Skills4Nuclear*

Funded by the
European Union

Project Number 101213280

Deliverable D4.3

Tiering the Typology of EU VET Trainings Based on Industry Needs

Lead Beneficiary: SNN

Due date: 15/07/2026 **Released on: 24/08/2026**

Authors:	**Raluca-Andreea Nedelcu**
Version:	**1.0**

For the Lead Beneficiary	Reviewed by WP Leader	Approved by Coordinator
Raluca Andreea Nedelcu	Gabriel Pavel	Teodora Retegan Vollmer

Dissemination level

PU	Public	**X**
SEN	Sensitive, only for Beneficiaries of the S4N project	

Version control table

Version no.	Date of issue	Author(s)	Brief description of changes made
0.1	10.07.2026	Raluca-Andreea Nedelcu	Initiation of document
1.0	24.08.2026	Gabriel Pavel, Teodora Retegan Vollmer	Review by the WP Leader, the coordinator, and the MST Final version

Project information

Project number:	101213280
Project full title:	Skills for nuclear
Acronym:	SKILLS4NUCLEAR
Call:	HORIZON-EURATOM-2024-NRT-01
Type of action:	EURATOM Coordination and Support Actions
Project Coordinator Organization:	CHALMERS
Coordinator:	Teodora Retegan Vollmer
EC Project Officer:	Katerina Ptackova
Start date – End date:	15/03/2025 – 14/03/2028
Coordinator contact:	tretegan@chalmers.se
Administrative contact:	jakub.heller@evalion.cz
Website:	https://www.skills4nuclear.eu/

Disclaimer

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 or European Commission. Neither the European Union nor the European Commission can be held responsible for them.

EXECUTIVE SUMMARY

The European nuclear sector is entering a period of unprecedented growth driven by life extension programs, refurbishment projects, new nuclear build, SMRs, fuel cycle developments, radioactive waste management related activities and decommissioning projects.

Evidence from the French MATCH Programme demonstrates that workforce demand across the nuclear ecosystem is expected to increase significantly during the next decade, requiring, in France only, approximately 60,000 additional recruitments [6] for core nuclear occupations and around 100,000 recruitments when considering the entire ecosystem. In other European evaluations such as the assessment done in the ENEN2plus project, Work Package (WP) number one escalated this estimation, at European level, to be around 500.000 direct and indirect jobs needed for the entire nuclear ecosystem [4],[18].

At the same time, workforce analysis performed using ESCO and EQF methodologies [1],[2] on a representative operating nuclear power plant indicates that the majority of occupations supporting nuclear activities are not purely nuclear occupations.

The analysis of the Match project implementation results correlated with Cernavoda NPP and Kozloduy NPP analysis confirms that:

- approximately 40–45% of positions belong to vocational and technical pathways;
- only a limited proportion of occupations require full nuclear specialization;
- most occupations require different levels of nuclearization;
- vocational education and training represent a critical component of the future nuclear workforce pipeline.

Consequently, a new European approach is required, based on a tiered VET training model aligned with industrial needs.

Contents

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

COR	Romanian Classification of Occupations
EHRO-N	European Human Resources Observatory for the Nuclear Sector
ENEN	European Nuclear Education Network
EQF	European Qualifications Framework
ESCO	European Skills, Competences, Qualifications and Occupations
LTO	Long Term Opeartion
NPP	Nuclear Power Plant
NWA	Nuclear Workforce Assesments
SMR	Small Modular Reactor
VET	Vocational Education and Training

1 INTRODUCTION

The transition towards a climate-neutral European economy has significantly reinforced the strategic importance of nuclear energy as a reliable, low-carbon source of electricity capable of supporting energy security, industrial competitiveness and the decarbonisation objectives of the European Green Deal. At the same time, the European nuclear sector is entering a period of unprecedented transformation driven by the long-term operation of existing reactors, large-scale refurbishment programmes, new nuclear build projects, the deployment of Small Modular Reactors (SMRs), the development of Generation IV technologies, the expansion of the nuclear fuel cycle and the increasing demand for decommissioning and radioactive waste management activities.

These developments are expected to generate substantial demand for a highly skilled workforce across the entire nuclear value chain. However, demographic changes, workforce ageing, increasing retirement rates, limited educational capacity in several technical disciplines and growing competition for engineering and technical talent have created significant challenges for ensuring the long-term availability of qualified personnel. Addressing these challenges requires not only accurate workforce forecasting but also the development of education and training pathways that are directly aligned with the competence requirements of the nuclear industry.

Within this context, Work Package 4 of the Skills4Nuclear project focuses on analysing vocational education and training (VET) needs and identifying future-oriented educational solutions capable of supporting the European nuclear workforce. Deliverable D4.3 contributes to this objective by proposing a structured European framework for lower and higher vocational qualifications that responds to current and future labour market requirements across the nuclear sector.

The methodology presented in these deliverable builds upon several complementary sources of evidence. First, it incorporates the findings of workforce analyses performed for two different European nuclear power plants, providing detailed information on occupational structures, qualification profiles and workforce composition. Second, it applies the MATCH methodology to identify occupational demand, occupations under tension, replacement needs and future workforce requirements throughout the nuclear lifecycle. Third,

occupations are systematically mapped to the European Skills, Competences, Qualifications and Occupations (ESCO) classification and the European Qualifications Framework (EQF), creating a common European reference for occupational analysis and qualification design. Finally, the analysis considers existing European and international education and training practices, including vocational education, higher vocational programmes, university education and continuing professional development initiatives.

Based on this integrated evidence base, the deliverable develops a comprehensive framework that links industrial activities, occupational families, qualification levels, nuclear specialization requirements, workforce forecasting and education and training responses. A key innovation of the proposed approach is the introduction of the concept of nuclearization, which differentiates occupations according to the level of nuclear-specific knowledge required and provides a structured basis for determining the appropriate balance between conventional technical education and nuclear-specific competence development.

The present analysis demonstrates that the future European nuclear workforce cannot be supported solely through traditional university engineering programmes. Instead, it highlights the strategic importance of strengthening vocational and advanced vocational education, developing nuclearized technical pathways, expanding workplace learning, and introducing flexible lifelong learning instruments such as micro-credentials and modular training programmes. Particular attention is given to addressing the current shortage of advanced vocational programmes positioned between upper-secondary vocational education and university engineering degrees, which represents a critical gap in the European nuclear skills pipeline.

The principal outcome of Deliverable D4.3 is the proposal of a European Nuclear VET Architecture that provides a coherent framework for aligning workforce demand with education and training provision. The proposed architecture establishes common principles for occupational mapping, qualification design, curriculum development and competency integration, while maintaining sufficient flexibility to accommodate national education systems, reactor technologies and regulatory environments. By combining industrial workforce analysis with the ESCO and EQF frameworks, the methodology provides a scalable

and evidence-based foundation for future European cooperation in nuclear vocational education and training.

Ultimately, this deliverable aims to support the development of a sustainable, resilient and future-ready European nuclear workforce by providing practical recommendations for policymakers, education and training providers, industry stakeholders and regulatory authorities. The proposed framework contributes to improving workforce planning, facilitating labour mobility, strengthening vocational education and ensuring that Europe possesses the skills and competencies required to safely operate, modernise and expand its nuclear sector over the coming decades.

2 METHODOLOGIES USED FOR THE ANALYSIS

The objective of the analysis of MATCH project (France), Cernavoda NPP(Romania) and Kozloduy NPP (Bulgaria) is to establish a structured framework for identifying and classifying the vocational education and training (VET) needs of the European nuclear sector. As Europe enters a period of significant nuclear expansion driven by lifetime extension projects, refurbishment programs, Small Modular Reactors (SMRs), new builds, plans for advanced reactor technologies, fuel cycle developments and decommissioning activities (e.g. see the newly Onkalo repository in Finland), the availability of a qualified workforce becomes a critical success factor.

Traditional workforce analyses often focus exclusively on highly specialized nuclear professionals. However, evidence from the nuclear industry demonstrates that only a limited proportion of the workforce requires extensive nuclear-specific expertise, while the majority of occupations rely on transferable technical, engineering, digital, managerial and support competencies that require varying levels of *nuclearization*.

To address this challenge, the present methodology combines two complementary perspectives:

- an **Industrial Demand Perspective**, which identifies future workforce requirements and occupational shortages based on projected industrial activity;
- a **Workforce Qualification Perspective**, which analyses existing occupations, qualification levels and educational pathways using European classification frameworks.

The integration of these two perspectives enables the development of a tiered model for nuclear VET programs aligned with actual industry needs.

2.1 Industrial Demand Perspective

The Industrial Demand Perspective is primarily derived from the methodology developed within the French MATCH Program (Métiers et Compétences pour les Talents Humains de la filière nucléaire) [6], coordinated by GIFEN and widely recognized as one of the most comprehensive workforce planning initiatives currently available in the European nuclear sector.

The MATCH methodology [6] establishes a direct relationship between industrial workload forecasts and future workforce requirements. Rather than estimating workforce demand based solely on historical recruitment patterns, MATCH analyses planned industrial activities and translates them into occupation-specific workforce needs.
The methodology is built upon several key components:

A. Industrial Activity Segments

The nuclear value chain is divided into approximately twenty industrial activity segments covering the full lifecycle of nuclear installations.

Figure 1 MATCH program industrial sequencing [6]

The segmentation presented in Figure 1 enables workforce needs to be analyzed according to specific industrial activities and technology deployment scenarios (related to fusion and fission).

B. Occupational Mapping

The MATCH framework [6] identifies approximately 84 core occupations (Figure 2) that support the operation and development of the nuclear sector.

Figure 2 Nuclear core occupations identified in the MATCH program [6]

The occupational approach allows workforce planning to move beyond generic staffing estimates and identify specific occupations where shortages may emerge.

C. Workforce Demand Projections

Workforce demand projections are generated by combining industrial activity forecasts with productivity assumptions and workforce requirements associated with each occupation.
This approach allows the estimation of:

- future recruitment needs;
- replacement demand caused by retirements;
- demand generated by new nuclear projects;
- workforce needs associated with emerging technologies such as SMRs and advanced reactors.

D. Occupations Under Tension

A key output of the MATCH methodology [6] is the identification of occupations under tension. Figure 3 illustrates the occupations identified as being under the greatest workforce pressure across the European nuclear sector, based on the occupational analysis undertaken using the MATCH methodology and supporting workforce evidence.
The identified occupations—welders, electricians, instrumentation and control (I&C) technicians, maintenance specialists, radiation protection professionals and project engineers—represent critical capabilities required throughout the nuclear installation lifecycle, from construction and commissioning to operation, long-term operation, refurbishment and decommissioning. These occupations combine high technical complexity with stringent safety, quality and regulatory requirements, while simultaneously experiencing increasing recruitment difficulties resulting from workforce ageing, retirements, limited education and training capacity, and growing competition for skilled personnel from other industrial sectors. The figure also highlights the complementary roles performed by each occupational group in ensuring the safe, reliable and efficient operation of nuclear facilities. Collectively, these occupations constitute the backbone of the European nuclear workforce and therefore represent priority areas for future investment in vocational education and training (VET), apprenticeships, workplace learning, upskilling, reskilling and career development pathways. Addressing shortages in these occupational families will be essential to support the long-term sustainability of existing nuclear installations, the deployment of

new nuclear technologies, including SMRs, and the overall resilience and competitiveness of the European nuclear sector.

Figure 3 Nuclear occupations in jeopardy based on MATCH project identification

These are occupations where projected demand significantly exceeds available workforce supply. Identifying occupations under tension enables educational institutions and training providers to prioritize investments in the most critical workforce segments.

E. Training Lead Time Analysis

The methodology also evaluates the time required to develop competence for each occupation.
Training lead times may vary significantly:

- a welder may require 1–3 years of vocational preparation;
- an instrumentation technician may require 3–5 years;
- a reactor operator may require 5–10 years before achieving full authorization;
- a nuclear safety specialist may require more than 10 years of combined education and operational experience.

Understanding these lead times is essential for proactive workforce planning and educational capacity development.

2.2 Workforce Qualification Perspective

The Workforce Qualification Perspective focuses on the existing workforce structure and the qualification pathways required to perform nuclear sector occupations.
The analysis done within the report combines several European frameworks and datasets.

2.2.1 ESCO Occupational Classification [1]

The European Skills, Competences, Qualifications and Occupations (ESCO) framework [1] serves as the primary occupational classification system. ESCO provides standardized occupation descriptions, associated skills and competences, cross-sector comparability and interoperability between education and labor market systems. The use of ESCO allows occupational profiles from different countries to be analyzed using a common European language (European Skills, Competences, Qualifications and Occupations (ESCO), 2026).

