

## LD-SAFE

### Laser Dismantling Environmental and Safety Assessment

## EDUCATION AND TRAINING REPORT

### DELIVERABLE D6.5

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## 1. INTRODUCTION

The complexity of decommissioning activities in nuclear facilities requires prepared and skilful professionals, making the training programmes a relevant factor to ensure the process is implemented with effectiveness and achieving the demanding safety standards.

In general, these training programmes are not only a solid start point for young students and professionals, but also a source of knowledge and skills for experienced nuclear personnel, stakeholders, researchers, or any person with interest in this matter. In the decommissioning field, there is a general acceptance that investing efforts for decommissioning training harmonization are considered beneficial (European Commission and University of Birmingham, 2015), and thus, the European Commission has promoted some initiatives on this regard, such as the ELINDER Programme<sup>1</sup>.

The important social, environmental, and economic implications of the promising future of nuclear decommissioning, bring the interest of organizations to participate and contribute to the implementation of more efficient methods and technologies. Those developments should come with a strong knowledge management process to ensure lessons learned and experiences from reactor decommissioning are reviewed and best practices implemented (IAEA, 2022). The development and implementation of training programmes considering best practices promote their implementation among the nuclear decommissioning field.

It is also important to remark that nuclear licensees adapt their training programmes as the conditions of their plant progress towards decommissioning, as indicated by the IAEA (IAEA, 2022). These training programmes can also benefit from the lessons learned and experiences gathered during the LD-SAFE project about the promising implementation of the laser cutting technology for the segmentation of Reactor Pressure Vessels (RPV) and Reactor Vessel Internals (RVI) of Pressurized Water Reactors (PWR) and Boiling Water Reactors (BWR).

## 2. OBJECTIVE AND SCOPE

This report is dedicated to the training programme developed under the LD-SAFE project, which aims to compile and transmit the best practices and knowledge of the use of laser cutting technology in decommissioning of nuclear facilities, in particular the dismantling of the RPV and RVI.

The report includes:

- The considerations taken during its development (section 3). Target groups, contents and associated learning objectives, and training methodologies and tools are described.
- The results achieved from its implementation are also addressed (section 4).

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<sup>1</sup> <https://ec.europa.eu/jrc/en/training-programme/elinder/courses>

### 3. TRAINING PROGRAMME METHODOLOGY

The following section depicts the considerations taken during the training programme development. As aforementioned, the training programme aims to compile and transmit the best practices and knowledge of the use of laser cutting technology in decommissioning of nuclear facilities, in particular the dismantling of the RPV and RVI. This is pursued through the development of an online training course (LD-SAFE project deliverable D6.8), referred as **Laser Cutting for Nuclear Reactor Dismantling Course**.

Additionally, a training session was held in the second day of the Final Technical Workshop to students, graduates, and young professionals.

For its development, research about different training programmes and training resources already available was performed, considering all of those that might be related to the topic to be addressed within this online course. The following was observed:

- Plenty of literature can be found about the use of laser as a cutting technique in the industry, as well as the other principal methods (plasma arc cutting, band saw, or hydraulic cutting technologies). The focus of laser cutting training resources is mainly given to the manufacture industry.
- There are also a relevant number of documents, seminars, classes, etc. that cover the dismantling of nuclear power plants during decommissioning (i.e., IAEA E-Learning on Spent Fuel and Radioactive Waste Management, Decommissioning and Environmental Remediation). The level of detail of these courses varies but are mostly focused on the operational experience from conventional techniques. A few training resources are also provided about the implementation of laser cutting for nuclear dismantling (i.e., laser snake operational experience<sup>2</sup>), but the potential segmentation of the RPV and RVI and the associated challenges are not addressed.

Due to the above, a training gap was observed in the implementation of laser cutting for the segmentation of the reactor vessel and internals, objective of the LD-SAFE project itself. In that regard, this training programme contributes with a novelty to the decommissioning matrix knowledge of the nuclear sector, and it will serve as another tool for disseminating the results achieved within the project.

#### 3.1. Target Groups

The audience of this training programme is expected to be very heterogeneous. Based on the novelty of the application of this technology for nuclear dismantling, young professionals might consider it attractive, and so, it will support the important challenge of developing and maintaining the nuclear dismantling competences. Additionally, experienced professionals may have interest on the application of most efficient dismantling methods in the decommissioning projects, building and maintaining their skills in the Best Available Technologies (BAT).

