.

## **5 CONCLUSIONS**

The Initial Training Programme presents the list of training courses planned to be implemented as part of the Education and Training Programme of the FREDMANS project.

It provides details on the learning objectives and learning outcomes, the envisaged place, period and duration, as well as the target audience for the training courses to be organized by FREDMANS. The general evaluation criteria and the selection procedure are also presented.

The Initial Training Programme will be updated with new requests received from the consortium partners as well as with nuclear fuel training events organized by- or in collaboration with other ongoing EU projects, European networks/associations, or international organisations, funded from the FREDMANS Travel Fund.