2.2.2 European Qualifications Framework (EQF)[2]

The European Qualifications Framework provides a reference system for comparing qualification levels across Europe. For the purpose of this analysis, particular attention is given to:

- Lower VET program (EQF 3–4);
- Higher VET program (EQF 4–5);
- Vocational Bachelor and Applied Higher Education program (EQF 5–6);
- Advanced Professional and Specialist program (EQF 6–7).

The EQF framework enables the identification of the most appropriate qualification level for each occupational group. [2]

2.2.3 ESCO-EQF Mapping for the European Nuclear Sector

The ESCO-EQF mapping demonstrates that the future European nuclear workforce should not be structured around educational institutions but around occupational families and nuclearization levels. While only a limited proportion of occupations require full nuclear specialization, the majority of workforce demand can be addressed through vocational and professional pathways complemented by targeted nuclear modules, micro-credentials and workplace learning. This supports the creation of a tiered European Nuclear Skills Ecosystem aligned with both industrial demand and qualification frameworks.

Table 1 ESCO-EQF mapping for the European Nuclear Sector

ESCO Occupational Family	Typical Occupations	EQF	Nuclearization Level	Recommended Training Pathway
Skilled Trades	Electrician, Welder, Pipefitter, Industrial Mechanic	3–4	Medium	Upper Secondary VET + Nuclear Modules

ESCO Occupational Family	Typical Occupations	EQF	Nuclearization Level	Recommended Training Pathway
Plant Operations Support	Auxiliary Operator, Field Operator, Logistics Support	3–4	Medium	Upper Secondary VET + Workplace Learning
Engineering Technicians	Electrical Technician, I&C Technician, Mechanical Technician	4–5	Medium-High	Advanced Vocational Programmes
Radiation Protection Technicians	RP Technician, Dosimetry Technician	4–5	High	Advanced Vocational Programmes + Specialized Nuclear Training
Quality & Inspection Technicians	NDT Technician, QA Technician, Inspection Technician	4–5	Medium	Advanced Vocational Programmes
Applied Engineering Professionals	Maintenance Engineer, Operations Engineer, Commissioning Engineer	5–6	Medium-High	Vocational Bachelor Programmes
Digital & Cybersecurity Professionals	Cybersecurity Specialist, Digital Systems Engineer	5–6	Medium	Vocational Bachelor + Nuclear Modules

ESCO Occupational Family	Typical Occupations	EQF	Nuclearization Level	Recommended Training Pathway
Nuclear Engineers	Nuclear Engineer, Reactor Engineer, Fuel Engineer	6–7	High	Engineering Degree + Nuclear Specialization
Nuclear Safety Professionals	Safety Analyst, PSA Specialist, Licensing Engineer	6–7	High	Advanced Professional Programmes
Project & Asset Management Professionals	Project Engineer, Asset Manager	6–7	Medium	Professional Programmes + Nuclear Modules
Operations Management	Shift Manager, Operations Manager	6–7	High	Advanced Professional Programmes
Executive Leadership	Plant Manager, Senior Leadership	7	Medium-High	Executive Nuclear Leadership Programmes
Corporate Support Functions	HR, Procurement, Finance, Legal	4–7	Low	Micro-Credentials + Awareness Training

The analysis undertaken in the present report supports the development of a Recommended European Nuclear Skills Framework, providing a structured progression of education and training pathways aligned with occupational requirements across the nuclear sector. The proposed framework, presented in Table 2 integrates the ESCO occupational classification, the EQF, and the concept

of nuclearization to define appropriate programme types for different occupational groups.

Organised into six progressive tiers and complemented by a cross-cutting pathway for corporate support functions, the framework establishes a coherent European reference for curriculum development, workforce progression and lifelong learning, while ensuring that education and training provision is closely aligned with the competence needs of the European nuclear industry.

Table 2 Recommended European Skills Framework

Tier	ESCO Group	EQF	Nuclearization	Programme Type
Tier 1	Skilled Trades	3–4	Medium	Upper Secondary VET
Tier 2	Plant Operations Support	3–4	Medium	Upper Secondary VET
Tier 3	Engineering Technicians	4–5	Medium-High	Advanced Vocational Programmes
Tier 4	Applied Engineering Professionals	5–6	Medium-High	Vocational Bachelor
Tier 5	Nuclear Engineers & Safety Specialists	6–7	High	Advanced Professional Programmes
Tier 6	Leadership & Management	6–7	Medium-High	Executive Programmes
Cross-cutting	Corporate Support Functions	4–7	Low	Micro-Credentials

2.2.4 Conjunction Between EHRO-N Findings and ENEN2plus Findings

The analysis performed within T4.3 builds upon the complementary contributions of EHRO-N [3](European Human Resources Observatory for the Nuclear Sector) and ENEN2plus [4][5], which together provide a comprehensive framework linking workforce demand, skills forecasting and education and training provision across Europe.

While EHRO-N[3] focuses primarily on workforce assessment, skills demand forecasting, job classification and identification of human resource gaps, ENEN2plus[4][5] focuses on education and training solutions, mobility, competence development and vocational training pathways. Together, they provide the analytical and operational foundations for the development of a European Nuclear Skills Ecosystem.

The findings from both initiatives converge on several key conclusions summarized in table 3.

Table 3 Conjunction Between EHRO-N Findings and ENEN2plus Findings

EHRO-N Findings [3]	ENEN2plus Findings [4][5]	Implication for T4.3
Ageing workforce and significant retirement waves	Need to attract new talent and strengthen education pipelines	Expand VET and higher education pathways
Skills shortages in engineering, radiation protection, project management and technical occupations	Need for enhanced E&T programmes and mobility actions	Develop targeted curricula and training programmes
Need for regular Nuclear Workforce Assessments (NWAs)	Need for continuous adaptation of education and training provision	Establish systematic workforce forecasting linked to VET planning
Gaps in education and training infrastructures	Fragmentation of nuclear education and vocational training opportunities	Harmonies VET provision across Europe
Need for harmonised job classifications and qualifications	Need for competence-based learning and recognition frameworks	Use ESCO and EQF as common European references

EHRO-N Findings [3]	ENEN2plus Findings [4][5]	Implication for T4.3
Need for stronger collaboration between industry and academia	Promotion of industry-academia partnerships and mobility schemes	Strengthen work-based learning and apprenticeships

These findings demonstrate a strong alignment between workforce demand analysis and education and training development.
When considered together, EHRO-N and ENEN2plus support a common conclusion: *Future workforce challenges in the European nuclear sector cannot be addressed solely through traditional university-level nuclear engineering programmes. A comprehensive skills ecosystem is required, combining workforce forecasting, vocational education, higher education, reskilling, upskilling and lifelong learning pathways.*
The combined findings support:

- the use of ESCO [1] for occupational classification;
- the use of EQF [2] for qualification mapping;
- the development of Lower VET programs (EQF 3–4);
- the expansion of Higher VET programs (EQF 4–5);
- the creation of Vocational Bachelor programs (EQF 5–6);
- the strengthening of Advanced Professional Programs (EQF 6–7);
- the implementation of micro-credentials and continuous professional development;
- the establishment of Train-the-Trainer initiatives.

2.2.5 Workforce Mapping Case Study

A detailed workforce mapping exercise was conducted using data from Romanian Cernavoda NPP and Bulgarian Kozloduy NPP two operating nuclear power plants using two different technologies. The analysis included occupational structure, educational requirements, ESCO mapping [1], EQF mapping [4],[5] and workforce segmentation. The case studies provide a realistic representation of workforce requirements within a large-scale nuclear facility and serves as a practical reference for the broader European nuclear ecosystem.

2.3 Integrated Analytical Framework

The combination of the Industrial Demand Perspective and the Workforce Qualification Perspective create a comprehensive analytical framework linking industrial needs with education and training solutions.

The four dimensions each occupation can be analysed in the Figure 4, below.

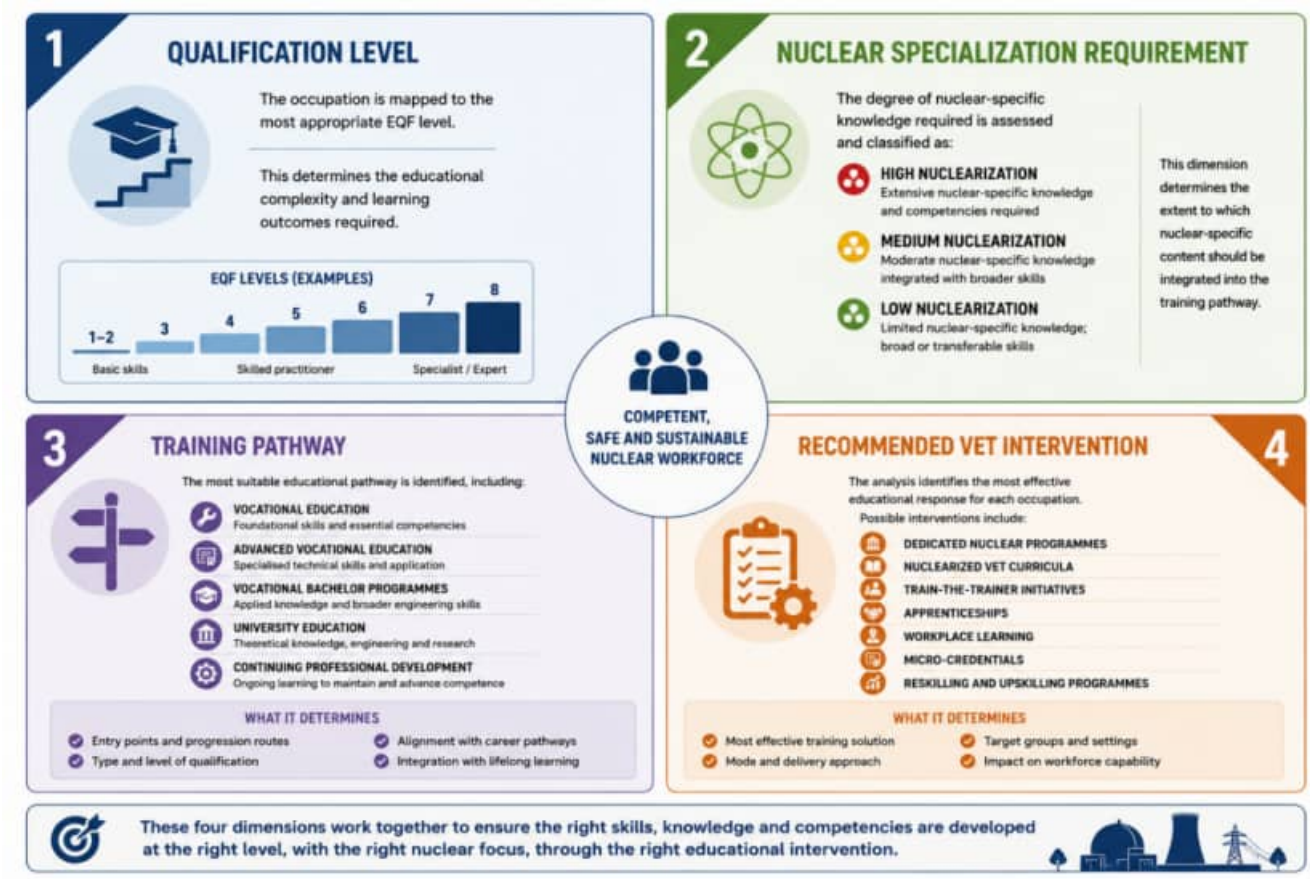

Figure 4 The four dimensions each occupation can be analysed

The present methodology provides a robust analytical framework for developing evidence-based recommendations to support the establishment of a future Nuclear Skills Strategy. By systematically mapping occupations, qualification requirements, nuclear specialization needs, training pathways and educational interventions, it enables a comprehensive understanding of current and future workforce requirements across the nuclear sector.

The present methodology supports the identification of critical occupations and skills shortages, facilitates the alignment of vocational education and training (VET) provision with industrial demand, and enables the prioritization of

occupations experiencing workforce tensions. Furthermore, it informs the development of nuclearized vocational pathways, targeted micro-credentials, train-the-trainer programs, apprenticeships, workplace learning opportunities, and reskilling and upskilling initiatives tailored to the specific needs of the sector. In addition, the present methodology strengthens collaboration between industry, research organizations, education and training providers, and public authorities by providing a common evidence base for workforce planning and skills development. This contributes to greater coherence between labor market needs and education and training provision at regional, national and European levels.

Ultimately, the methodology establishes a structured mechanism for translating workforce demand into targeted education and training solutions. In doing so, it supports the availability of a qualified, competent and future-ready workforce capable of sustaining the safe operation, modernization and long-term growth of the European nuclear sector while contributing to Europe's energy security, decarbonization objectives and industrial competitiveness.

3 ESCO OCCUPATIONAL MAPPING

A key objective of Task 4.3 is to identify and characterize the vocational education and training (VET) pathways required to support the current and future workforce needs of the European nuclear sector. Achieving this objective requires a common framework capable of linking occupations, skills requirements, qualification levels and training pathways across different national education systems and labor markets.