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<sup>2</sup> <https://www.youtube.com/watch?v=hqOfRhjsaEQ>

As per the above, target groups are considered the following:

- Students, graduates, young professionals with no or little experience in nuclear decommissioning, and researchers.
- Decommissioning personnel<sup>3</sup>, nuclear professionals, stakeholders, or any other person related to the sector that seeks to acquire competences in new technologies and developments.

### 3.2. Training Content and Learning Objectives

The training course content considers all data and results generated during the LD-SAFE project. Within this information, lessons learned and experience from previous decommissioning projects and research data is also addressed, since it was also collected and analysed during the different Work Packages (i.e., by means of the feedback provided by the Advisory Board). Addressing the results of the LD-SAFE project within the training course aims at achieving two goals: capacity building of trainees and dissemination of project objectives and results. Other verified international sources of information were also used, resorting to reliable organizations and leading figures in the field (IAEA, EPRI, etc.).

The heterogeneity of potential target groups is considered in the training content, ensuring that, even if some type of foundation in decommissioning and dismantling methods would be beneficial, any trainee profile could reach the training learning objectives by means of an adequate contextualization of the topics and with a structure with logical progression (incremental acquisition of knowledge).

The content is arranged in the following sections:

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<sup>3</sup> Decommissioning training should be provided to all involved personnel (IAEA, 2022), considering all categories of personnel (i.e., management staff, professionals, and other workers). Training should be provided to build their necessary competences, including in Best Available Technologies (BAT).

Table 3.1. Training Course Content

ID	Chapter	Content
1	Introduction to Laser Cutting for Nuclear Decommissioning	Context of nuclear decommissioning
		Challenges of RPVI and RVI dismantling
		Laser cutting - Previous experiences
		LD-SAFE Project and associated objectives
2	Laser Cutting Technology	Working principles
		Components of the laser cutting system
		Cutting performances and other relevant aspects
3	Conventional Cutting Techniques – Comparative Analysis	Conventional techniques to dismantle nuclear reactors
		Comparative analysis with the laser cutting technique
4	Reactor Pressure Vessels and Internals Segmentation in Nuclear Reactors	Reactor pressure vessel and internals
		Segmentation plan
		Layout of laser cutting system in nuclear power plants
5	Safety Aspects	Generic Safety Assessment
		Evaluation of Specific Risks <ul style="list-style-type: none"> <li>Residual Power Laser Beam</li> <li>Aerosols generation</li> <li>Hydrogen generation</li> </ul>
		Safety Conclusions
6	Technology Qualification and Demonstrators	Introduction
		Technology Qualification
		In-air Demonstrator
		Underwater Demonstrator
7	Conclusions	Summary of main conclusions

Each chapter of the training programme is considered as a main learning area, being the backbone of the course and organising the content. Learning areas are associated to learning objectives, following Systematic Approach to Training (SAT) principles. Learning objectives are the following:

- Describe the current situation of nuclear decommissioning and explain the relevant characteristics of nuclear reactors.
- Identify the attributes of the laser cutting technique, pointing out similarities and differences with other methods.
- Outline the critical factors associated with performance, risks, and implementation of a laser cutting system in a nuclear reactor environment.
- Describe the main safety aspects about the reactor pressure vessel and internals segmentation using laser technology.
- Identify how the LD-SAFE project promote the future implementation of laser cutting technology on nuclear decommissioning projects.

### 3.3. Training Evaluation and Certification

After finalizing the training content, trainees will be evaluated ensuring that learning objectives are achieved. Following SAT principles, each learning objective is associated to an evaluation criterion.

With a score of 60% or higher in the training evaluation, the trainees will get a certificate of course completion.

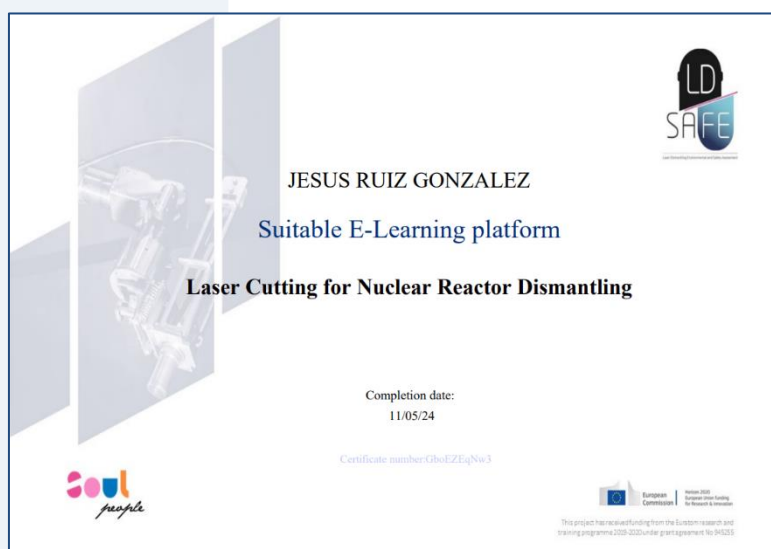


Figure 3.1. Example of Certificate



### 3.4. Training Methodology and Tools

The training format considered for this course is E-Learning, for the following reasons:

- It will facilitate reaching more target audience, and so, achieving the goals established under the Dissemination Management Plan (D6.2). It will remain available even after project finalization.
- It will ease trainees' participation, based on their time availability.

For increasing its visibility and impact, the course is at everyone disposal in an online platform: <https://learningwithsoul.com/en>. The course will also be proposed to the ELINDER program for a wide dissemination.

The online course is designed with different training digital resources (presentation, videos, models, questions, etc.) as to increase trainees' engagement. Basic content is provided, and recommendations for further documentation and training resources are also identified for those trainees seeking for additional information. The training course has an estimated duration of 3.5 hours.



Figure 3.2. Examples of Training Resources

After the course completion, trainees may provide feedback about the training course through a survey. This may allow the potential future improvement of the associated content.



## 4. TRAINING PROGRAMME RESULTS

### 4.1. Online Training Course

The online training course was released in two stages:

- First, the course was released only for consortium members for providing feedback of the course. In general, highly positive feedback was obtained from project partners, highlighting among other aspects the interactivity of the content. From this initial stage, valuable comments and suggestions for improvement were addressed and incorporated into the final version of the course.
- Finally, the training course was publicly released at the end of the project (28/06/2024). There has not been time to obtain feedback of participants outside of the consortium, so this will be internally assessed later for potential future improvements of training content.

### 4.2. Training Session on Technical Workshop

A reduced version of the online training course was prepared for the 2<sup>nd</sup> day of the Technical Workshop (31<sup>st</sup> of May 2024). The content and associated learning objectives were aligned with those of the online course. Positive feedback was received from the approximately 70 participants.

## 5. CONCLUSIONS

This document describes the training programme developed in the context of the LD-SAFE Project related to the decommissioning of the nuclear power plants. It focuses on the dismantling of nuclear reactors, specifically in the laser technique as an innovative technology for the segmentation of RPV and RPI (vessel and internals) of PWR and BWR.

The training methodology relies on an online course that integrates LD-SAFE project results, lessons learned, and experiences, and the state of the art of the laser cutting technology as a cutting tool and its comparison with conventional technologies.

The online training course is publicly available<sup>4</sup> since mid-June 2024. Positive feedback was obtained from project partners, specially about the interactivity of the course. Additionally, the great welcome of the training session held in the second day of the technical Workshop, with approximately 70 participants, positively reflects the interest of students, graduates, and young professionals on the innovative laser cutting technology for reactor dismantling. The availability of the online training course in a public platform will promote the capacity building of trainees and the dissemination of project results in the oncoming months.

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<sup>4</sup> <https://tecnaatom.learningwithsoul.com/campus/course/view.php?id=169>

## 6. ACRONYMS

BAT	Best Available Technologies
BWR	Boiling Water Reactor
ELINDER	European Learning Initiatives for Nuclear Decommissioning & Environmental Remediation
EPRI	Electric Power Research Institute
IAEA	International Atomic Energy Agency
LD-SAFE	Laser Dismantling Environmental and Safety Assessment
PWR	Pressurized Water Reactor
RPV	Reactor Pressure Vessel
RVI	Reactor Vessel Internals

## 7. REFERENCES

- [Ref. 1] European Commission and University of Birmingham, 2015. Education and Training in Decommissioning. Needs, Opportunities and Challenges. Report EUR 27460 EN.
- [Ref. 2] LD-SAFE Consortium, 2019. Proposal ID 945255, Laser Dismantling Environmental and Safety Assessment. Horizon 2020 European Union Program.
- [Ref. 3] LD-SAFE Consortium, 2023. D6.2 vC - Plans for Dissemination of the Results.
- [Ref. 4] IAEA, 2022. IAEA Nuclear Energy Series No. NG-T-2.3 R1. Training and Human Resource Considerations for Nuclear Facility Decommissioning.