The European Skills, Competences, Qualifications and Occupations (ESCO) framework provides such a reference by establishing a common European taxonomy of occupations and associated competences. The use of ESCO facilitates the translation of national occupational classifications, such as the Romanian Classification of Occupations (COR) (COR 2026, 2026) into a standardized European framework, thereby enabling the comparison of workforce structures, occupational profiles and training needs across Member States.

Within the context of the present report, ESCO mapping [1] fulfils three main functions:

1. identification and categorization of occupational families contributing to the nuclear value chain;
2. alignment of occupational profiles with qualification levels defined by the European Qualifications Framework (EQF)[2];
3. identification of common competence requirements that can be addressed through coordinated European VET initiatives.

One of the most important findings emerging from the ESCO analysis is that occupational families differ significantly in their nuclear specialization requirements. This observation allows occupations to be grouped according to three levels of nuclearization as it is shown in Table 4 [3],[4], [6].

Tabel 4 ESCO Occupational Families with the nuclearization level

ESCO Occupational Family	**Nuclearization Level**
Reactor Operations	High
Nuclear Engineering	High

ESCO Occupational Family	Nuclearization Level
Radiation Protection	High
Engineering Technicians	Medium
Skilled Trades	Medium
ICT & Cybersecurity	Medium
Management	Medium-Low
HR, Finance, Legal, Procurement	Low

This classification provides the foundation for the tiered VET model proposed in this report. Rather than developing fully nuclear curricula for all occupations, educational programs can be tailored according to the actual level of nuclear knowledge required.

The ESCO mapping exercise ultimately demonstrates that workforce development for the European nuclear sector should be based on occupational families rather than individual job titles.

This approach provides several advantages:

- **European comparability** – occupations from different countries can be analyzed using a common framework.
- **Alignment with EQF** – occupational families can be directly linked to qualification levels.
- **Identification of transferable skills** – competencies from adjacent industries can be leveraged to support nuclear workforce development.
- **Support for micro-credentials** – nuclearization modules can be developed and assigned to specific occupational families.
- **Facilitation of reskilling and upskilling** – workers from other sectors can transition more easily into nuclear occupations.
- **Improved workforce forecasting** – workforce demand can be analyzed at occupational-family level, following the MATCH methodology.

From the report's perspective, the ESCO analysis clearly demonstrates that the future European nuclear workforce will not be built exclusively through traditional

nuclear engineering programs. Instead, it will depend on a broad ecosystem of occupational families, most of which require varying degrees of nuclearization rather than full nuclear specialization. This finding strongly supports the development of tiered VET programs, micro-credentials, reskilling pathways and train-the-trainer initiatives across the European nuclear sector.

4 EUROPEAN QUALIFICATIONS FRAMEWORK MAPPING

The European Qualifications Framework (EQF)[2] mapping was performed to identify the qualification levels required across the workforce and to determine how future education and training interventions should be distributed between vocational education, advanced vocational programs and higher education.
Within the context of the report, the EQF analysis serves several important purposes:

- identifying the qualification profile of the current workforce;
- determining the relative importance of Lower VET and Higher VET pathways;
- identifying potential qualification gaps;
- supporting the design of targeted VET curricula;
- facilitating alignment between industrial needs and educational provision across Europe.

The EQF framework is particularly relevant because it provides a common reference system that enables comparison between educational systems and qualifications across EU Member States. Furthermore, the EQF mapping demonstrates that the future European nuclear workforce cannot be supplied exclusively through university-level nuclear engineering programs. Nearly half of the workforce depends on vocational education pathways, while a substantial proportion of higher education occupations require only partial nuclear specialization. Consequently, future workforce strategies should focus on creating an integrated skills ecosystem that combines Lower VET, Higher VET, Vocational Bachelor programs, higher education, micro-credentials and lifelong learning pathways aligned with industrial workforce demand.

5 ANALYSIS OF THE CERNAVODA NPP WORKFORCE STRUCTURE

To better understand the workforce requirements of large nuclear facilities, a workforce mapping exercise was conducted using occupational and qualification data corresponding to Cernavoda NPP (Romania), an operating two-unit nuclear power plant with the ambition refurbish one unit, to commission 2 more CANDU6 units, a build a Tritium Removal Facility, to run Medical Isotopes Program and to develop human resources to deploy a SMR project. The analysis covered approximately 2,300 positions currently from the organizational chart for the Nuclear Power Plant and included the mapping of occupations to the ESCO classification system, qualification levels according to the EQF, and the assessment of nuclear specialization requirements.

The purpose of this analysis is not only to describe the current workforce composition, but also to identify the implications for VET, workforce planning, reskilling and upskilling initiatives, and future curriculum development.

As Cernavoda NPP represents a mature operating nuclear facility, its workforce structure provides a realistic representation of the skills ecosystem required to operate, maintain and support nuclear power generation safely and efficiently. The findings could constitute a valuable case study for the broader European nuclear sector.

5.1 Workforce Structure by Educational Level

The analysis reveals that the workforce is almost evenly distributed between personnel requiring secondary-level technical qualifications and personnel requiring higher education qualifications.

Table 5 Percentage of education Level at Cernavoda NPP

Education Level	Percentage
Secondary / Technical Education	44.1%
Higher Education	55.9%
Total	100%

These results demonstrate that vocational and technical education pathways remain fundamental for the operation of a nuclear power plant. While nuclear

engineering and scientific disciplines often receive most attention in workforce discussions, nearly half of all positions require vocational and technical competencies rather than university-level education. This confirms that workforce sustainability cannot be achieved solely through higher education programs and that vocational education institutions represent a critical component of the nuclear talent pipeline.

The results also illustrate the multidisciplinary nature of the nuclear sector, which requires a balanced combination of engineers, technicians, skilled trades, operators, managers and support personnel.

5.2 Workforce Structure by EQF Level

The workforce was mapped against the European Qualifications Framework to determine the relative importance of Lower VET, Higher VET and higher education pathways.

Table 6 Cernavoda NPP workforce mapped against the European Qualifications Framework

EQF CategoryPositions	Percentage
Lower VET (EQF 3-4)	44.1%
Higher VET (EQF 4-5)	2.6%
Higher Education (EQF 6-7)	53.2%
Total	100%

Several observations emerge from this analysis of Cernavoda NPP workforce structure. First, Lower VET occupations represent a substantial proportion of the workforce. These positions include electricians, industrial mechanics, maintenance personnel, operators, skilled trades and technical support occupations. Such occupations form the operational backbone of the plant and are essential for ensuring reliable day-to-day operation. Second, the relatively small proportion of **Higher VET occupations** suggests **a potential structural gap** between secondary vocational education and university education. This finding is particularly relevant for European workforce planning because it highlights the need to strengthen advanced vocational pathways, professional bachelor programs and applied technical qualifications.

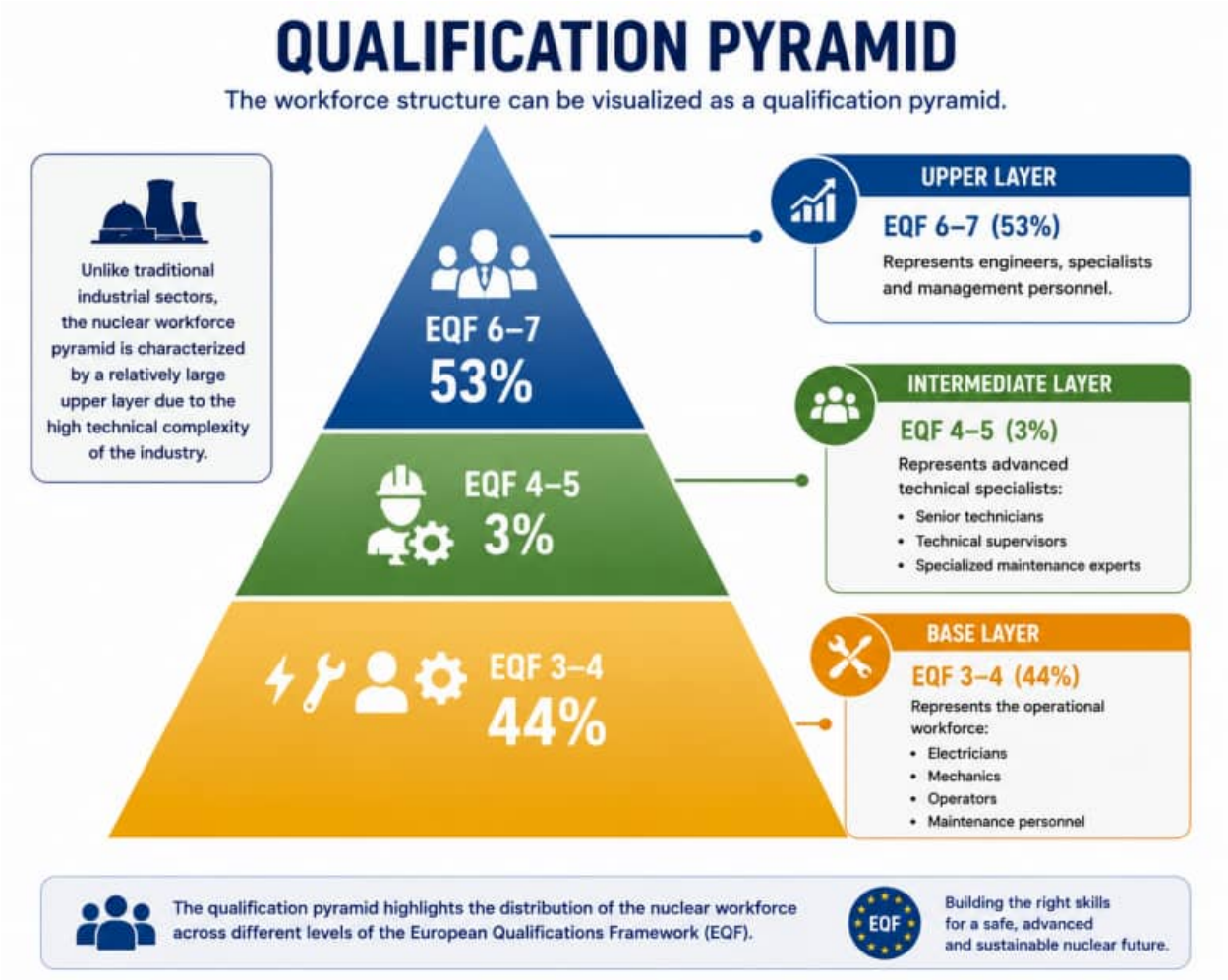

Figure 5 Qualifications pyramid for Cernavoda NPP

Third, more than half of the workforce requires qualifications corresponding to EQF levels 6–7, reflecting the high technological complexity, safety requirements and regulatory obligations associated with nuclear power plant operation.
These findings (as shown in Figure 5) support the development of flexible educational pathways that allow individuals to progress from vocational training to higher education through lifelong learning and stackable qualifications.

5.3 ESCO Occupational Segmentation

The occupational structure of Cernavoda NPP was mapped to the ESCO framework (see Figure 6) and grouped into six major occupational families illustrated below.

Figure 6 Cernavoda NPP workforce mapped to the ESCO Framework

The occupational structure of Cernavoda Nuclear Power Plant was systematically mapped to ESCO framework (Figure 6), allowing the workforce to be grouped into six major occupational families that reflect the diversity of competencies required for the safe and reliable operation of a nuclear power plant. The mapping demonstrates that the workforce extends well beyond traditional nuclear professions, encompassing engineering professionals, engineering technicians, skilled trades, ICT and cybersecurity specialists, management and leadership functions, and corporate support services.

Engineering professionals constitute the core of the highly qualified workforce and are primarily responsible for engineering analyses, plant design support, safety assessments, configuration management, modernization activities and long-term operation programmes. These occupations are typically associated with EQF Levels 6–7 and require advanced technical, analytical and regulatory competencies.

Engineering technicians represent one of the largest and most strategically important occupational families. Acting as the interface between engineering design and plant implementation, they support maintenance, testing, instrumentation and control, electrical and mechanical systems. The analysis identifies this group as a priority for future workforce development due to its combination of high operational demand and significant replacement needs resulting from workforce ageing and retirements.

Skilled trades, including electricians, welders, pipefitters and industrial mechanics, provide the practical expertise required for routine maintenance, outage execution, refurbishment projects and future construction activities. Although these occupations are not exclusively nuclear-specific, they are indispensable for plant operation and are expected to experience increasing demand across Europe as new build, refurbishment and lifetime extension program accelerate.

The increasing digitalization of nuclear facilities has also strengthened the importance of ICT and cybersecurity occupations. Software developers, system administrators, network engineers and cybersecurity specialists are becoming essential contributors to plant operation, requiring not only conventional digital competencies but also specialized knowledge of nuclear safety, industrial control systems and cybersecurity requirements applicable to safety-classified environments.

Management and leadership occupations provide strategic direction, operational oversight and project governance, combining technical understanding with leadership capabilities, safety culture and organizational management competencies. Complementing these functions, corporate support services—including human resources, procurement, finance, legal, communications and administration—ensure the effective functioning of the organization by enabling workforce management, regulatory compliance, resource allocation and institutional support.

Overall, the ESCO mapping confirms that the Cernavoda NPP workforce comprises a balanced combination of highly specialized nuclear occupations and cross-sector professional profiles. This structured occupational classification provides a common European reference for analysing workforce composition, identifying skills needs, and aligning VET provision with labour market demand. It also establishes a robust evidence base for the development of targeted

education pathways, nuclear-specific curricula, micro-credentials and workforce planning measures that support the long-term sustainability and competitiveness of the European nuclear sector.

5.4 Nuclearization Analysis

One of the most significant findings of the analysis of Cernavoda NPP workforce concerns the degree of nuclear specialization required across the workforce. The workforce was classified into three categories according to the level of nuclear knowledge required presented in Figure 7.

The analysis of the Cernavoda Nuclear Power Plant workforce demonstrates that the level of nuclear-specific knowledge required varies significantly across occupational groups, providing an important basis for the design of differentiated education and training pathways. Approximately 42.8% of occupations were classified as purely nuclear, requiring extensive nuclear-specific competencies, dedicated nuclear education, prolonged on-the-job training and, where applicable, regulatory authorization. These occupations include reactor operations, radiation protection, nuclear safety, reactor physics, fuel management and nuclear engineering, all of which are directly associated with the safe operation and long-term sustainability of the plant.

A further 47.2% of occupations were identified as nuclearized occupations, combining transferable technical competencies with sector-specific nuclear knowledge. This category includes electricians, mechanical and instrumentation & control technicians, maintenance specialists, quality inspectors and cybersecurity professionals. For these occupations, the analysis indicates that dedicated nuclear degree programs are generally unnecessary; instead, competency development can be effectively achieved through nuclearized vocational curricula, workplace learning, targeted micro-credentials and continuous professional development. Given the ageing workforce and the strategic importance of technical occupations for plant operation, refurbishment activities and future nuclear projects, this category represents the greatest opportunity for expanding VET provision.

The remaining 10.0% of occupations require low levels of nuclear specialization and primarily support the organization's business functions, including human resources, procurement, finance, legal services and communications. For these occupations, short awareness programmes focusing on nuclear safety culture,

the regulatory framework and sector-specific operational requirements are considered sufficient to ensure effective integration within the nuclear environment.

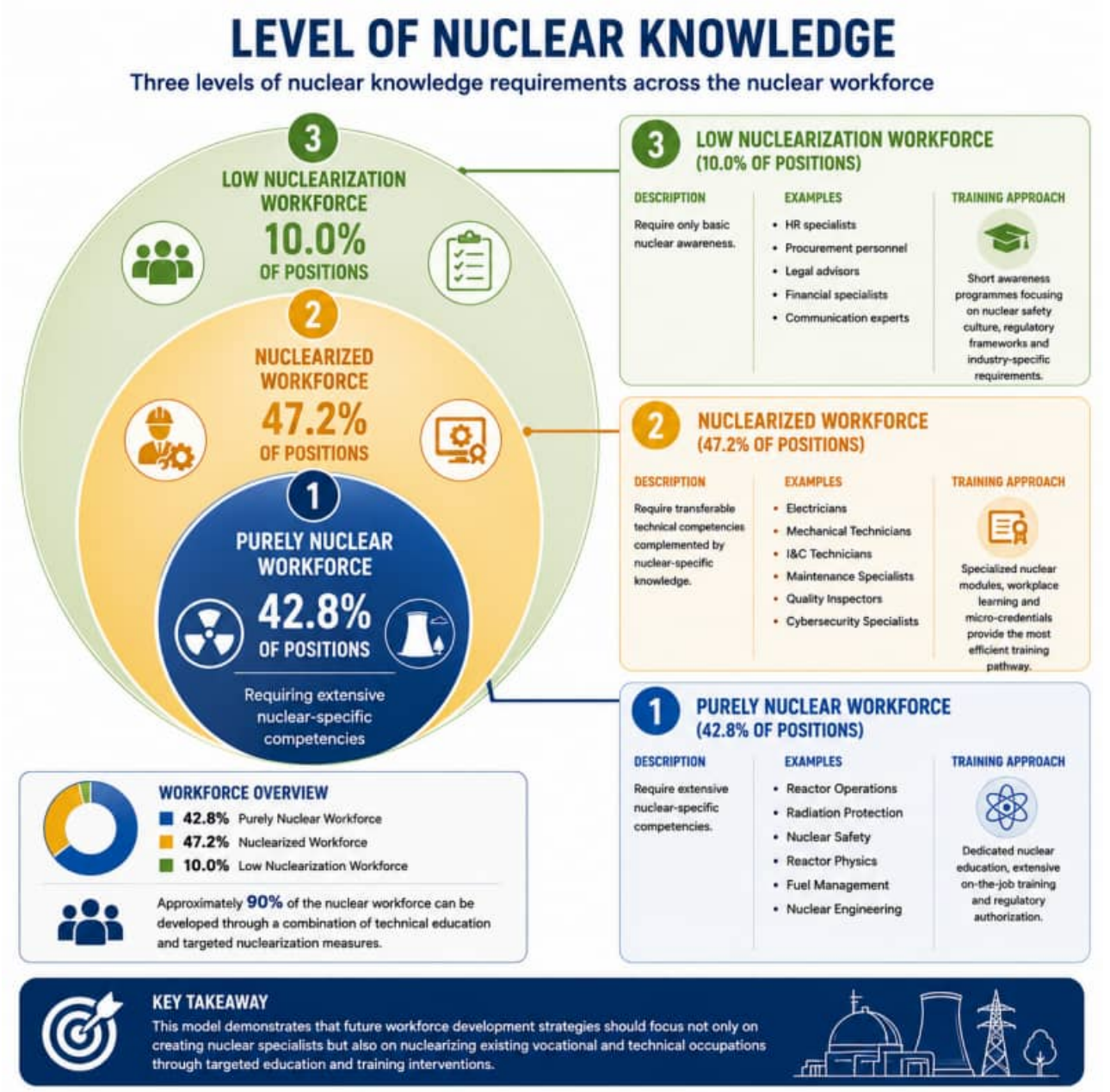

Figure 7 Level of Nuclear Knowledge at Cernavoda NPP

Overall, the findings demonstrate that while a substantial proportion of the Cernavoda NPP workforce requires highly specialized nuclear expertise, nearly half of the workforce can be developed through the nuclearization of existing technical occupations. This provides strong evidence for prioritizing modular

learning pathways, micro-credentials and targeted VET interventions as key components of the future European Nuclear Skills Ecosystem, ensuring a sustainable pipeline of qualified personnel capable of supporting both current plant operations and future nuclear investments.

5.5 Comparison of Cernavoda NPP with the European Nuclear Ecosystem

An important observation is that the proportion of purely nuclear occupations identified at Cernavoda NPP—approximately 42.8%—is considerably higher than the share generally estimated for the wider European nuclear ecosystem. The European Human Resources Observatory for the Nuclear Energy Sector (EHRO-N) report Putting into Perspective the Supply of and Demand for Nuclear Experts by 2020 within the EU-27 Nuclear Energy Sector estimated that approximately 16% of the European nuclear workforce consisted of nuclear experts, compared with 74% nuclearized engineers, graduates and technicians and 10% support personnel requiring mainly nuclear awareness [27]. This distinction was subsequently incorporated into the Joint Research Centre workforce-modelling methodology, which divides the workforce into three broad categories: nuclear experts, nuclearized personnel and nuclear-aware personnel [28]. More recent sectoral evidence also indicates that only a relatively limited proportion of skills across the extended nuclear industry are exclusively nuclear-specific; for example, the Midlands Nuclear Skills Study reports stakeholder estimates of approximately 10%, while emphasizing that most workforce needs can be met by adapting transferable technical and professional skills to the nuclear context [29].

The higher proportion identified for Cernavoda NPP can therefore be explained primarily by the scope and organizational boundary of the case study. The analysis focuses exclusively on the workforce of an operating nuclear power plant, where a substantial proportion of personnel is directly engaged in reactor operations, maintenance, engineering, nuclear safety, radiation protection, fuel management and other safety-significant activities. These functions require greater depth of nuclear knowledge, extensive plant-specific training and, for certain positions, formal regulatory authorization. By contrast, European-level assessments cover the broader nuclear value chain, including equipment suppliers, manufacturers, construction companies, research organizations, universities, training providers, regulators, consultancies and other service

organizations. The Joint Research Centre's nuclear job-classification work confirms the breadth and diversity of occupations involved across this wider ecosystem and highlights the need to distinguish genuinely nuclear-specific professions from conventional occupations employed in a nuclear environment [30]. Consequently, the Cernavoda NPP results should be interpreted as representative of the workforce structure of an operating nuclear facility, rather than as directly representative of the entire European nuclear value chain.

Cernavoda NPP workforce analysis provides several important conclusions for the development of European VET initiatives. First, vocational education represents a critical pillar of workforce sustainability, as almost half of all positions correspond to Lower VET pathways. Second, technicians and skilled trades represent some of the most strategically important workforce categories and should therefore be prioritized in future VET investments. Third, the majority of occupations do not require full nuclear specialization but rather different levels of nuclearization. This finding supports the development of modular curricula, micro-credentials and reskilling programs. Fourth, stronger Higher VET pathways are needed to bridge the gap between vocational education and university-level programs. Finally, the analysis confirms that future workforce development strategies should adopt a layered approach combining Lower VET programs (EQF 3–4) with Higher VET programs (EQF 4–5), Vocational Bachelor programs (EQF 5–6), Advanced Professional Programs (EQF 6–7), Micro-credentials and Train-the-Trainer initiatives. Such an approach would provide the flexibility and scalability required to support both existing nuclear facilities and future European nuclear projects.

6. ANALYSIS OF THE KOZLODUY NPP WORKFORCE STRUCTURE

Kozloduy NPP is the only operating nuclear power plant in Bulgaria and one of the largest nuclear facilities in Southeast Europe. As the operator of two VVER-1000 units and with an important role in the country's future nuclear program, the plant requires a highly qualified and multidisciplinary workforce. Understanding the composition of this workforce is essential for identifying current competence profiles and designing future education and training pathways aligned with European workforce needs.

The analysis presented below is based on detailed job requirements covering the entire organizational structure of Kozloduy NPP. The available dataset includes educational requirements, professional fields, qualification levels and occupational profiles for all positions, allowing a comprehensive assessment of the workforce using both the EQF and ESCO frameworks.

6.1 Workforce Structure by Educational Level

The workforce structure of Kozloduy NPP demonstrates a balanced distribution between vocationally educated personnel and employees holding higher education qualifications (see Table 7).

Table 7 Percentage of education Level at Kozloduy NPP

Education Level	Percentage
General Secondary Education	8.5%
Secondary Vocational Education	46.68%
Bachelor Degree	13.17%
Master Degree	31.61%

The results reveal that personnel with secondary vocational education constitute the larger workforce segment, representing more than half of all employees, more than 55% of the workforce is supported by educational pathways below university level.

This finding confirms that nuclear power plants depend not only on engineers and highly specialized experts but also on a large population of technicians, operators, maintenance personnel, skilled trades and support workers.

Vocational education therefore represents a strategic component of workforce sustainability and operational reliability.
These findings provide the first indication that future workforce development cannot rely exclusively on university graduates but must also ensure a sustainable pipeline of vocationally trained specialists.

6.2 Workforce Structure by EQF Level

While educational attainment provides an overview of the workforce profile, it does not directly indicate the qualification levels required by different occupational groups. To establish comparability with other European nuclear organizations and to support the development of common education pathways, the workforce is subsequently mapped to the European Qualifications Framework (EQF) (see Table 8).

Table 8 Kozloduy NPP workforce mapped against the European Qualifications Framework

EQF Level	Educational Requirement	Share
EQF 3	General Secondary Education	8,5%
EQF 4	Secondary Vocational Education	46,68%
EQF 5	Professional Bachelor	0%
EQF 6	Bachelor Degree	13,17%
EQF 7	Master Degree	31,61%

The EQF analysis highlights the dominant role of qualification Levels 3 and 4, which together represent more than half of the workforce. These qualification levels correspond primarily to operational personnel, engineering technicians, maintenance staff, skilled trades and plant support functions.
Higher qualification levels (EQF 6-7) are mainly associated with engineering professionals, reactor operations, safety functions, management and strategic decision-making roles. (Figure 8)

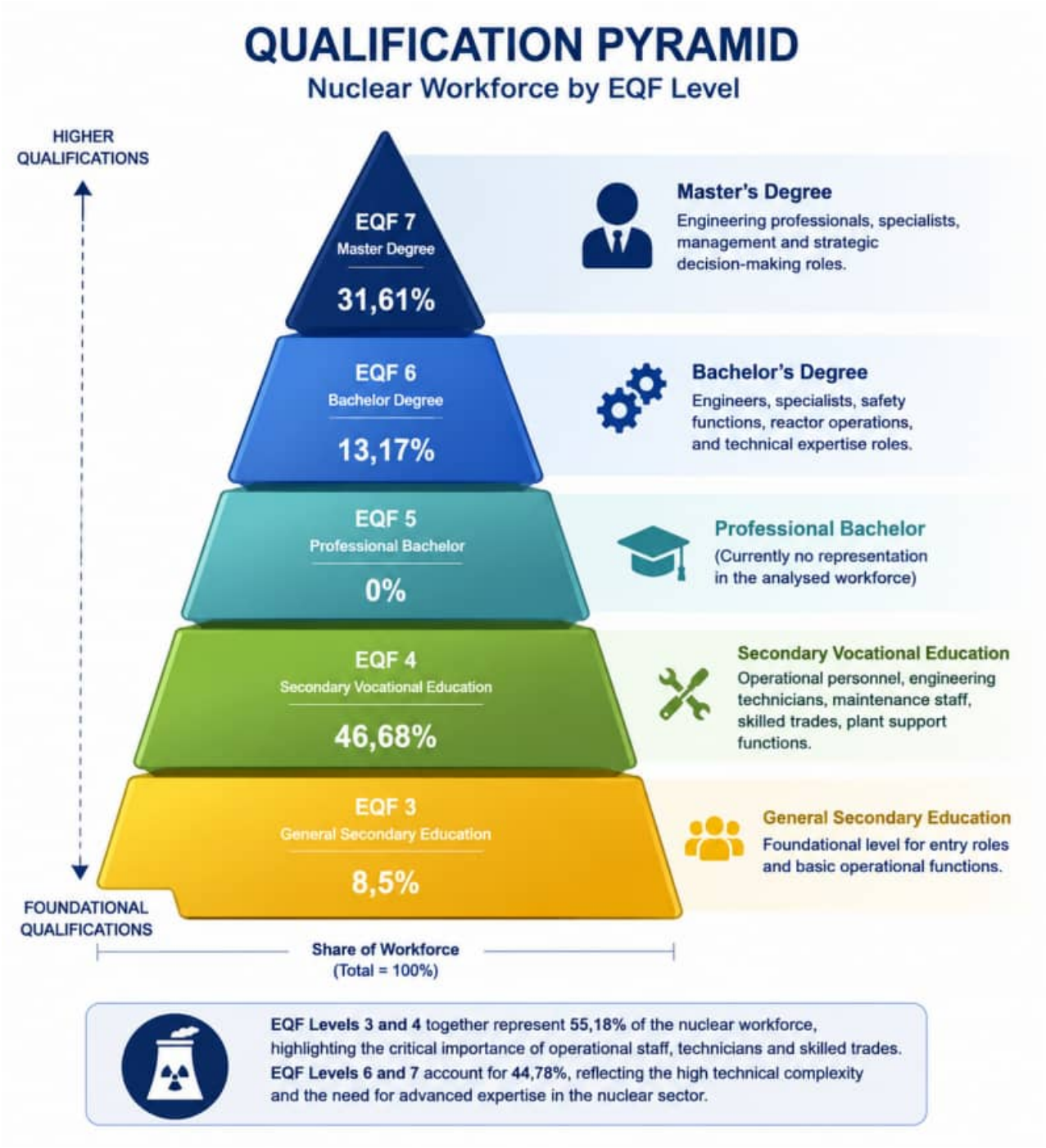

Figure 8 Qualification Pyramid for Kozloduy NPP

The overall distribution closely resembles the findings obtained from the Cernavoda NPP case study, suggesting that operating nuclear power plants across Europe share a similar qualification profile despite differences in reactor technology and national education systems.

6.3 Workforce Segmentation according to ESCO Occupational Families

Qualification levels alone do not fully describe the complexity of nuclear workforce requirements. To better understand occupational diversity, all positions were mapped to ESCO occupational families based on job title, required education and professional field.

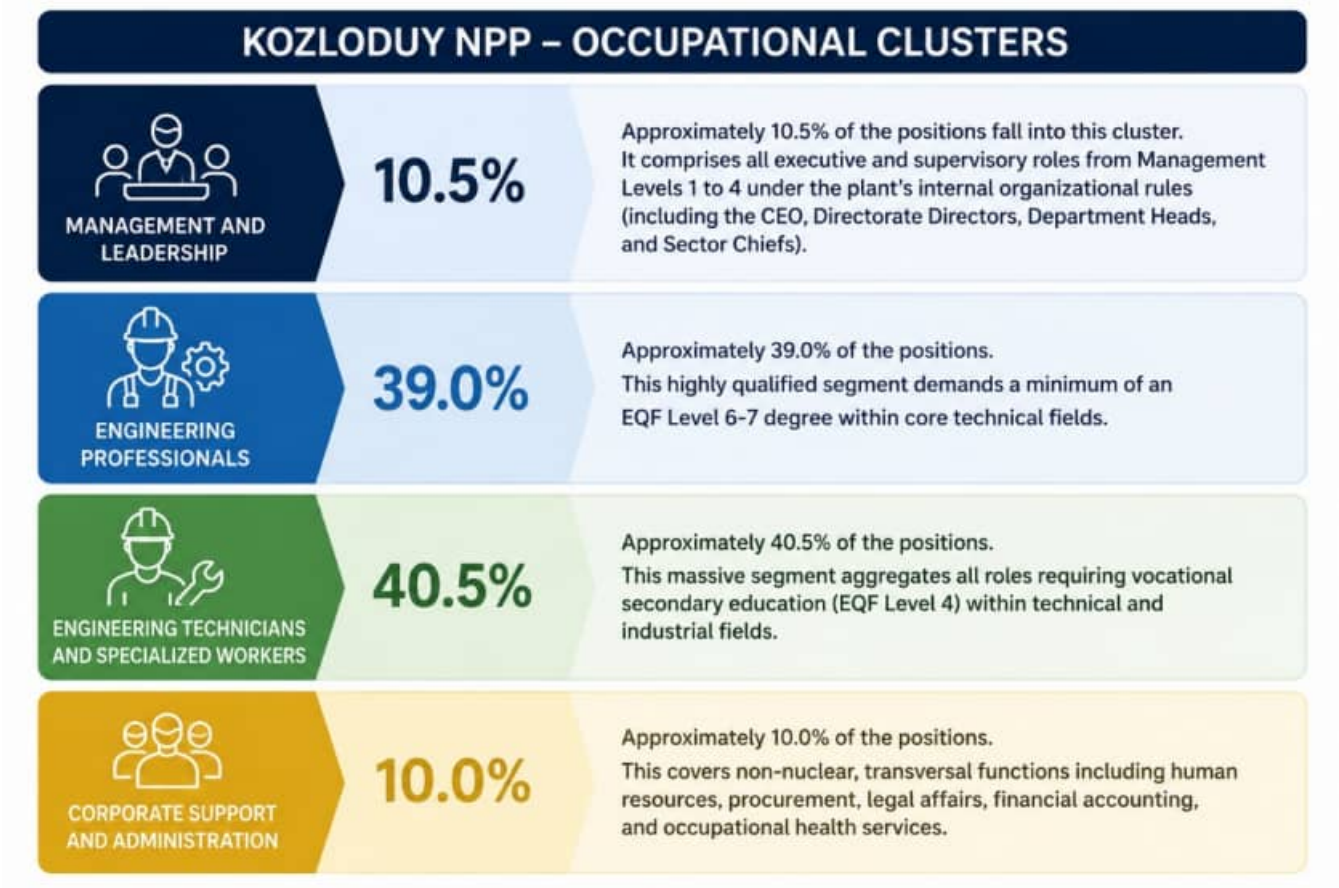

Figure 9 Kozloduy NPP workforce mapped to the ESCO Framework

The analysis identified several major occupational groups (see Figure 9):

- **Management and Leadership:** Approximately ***10.5%*** of the positions fall into this cluster. It comprises all executive and supervisory roles from Management Levels 1 to 4 under the plant's internal organizational rules (including the CEO, Directorate Directors, Department Heads, and Sector Chiefs).

- **Engineering Professionals**: Approximately ***39.0%*** of the positions. This highly qualified segment demands a minimum of an EQF Level 6-7 degree within core technical fields.
- **Engineering Technicians and Specialized Workers**: Approximately ***40.5%*** of the positions. This massive segment aggregates all roles requiring vocational secondary education (EQF Level 4) within technical and industrial fields.
- **Corporate Support and Administration**: Approximately ***10.0%*** of the positions. This covers non-nuclear, transversal functions including human resources, procurement, legal affairs, financial accounting, and occupational health services.

The results demonstrate that engineering technicians and skilled technical occupations constitute the largest occupational family within Kozloduy NPP. Engineering professionals and management positions form a second major group, while specialized occupations such as radiation protection, quality assurance and digital technologies represent smaller but strategically important workforce segments.

This distribution confirms that the nuclear workforce should be viewed as an integrated skills ecosystem rather than a collection of isolated professions. It also supports the use of ESCO occupational families as the basis for workforce forecasting, curriculum development and competence management across Europe.

6.4 Nuclearization Analysis

Following ESCO mapping, occupational groups were further classified according to the level of nuclear-specific competence required, Figure 10.

High nuclearization applies primarily to reactor operations personnel, nuclear engineers, radiation protection specialists, safety analysts and selected management positions with direct responsibility for nuclear safety.

Medium-high nuclearization includes engineering professionals, maintenance engineers, quality assurance specialists, instrumentation and control experts and technical supervisors.

Medium nuclearization characterizes engineering technicians, electricians, mechanics, maintenance personnel and skilled trades, where conventional technical competences are complemented by nuclear safety culture, radiation protection awareness and regulatory compliance.

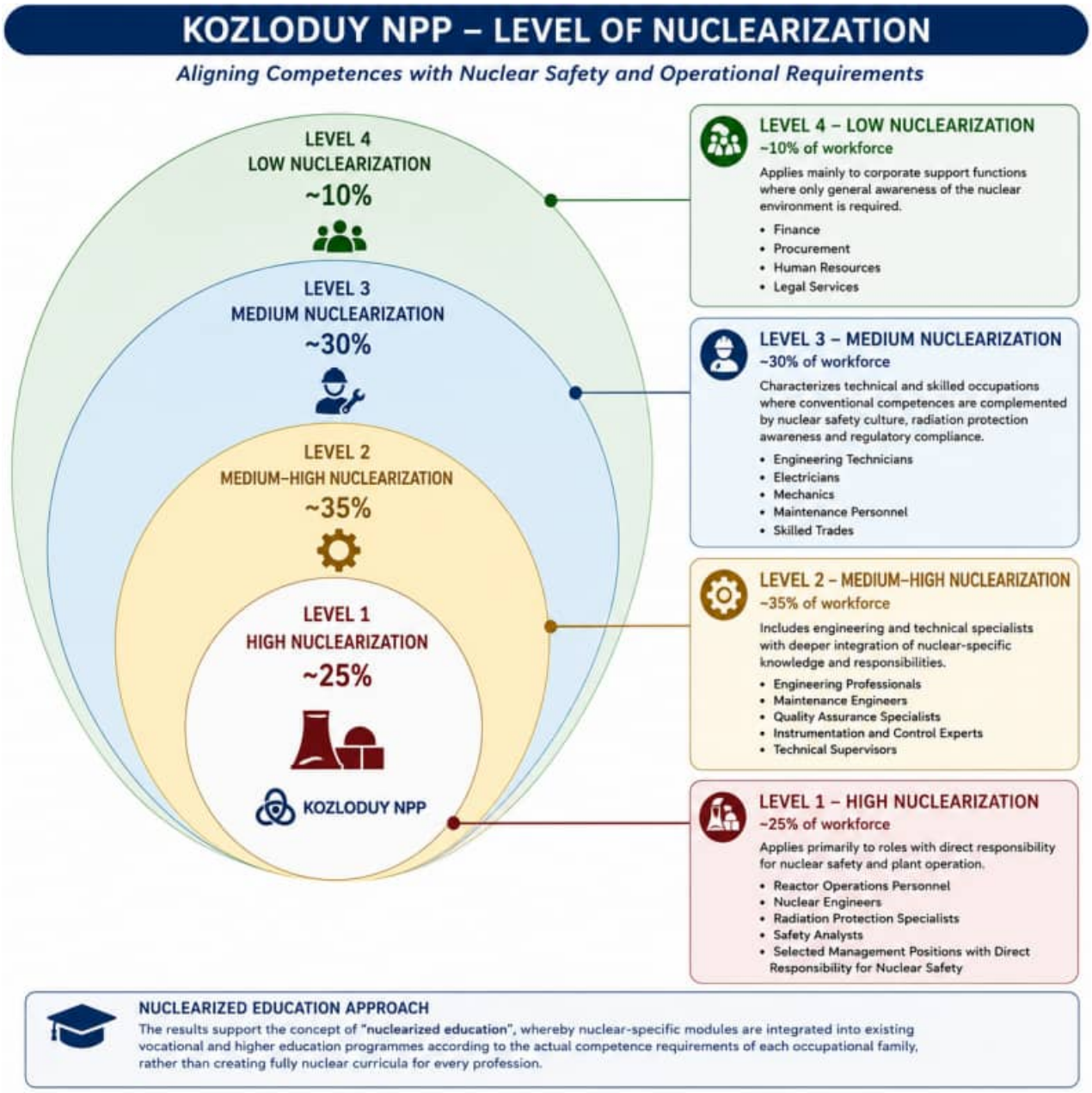

Figure 10 Level of Nuclear Knowledge at Kozloduy NPP

Low nuclearization applies mainly to corporate support functions such as finance, procurement, human resources and legal services, where only general awareness of the nuclear environment is required.

The results support the concept of "nuclearized education", whereby nuclear-specific modules are integrated into existing vocational and higher education programmes according to the actual competence requirements of each

occupational family, rather than creating fully nuclear curricula for every profession.

6.5 Critical Occupations and Future Workforce Risks

The analysis of these structural lines reveals specific organizational challenges:

- **The Core Engineering Pipeline Risk**: A large block of the ***533*** distinct Engineering Professional jobs requires rare qualifications in Nuclear Power Engineering or Thermal Power Engineering. The limited number of university programs offering these specializations creates a risk of unfilled roles as personnel retire.
- **VET Maintenance Specialization**: Over ***300*** unique technical roles rely heavily on cross-cutting industrial trades (welders, turbine fitters, electrical technicians). The core challenge is not the baseline technical skill, but rather transforming these profiles to meet Nuclear Readiness standards through targeted safety culture and human performance training.

6.6 Implications for European Nuclear Workforce Development

Taken together, the educational analysis, EQF mapping, ESCO occupational segmentation and nuclearization assessment provide a comprehensive picture of the workforce structure at Kozloduy NPP.

The consistency of these findings with the Cernavoda case study strengthens confidence that the identified trends are representative of operating nuclear power plants across Europe rather than isolated national characteristics.

The analysis confirms that future workforce shortages are likely to be concentrated among technical occupations, engineering technicians and vocationally educated personnel rather than exclusively among nuclear engineers. Consequently, future education strategies should prioritise strengthening vocational education and training (VET), while also creating flexible progression pathways towards higher qualifications.

The findings support the development of:

- strengthened Lower VET programs (EQF 3-4);
- expanded Higher VET programs (EQF 4-5);
- Vocational Bachelor programs (EQF 5-6);
- Advanced Professional programs (EQF 6-7);

- stackable micro-credentials aligned with ESCO occupations;
- work-based learning and apprenticeships;
- digital competence modules covering AI, Digital Twins, cybersecurity and data analytics;
- structured knowledge transfer, mentoring and succession planning programs supporting long-term operation (LTO).

Overall, the Kozloduy case study reinforces the central conclusion of Task 4.3: the future European nuclear workforce cannot be developed solely through traditional university-level nuclear engineering programmes. Instead, it requires an integrated Nuclear Skills Ecosystem combining vocational education, higher education, workplace learning, modular nuclear specialization and lifelong learning.

6.7 Digital Transformation in the Nuclear Industry

Modern reactor operations, plant life extensions, and the deployment of advanced Gen III+ or SMR technologies require the immediate horizontal integration of digital and data-driven competencies across all educational tiers (from EQF Level 4 to EQF Level 7):

- **AI-Assisted Operations**: Integration of Artificial Intelligence and Machine Learning tools into control room environments.
- **Digital Twins**: Deploying immersive, high-fidelity virtual 3D replicas of physical reactor systems and plant components. This allows maintenance technicians (EQF Level 4) to visually simulate repair pathways, practice ALARA (As Low As Reasonably Achievable) routing, and run virtual dry-runs before physically entering radiation-controlled zones.
- **Predictive Maintenance**: Training engineering and maintenance professionals to interpret advanced multi-sensor data streams (vibration, acoustics, thermal profiling) to detect degradation mechanisms early, shifting the plant from reactive or fixed-interval maintenance to condition-based, predictive schedules.
- **Cybersecurity for I&C Systems**: A mandatory, cross-cutting competency. As digital instrumentation and control (I&C) architectures become more interconnected, shielding safety-classified operational technology systems from external cyber threats is now an absolute pillar of comprehensive Nuclear Security.

6.8 Systemic Knowledge Management to support Long-Term Operation (LTO)

The prolongation of operating licenses for existing nuclear assets highlights the critical necessity of retaining operational experience. It could be instrumental to establish a dedicated European Framework for Nuclear Knowledge Management, focusing on (Figure 11):

- **Formal Mentoring Programmes**: Introducing structured, institutionalized mentoring periods (spanning 12 to 24 months) where senior retiring experts are paired with junior engineers to systematically transfer "tacit knowledge".
- **Proactive Succession Planning**: Implementing predictive workforce software mapping to identify safety-critical and highly specialized positions across the organization.
- **Digital Knowledge Retention and Capture**: Utilizing advanced digital repositories, expert video capturing of non-routine maintenance activities, and interactive semantic wikis. This ensures that when an expert generation reaches retirement age, their unique technical diagnostic insights remain permanently embedded within the plant's operational memory.

Figure 11 Systemic Knowledge Management to support Long-Term Operation (LTO)

7 LOWER VET ANALYSIS (EQF 3–4)

Based on the analysis of Cernavoda NPP and Kozloduy NPP, it could be observed that the majority of Lower VET occupations belong to the category of **Medium Nuclearization**.

Personnel require strong vocational competences, understanding of nuclear safety culture, basic radiation protection knowledge, quality assurance requirements, nuclear documentation practices, human performance tools. The technical core of the occupation remains largely unchanged.

For example, an industrial electrician working in a conventional power plant and an industrial electrician working in a nuclear power plant perform many similar technical tasks. The difference lies primarily in the additional nuclear requirements associated with safety, quality and regulatory compliance. This finding supports the concept of "nuclearized vocational training" rather than fully nuclear vocational programs.

The review of existing European vocational curricula indicates that the optimal approach for occupations requiring partial nuclearization is the integration of nuclear-specific modules into established vocational programs. A curriculum structure comprising approximately 75–80% core vocational content and 20–25% nuclear-specific training is considered appropriate for most EQF 3–4 occupational profiles, ensuring both transferability of skills across industries and adequate preparation for employment within nuclear facilities.

The proposed nuclear-specific modules are derived from competency areas consistently identified across internationally recognized nuclear education and training frameworks, including the IAEA Systematic Approach to Training (SAT), WANO performance and training guidance, ENEN educational frameworks and qualification programs implemented by European and international nuclear operators. Collectively, these frameworks emphasize the need for the following nuclear modules:

- Nuclear Safety Culture
- Radiation Protection Awareness
- Nuclear Quality Assurance
- Human Performance Tools
- Conduct of Operations
- Working in Controlled Areas

– Nuclear Documentation Practices

The MATCH Program identifies many skilled trades occupations among those expected to face the largest shortages in the coming decade. As Europe moves forward with life extension programs, refurbishment projects, new nuclear constructions and SMR deployment, the demand for skilled workers is expected to increase significantly. Therefore, Lower VET should be considered one of the highest priorities for European workforce development initiatives.

8 HIGHER VET ANALYSIS (EQF 4–5)

One of the most important findings of the analysis done on the NPPs is the relatively small proportion of Higher VET personnel. This may indicate a structural weakness within the European nuclear skills pipeline. Many educational systems offer vocational education (EQF 3–4) and university education (EQF 6–7), but relatively few advanced vocational pathways positioned between these two levels. This creates difficulties for workforce progression, technician specialization and succession planning.

Based on the analysis of the NPPs workforce structure, the occupational and qualification mapping performed using the ESCO and EQF frameworks, the workforce demand projections and occupational profiles identified through the MATCH methodology, and the review of existing European vocational and advanced vocational programmes, it is recommended that curricula for EQF 5 Advanced Vocational Programmes comprise approximately 60% technical specialization content, 30% nuclear-specific training and 10% workplace-based learning. This distribution reflects the competency profile of technical occupations within the nuclear sector, where strong occupation-specific technical skills remain the primary requirement, complemented by nuclear-specific knowledge and practical workplace experience.

Based on the above-mentioned frameworks, for higher VET the recommended nuclear modules are:

- Nuclear Systems Overview
- Nuclear Maintenance
- Radiation Protection
- Nuclear Quality Management
- Outage Management
- Configuration Management
- Operational Experience (OPEX)
- Human Performance Improvement

Higher VET represents one of the most promising educational segments for future workforce development. Investment in advanced technician programs can provide faster workforce development than engineering degrees, strong

practical competencies, improved workforce retention and effective succession planning.

9 VOCATIONAL BACHELOR ANALYSIS (EQF 5–6)

Vocational Bachelor programs occupy an important position between advanced vocational education and traditional university engineering programs. These programs are particularly relevant because many future nuclear occupations require applied engineering knowledge, practical industrial experience, understanding of nuclear systems and multidisciplinary competencies.

Vocational Bachelor programs can provide these competences more efficiently than traditional academic programs. These programs provide stronger industry orientation, extensive workplace learning, shorter adaptation periods after recruitment and greater flexibility for upskilling. This model aligns particularly well with the requirements identified through the MATCH methodology.

Based on the analysis of workforce requirements identified through the ESCO-EQF mapping, the occupational profiles observed within the Cernavoda NPP workforce, the skills needs highlighted by the MATCH methodology, and the review of existing European applied engineering and nuclear education programmes, it is recommended that Vocational Bachelor curricula (EQF 5–6) comprise approximately 40% engineering fundamentals, 30% applied engineering practice, 20% nuclear specialization and 10% industrial placement.

This curriculum structure aims to provide learners with a strong foundation in engineering principles while ensuring sufficient practical experience and sector-specific nuclear competencies. The proposed balance reflects the profile of applied engineering occupations within the nuclear sector, where graduates are expected to combine technical problem-solving capabilities with operational awareness, regulatory understanding and practical experience gained in industrial environments.

The inclusion of a significant applied engineering component supports the development of work-ready graduates, while the nuclear specialization component ensures familiarity with nuclear safety culture, nuclear technologies, quality assurance requirements and the regulatory framework governing nuclear activities. The industrial placement component further strengthens the connection between education and industry, facilitating the transition from learning to professional practice and improving graduate employability.

Based on the above-mentioned frameworks, for higher VET the recommended nuclear modules are:

- Nuclear Technology Fundamentals
- Systems Engineering
- Reliability Engineering
- Asset Management
- Nuclear Project Management
- Digital Technologies
- Introduction to SMRs

Vocational Bachelor programs can serve as a critical bridge between higher VET, university education and industrial workforce needs. Their development should therefore be strongly encouraged within future European nuclear education initiatives.

10 ADVANCED PROFESSIONAL PROGRAM (EQF 6–7)

Advanced Professional Programs represent the highest level of professional specialization addressed within T4.3. These programs target highly qualified professionals requiring advanced nuclear expertise. They typically build upon existing engineering or scientific degrees and provide specialized competencies for strategic nuclear roles.

The occupations targeted through Advanced Professional Programs require a combination of advanced technical expertise and high-level professional competencies. In addition to possessing in-depth knowledge within their specific technical domain, professionals in these roles must demonstrate systems thinking, enabling them to understand complex interactions between technical, organizational and regulatory aspects of nuclear operations. They are also expected to exercise sound judgement in safety-related decision-making, apply regulatory requirements effectively, and provide leadership within multidisciplinary and highly regulated environments. Given the complexity and responsibilities associated with these positions, competency development typically requires longer learning pathways that combine postgraduate education, professional certifications and extensive workplace experience. This combination of formal education and practical experience is essential to ensure that professionals are capable of supporting the safe, reliable and efficient operation of nuclear facilities as well as the deployment of future nuclear technologies.

Based on the analysis of workforce requirements identified through the ESCO-EQF mapping, the occupational profiles observed within the Cernavoda NPP workforce, the skills needs highlighted by the MATCH methodology, and the review of existing European advanced nuclear education and professional development programs, it is recommended that Advanced Professional Programs (EQF 6–7) comprise approximately 50% advanced technical specialization, 30% nuclear specialization and 20% leadership and project management content.

This curriculum structure reflects the competency requirements of highly qualified professionals working in strategic nuclear roles, where advanced technical expertise remains the primary competency area, supported by in-depth nuclear knowledge and the leadership capabilities required to operate within highly regulated, safety-critical and multidisciplinary environments.

The advanced technical specialization component should focus on the specific discipline of the learner, such as reactor engineering, safety analysis, fuel management, instrumentation and control, digital systems, cybersecurity or advanced reactor technologies. The nuclear specialization component should strengthen competencies related to nuclear safety, radiation protection, licensing, regulatory frameworks, quality management and nuclear technology. The leadership and project management component should support the development of future technical leaders capable of managing complex projects, multidisciplinary teams, organizational change and strategic decision-making within the nuclear sector.

The proposed balance is intended to support the development of specialists who not only possess advanced technical and nuclear expertise, but are also prepared to assume leadership responsibilities associated with the deployment of new nuclear projects, long-term operation programs, SMR deployment, advanced reactor technologies and the future growth of the European nuclear industry.

Based on the above-mentioned frameworks, for higher VET the recommended nuclear modules are:

- Advanced Reactor Technologies
- Nuclear Safety Assessment
- Probabilistic Safety Analysis
- Licensing and Regulation
- SMR Technologies
- Nuclear Cybersecurity
- Leadership in High-Reliability Organizations

11. MATCH METHODOLOGY EXTRAPOLATION TO EU LEVEL

The French MATCH Program (Métiers et Compétences pour les Talents Humains de la filière nucléaire) represents one of the most mature and comprehensive workforce planning methodologies currently available in the European nuclear sector. Developed under the coordination of GIFEN and supported by major French nuclear stakeholders, MATCH provides a systematic approach for translating industrial workload forecasts into workforce demand, occupational requirements and training needs.

The program was developed in response to a rapidly expanding nuclear program in France, where workforce requirements associated with life extension, new build projects, fuel cycle activities, decommissioning and advanced technologies significantly exceed current workforce availability.

Although initially designed for the French nuclear sector, the methodology provides a robust framework that can be adapted and scaled to the European level. The objective of T4.3 is not to replicate MATCH directly, but to extract the core principles of the methodology and adapt them to the diversity of national nuclear ecosystems across Europe.

The MATCH methodology is based on a simple but powerful concept: *Industrial workload generates workforce demand, workforce demand generates competence requirements, and competence requirements generate training needs.*

Rather than beginning with educational programs and attempting to fit them to labor market needs, MATCH starts with the industrial reality. The methodology consists of five interconnected layers displayed in the diagram below[6], Figure 12..

Figure 12 MATCH methodology extrapolation to EU level

The European nuclear sector is entering a period of unprecedented workforce demand. Several major programs are occurring simultaneously as it is announced across EU member states.

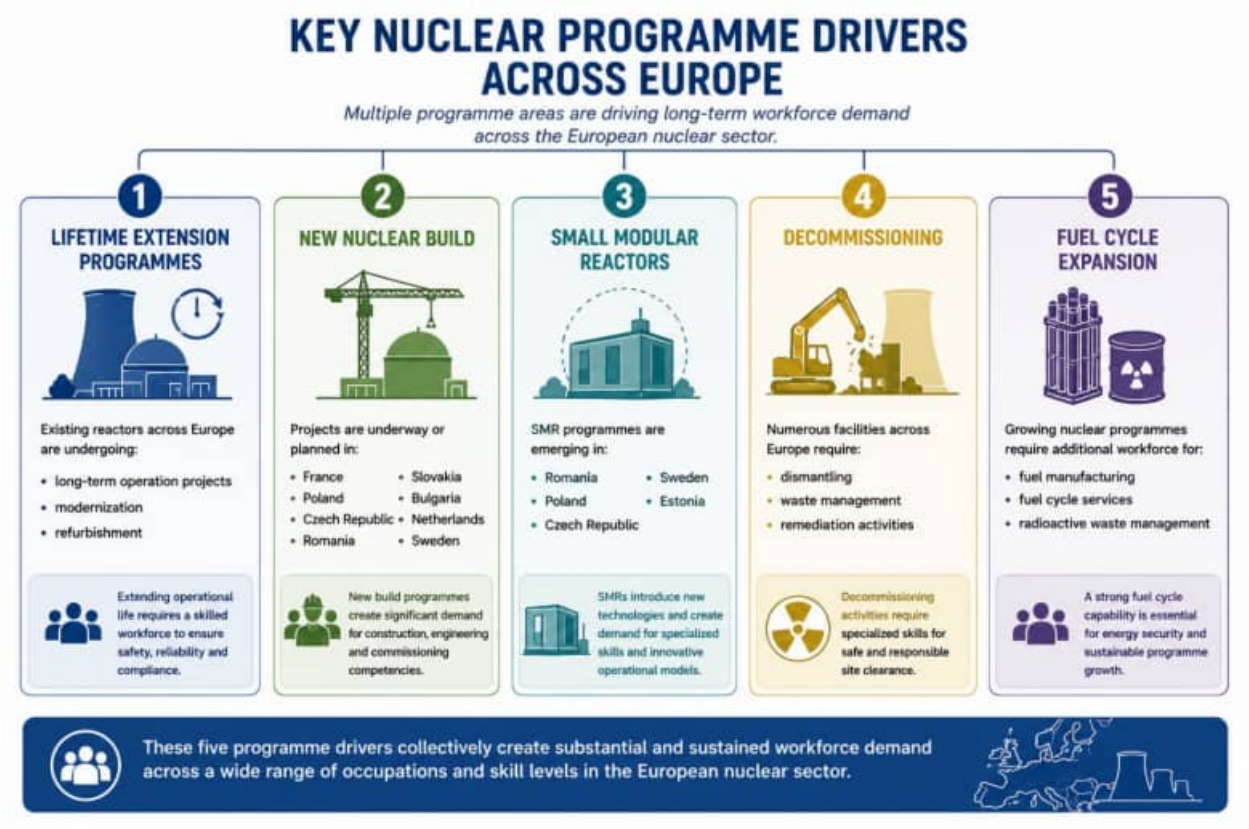

Figure 13 Key Nuclear Program Drivers across Europe

As a result, Europe faces a common challenge: *Workforce shortages are becoming a pan-European issue rather than a national issue* and a common methodology is therefore required. The present report proposes the creation of a European Nuclear Workforce Observatory based on MATCH principles. The framework would consist of six analytical layers.

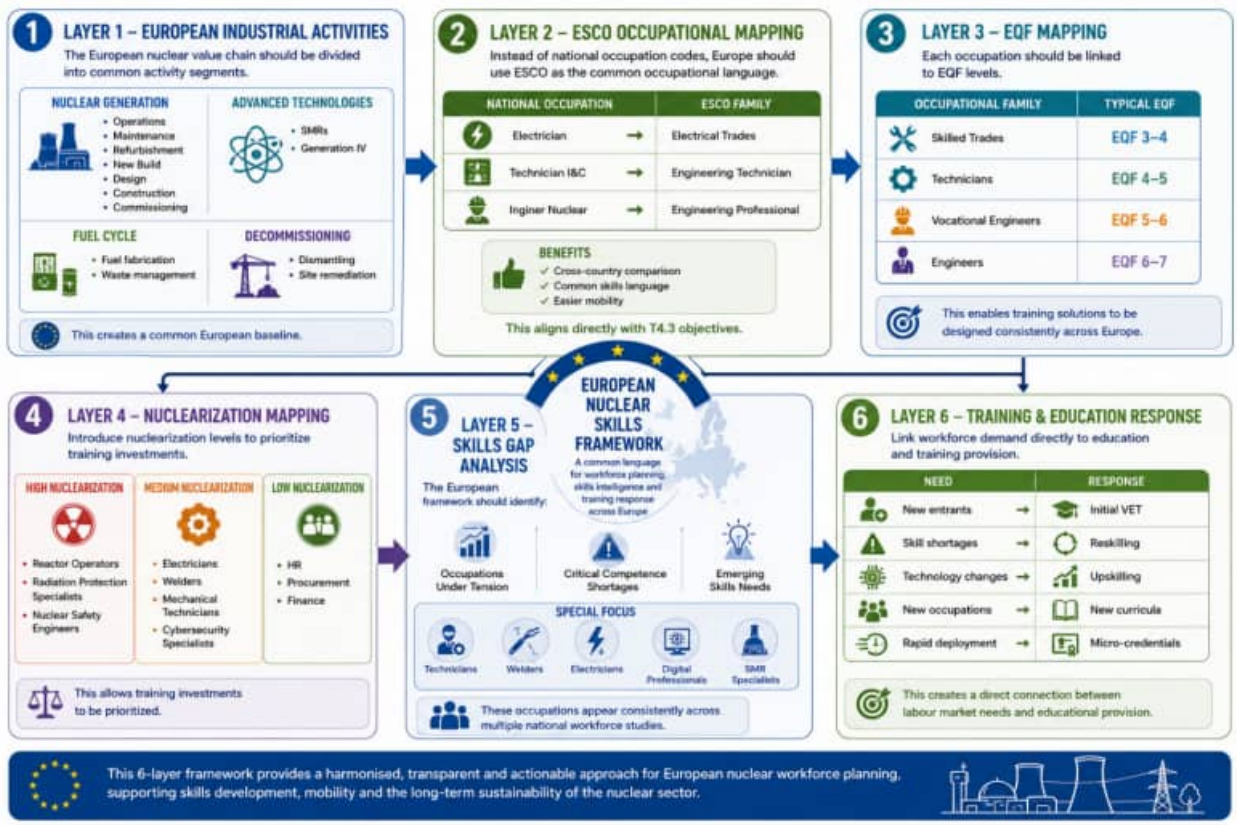

Figure 14 European Nuclear Workforce Observatory based on MATCH principles

The extrapolated MATCH methodology supports the creation of a European Nuclear Skills Pyramid. Figure 15 presents the proposed **European Nuclear Skills Pyramid**, developed through the extrapolation of the MATCH methodology and the analyses performed within Deliverable D4.3. The pyramid provides a structured European framework for the progressive development of competencies across the nuclear workforce, linking occupational profiles with appropriate qualification levels and education pathways. It illustrates that workforce development should not be viewed as a single educational route but as a continuum that begins with fundamental nuclear awareness, progresses through increasingly specialised vocational and higher education programmes, and is supported throughout by continuous professional development. The framework reflects the diversity of occupational requirements across the European nuclear sector while providing a common reference that can be adapted to different national education systems.

The lower levels of the pyramid emphasise the strategic importance of vocational education and training (VET) for developing the operational workforce required

by the nuclear industry. **Tier 1** introduces nuclear awareness for support functions and contractors, ensuring that all personnel working within the nuclear environment possess a basic understanding of nuclear safety culture and regulatory requirements. **Tier 2** focuses on nuclearized skilled trades, including electricians, welders and mechanics, by complementing conventional technical education with nuclear-specific competencies. **Tier 3** addresses advanced nuclearized technicians, particularly instrumentation and control (I&C) and maintenance technicians, who require higher levels of technical expertise and represent one of the most critical occupational groups for future workforce development. These tiers collectively strengthen the vocational skills pipeline and address the shortage of advanced technical personnel identified through the workforce analysis.

The upper part of the pyramid represents progressively higher levels of specialization and responsibility. **Tier 4** proposes vocational bachelor programs designed for applied engineering professionals, bridging the gap between advanced vocational education and traditional university engineering degrees. **Tier 5** focuses on advanced nuclear specialists, including reactor engineers, safety analysts and licensing specialists, whose roles require extensive nuclear-specific knowledge and advanced professional competencies. The pyramid is complemented by **Tier 6**, which extends across all qualification levels and highlights the importance of continuous professional development (CPD), recognizing that technological innovation, evolving regulatory requirements and workforce mobility necessitate lifelong learning, upskilling and reskilling throughout professional careers.

Beyond describing educational pathways, the proposed European Nuclear Skills Pyramid establishes a common strategic framework for aligning occupational requirements with education and training provision across Europe. By integrating qualification levels, occupational progression and nuclear-specific competence development within a single model, the framework supports the harmonization of skills development, facilitates labor mobility between Member States, and promotes greater consistency in curriculum design. It also provides a practical foundation for future European initiatives related to vocational education, micro-credentials, workforce planning and lifelong learning, thereby contributing to the development of a skilled, adaptable and resilient workforce capable of

supporting the long-term sustainability, safety and competitiveness of the European nuclear sector.

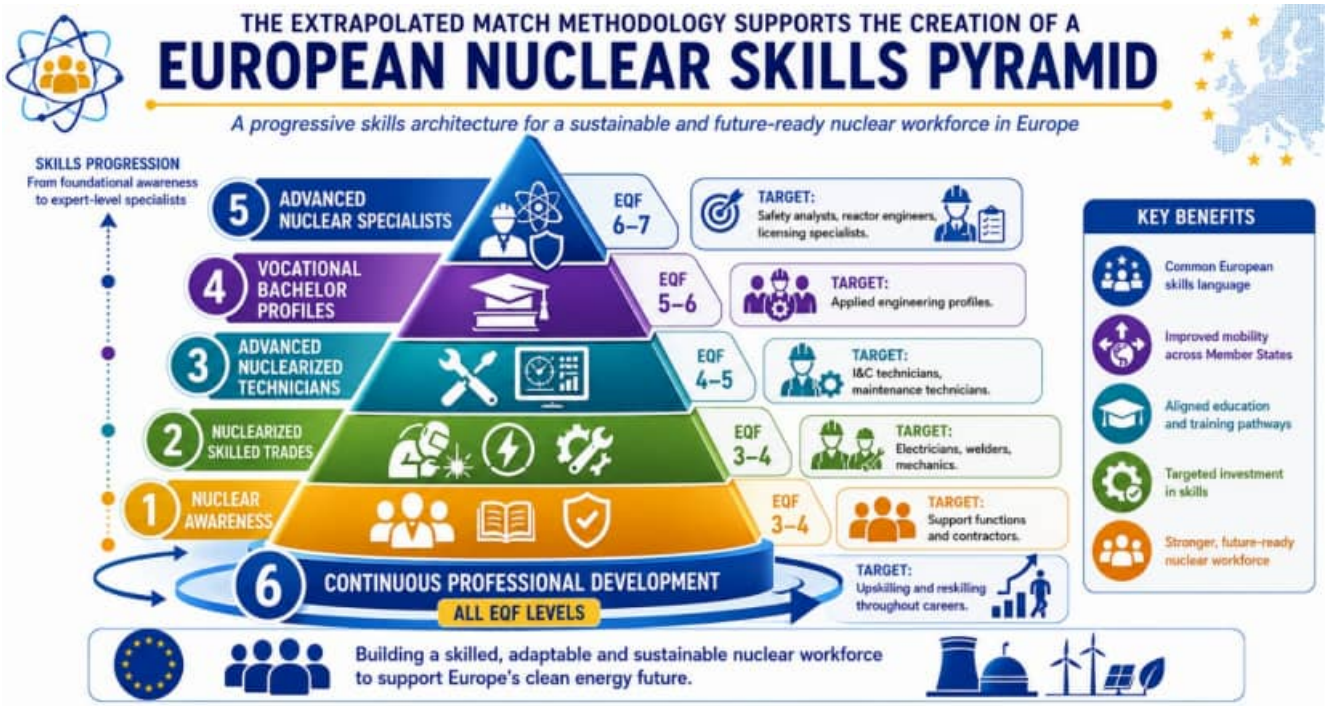

Figure 15 A proposal for European Nuclear Skills Pyramid

The MATCH methodology demonstrates that workforce planning should begin with industrial demand and end with targeted education and training interventions. Extrapolated to the European level, this approach provides a structured mechanism for connecting workforce forecasts, occupational requirements, qualification frameworks and training provision. Combined with ESCO, EQF, ENEN2plus outcomes and the findings of the NPPs workforce analysis, the methodology provides a robust foundation for a future Nuclear Skills Strategy capable of supporting reactor operations, life extension programs, new build projects, SMRs, fuel cycle activities and decommissioning across the European Union.

12 RECOMMENDATIONS FOR EU IMPLEMENTATION INSTEAD OF CONCLUSIONS

The analysis undertaken within this report demonstrates that the future competitiveness and sustainability of the European nuclear sector will depend on the establishment of a coherent, flexible and industry-driven education and training ecosystem capable of responding to rapidly evolving workforce requirements. The combination of workforce analysis, occupational mapping using ESCO, qualification mapping through the EQF, the industrial demand forecasting approach derived from the MATCH methodology and the educational experience gained through ENEN2plus provides a robust evidence base for the following strategic recommendations.

Recommendation 1. Establish a European Nuclear Workforce Observatory

A permanent European Nuclear Workforce Observatory should be established to provide continuous monitoring of workforce trends, occupational shortages, demographic developments and future competence needs across the European nuclear sector.

Building upon the principles of the French MATCH methodology, the Observatory should integrate industrial workforce forecasting with education and training planning, enabling proactive rather than reactive responses to emerging skills shortages. The Observatory should collect harmonised workforce data from nuclear operators, supply chain companies, research organisations, educational institutions and regulatory bodies, providing periodic assessments of workforce demand associated with reactor operation, long-term operation, new build, Small Modular Reactors (SMRs), decommissioning and fuel cycle activities. Such a mechanism would support evidence-based policy making and facilitate coordinated workforce planning across Member States.

Recommendation 2. Adopt ESCO as the Common European Occupational Framework

The ESCO classification should be adopted as the common reference framework for describing occupations, competences and skills required within the European nuclear sector. The use of ESCO would establish a common occupational language, improving comparability between national education systems, facilitating workforce mobility and enabling consistent identification of occupational profiles across Member States. Furthermore, ESCO provides the foundation for developing common occupational standards, competence profiles and learning outcomes that can be recognised throughout Europe.

Recommendation 3. Use the European Qualifications Framework (EQF) as the Reference Qualification Framework

Future European nuclear education and training initiatives should systematically align curricula with the European Qualifications Framework. The use of EQF provides transparency regarding qualification levels, supports mutual recognition of learning outcomes and facilitates progression between vocational education, higher education and continuous professional development.

Particular attention should be given to strengthening pathways between Lower VET (EQF 3–4), Higher VET (EQF 4–5), Vocational Bachelor programmes (EQF 5–6) and Advanced Professional Programmes (EQF 6–7), thereby promoting lifelong learning and career progression within the nuclear sector.

Recommendation 4. Develop a European Nuclearization Framework

The analysis undertaken within the present report demonstrates that the majority of occupations supporting the nuclear sector do not require full nuclear specialization but rather different degrees of sector-specific nuclear competencies. A European Nuclearization Framework should therefore be developed to define the minimum nuclear knowledge required for different occupational families according to their responsibilities and level of interaction with nuclear technologies.

The framework should classify occupations according to high, medium and low nuclearization levels and define the corresponding competence requirements, recommended training modules and expected learning outcomes. Such an approach would provide a consistent basis for curriculum development while avoiding unnecessary duplication of existing technical education programmes.

Recommendation 5. Develop Common European VET Curricula for Priority Occupational Families

The workforce analysis indicates that several occupational families experience similar competence requirements across Europe, irrespective of national educational systems. Common European curricula should therefore be developed for priority occupations including engineering technicians, instrumentation and control technicians, electrical technicians, maintenance specialists, welders, pipefitters, radiation protection technicians and digital professionals.

The curricula should be competence-based, modular and directly linked to occupational profiles defined through ESCO. At the same time, they should remain sufficiently flexible to accommodate national regulatory requirements and technology-specific adaptations. A harmonised curriculum framework would facilitate mutual recognition of qualifications and contribute to the development of a more integrated European nuclear labour market.

Recommendation 6. Develop Stackable Micro-Credentials Linked to ESCO Occupations

Micro-credentials should become a core component of the European Nuclear Skills Ecosystem. Rather than replacing existing qualifications, they should complement vocational and higher education programmes by providing targeted nuclear-specific competencies that can be accumulated progressively throughout an individual's career. Each micro-credential should be linked to specific ESCO occupations, competences and EQF levels, ensuring transparency, portability and recognition across Member States. Priority areas include nuclear

safety culture, radiation protection, nuclear quality assurance, outage management, configuration management, digital technologies, cybersecurity, SMR technologies and leadership in high-reliability organisations.

The use of stackable micro-credentials would significantly increase the flexibility of education and training provision while supporting rapid upskilling and reskilling in response to changing industrial needs.

Recommendation 7. Establish a European Train-the-Trainer Programme

One of the principal constraints affecting the expansion of vocational education is the limited availability of qualified trainers with both technical expertise and pedagogical competencies. A coordinated European Train-the-Trainer Program should therefore be established to increase the capacity of educational institutions and industrial training centers to deliver high-quality nuclear education.

The program should target vocational teachers, technical instructors, industry experts and university staff and should cover both modern teaching methodologies and emerging nuclear technologies. Special emphasis should be placed on workplace learning, simulator-based training, digital education tools, competence assessment and mentoring approaches. Strengthening the trainer community will be essential for scaling up education and training activities across Europe.

Recommendation 8. Establish Periodic European Nuclear Workforce Forecasting Exercises

Workforce planning should become a continuous rather than a one-off activity. Periodic European Nuclear Workforce Forecasting exercises should be organised at regular intervals to assess changes in workforce demand, occupational shortages, qualification needs and emerging competence requirements.

These assessments should integrate industrial investment plans, demographic trends, retirement projections, technology developments and educational

capacity. The results should directly inform future updates of VET curricula, higher education programmes, micro-credentials and workforce development policies, ensuring that education and training systems remain aligned with the evolving needs of the European nuclear sector.

The recommendations presented in this deliverable provide the foundation for a coordinated European approach to nuclear workforce development. Together, they establish a coherent framework that connects workforce intelligence, occupational classification, qualification frameworks and education and training provision into a single integrated system.

By combining the workforce forecasting principles developed through the MATCH methodology, the workforce intelligence generated by EHRO-N, the educational experience of ENEN2plus and the occupational analysis performed within Task 4.3, the proposed European Nuclear VET Architecture offers a scalable and future-oriented model capable of supporting the full spectrum of workforce needs associated with reactor operation, long-term operation, new build, SMRs, fuel cycle activities and decommissioning.

Its implementation would contribute to strengthening the resilience, mobility, competitiveness and long-term sustainability of the European nuclear workforce while supporting the strategic objectives of the European Union in relation to energy security, decarbonisation and technological leadership.

13. REFERENCES

[1] European Commission. *European Skills, Competences, Qualifications and Occupations (ESCO).* https://esco.ec.europa.eu

[2] European Commission. *European Qualifications Framework for Lifelong Learning (EQF).* Publications Office of the European Union.

[3] European Commission, Joint Research Centre (JRC). *European Human Resources Observatory for the Nuclear Energy Sector (EHRO-N).* Luxembourg.

[4] ENEN Association. *ENEN2plus Project – Deliverables and Final Results.* https://www.enen.eu

[5] ENEN2plus Deliverable D4.1. *Inventory and Gap Analysis of Existing Nuclear Education and Training Programmes.*

[6] GIFEN. *MATCH – Métiers et Compétences pour les Talents Humains de la filière nucléaire.* France.

[7] IAEA. *Systematic Approach to Training (SAT).* IAEA Nuclear Energy Series.

[8] IAEA. *Managing Human Resources in the Field of Nuclear Energy.* Nuclear Energy Series.

[9] IAEA. *Managing Nuclear Knowledge.* Nuclear Energy Series NG-T-6.

[10] World Association of Nuclear Operators (WANO). *Guidelines for Training and Qualification of Nuclear Personnel.*

[11] World Association of Nuclear Operators (WANO). *Performance Objectives and Criteria.*

[12] OECD Nuclear Energy Agency (NEA). *Nuclear Education, Skills and Technology.*

[13] OECD/NEA. *Building Capacity in Nuclear Education and Training.*

[14] European Commission. *Council Recommendation on a European Approach to Micro-credentials for Lifelong Learning and Employability (2022/C 243/02).*

[15] European Commission. *European Digital Credentials for Learning.*

[16] European Commission. *Council Recommendation on Vocational Education and Training for Sustainable Competitiveness, Social Fairness and Resilience (2020).*

[17] Cedefop. *Vocational Education and Training in Europe.*

[18] Euratom Research and Training Programme.

[19] European Commission. *European Nuclear Skills Academy Call.*

[20] Skills4Nuclear Project Consortium. *Task 4.3 Internal Analysis.*

[21] European Commission (2024). European Industrial Strategy for Nuclear Skills.

[22] IAEA Nuclear Energy Series NG-T-6.10 – Human Resource Development for Nuclear Power Programmes.
[23] OECD/NEA (2023). Meeting Future Nuclear Workforce Needs.
[24] Council Recommendation on Individual Learning Accounts (2022).
[25] Council Recommendation on Micro-credentials (2022).
[26] European Year of Skills documentation (2023–2024).
[27] European Commission, Joint Research Centre/EHRO-N, Putting into Perspective the Supply of and Demand for Nuclear Experts by 2020 within the EU-27 Nuclear Energy Sector, 2012.
[28] European Commission, Joint Research Centre, Top-down Workforce Demand Extrapolation from Nuclear Energy Scenarios, 2013.
[29] Midlands Nuclear, Midlands Nuclear Skills Study, 2025.
[30] European Commission, Joint Research Centre, Job Classification and Taxonomy in the Nuclear Sector, 2023.