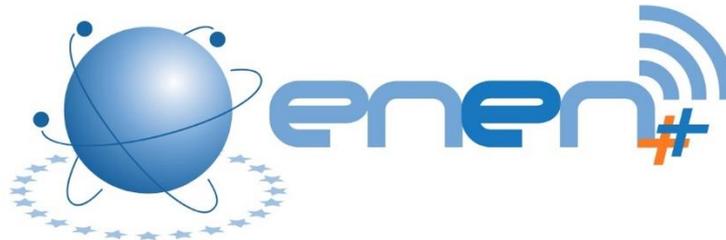




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EXECUTIVE SUMMARY

Nuclear power and non-power technologies are technically very complex facilities that operate in increasingly challenging regulatory frameworks and market conditions. The global nuclear industry faces many technical and political challenges but sourcing sufficient workers in due time with appropriate skills may be its biggest one, as the nuclear sector relies heavily on a specialized and highly trained workforce for its safety, security and sustainability. The nuclear industry sustains a greater share of highly skilled employees compared to the electricity sector in general.

With an expected increase in nuclear power capacity in Europe, particularly with the commitment of some Member States to 150 GW of nuclear installed capacity by 2050, there will be a strong demand for a highly qualified workforce. New build projects will require skilled personnel in addition to the needs of the existing fleet operations. Ensuring the availability of the right skilled workforce is crucial to avoid issues in new build projects, including delays and cost overruns.

Countries phasing out nuclear will also need a qualified workforce specializing in decommissioning. For all countries, including those phasing out nuclear activities, having a qualified workforce in regulatory aspects and waste management will be compulsory.

Regarding methodology, the Task Force 1.1 has faced some difficulties in obtaining precise data on the nuclear workforce through European-wide surveys, and even more to obtain forecast from relevant stakeholders at the 2035 time horizon. It is important to note that the responses received in the present study's survey covered eight countries (see Chapter 4), whereas the report aims to encompass the EU27+UK. This is the reason why extrapolations were used, and scenarios were introduced. The methodology should be improved in the future, for example regarding common jobs / skills description. It also appears that the categories used in the study do not pay enough attention to some critical skills and jobs (e.g. welders, etc.) that were grouped under an "other" category that ends up being too broad and general.

Regarding the quantitative outputs of the study, the tables below show, in thousands of employees within the perimeter of Task Force 1.1 (industry for nuclear energy), the orders of magnitude of the numbers of new recruitments needed for operations to replace retiring personnel and account for capacity expansions until 2035, in a rather conservative scenario assuming roughly ten new nuclear power plants (NPPs) to be built.

These numbers result from the synthesis of the full WP1 perimeter work conducted during the project, gathering data from surveys and other sources from literature reviews. Parameters of a simplified model have been adjusted to fit as far as possible results from the three Task Force reports. The Work Package 1 final report includes detailed comments on the limits of the results and suggestions for improvements in the methodology.

These tables underline the high sensitivity of final results to the value of the annual recruitment rate to replace retirements. The value usually considered in industry is 2.5%/year. Further demographic studies should be conducted to check this hypothesis in the specific case of the nuclear industry.

Task-Force	2023			Needed recruitments horizon 2035						
	Workforce			Retirement compensation			For growth			Total
	Direct jobs	Indirect jobs (supply chain)	Total Nuclear sector	Direct jobs	Indirect jobs (supply chain)	Sub-total	Direct jobs	Indirect jobs (supply chain)	Sub-total	
TF1.1	170	210	380	43	53	95	17	55	72	167

Hypothesis 2.5%/year recruitments for retirement compensation

Task-Force	2023			Needed recruitments horizon 2035						
	Workforce			Retirement compensation			For growth			Total
	Direct jobs	Indirect jobs (supply chain)	Total Nuclear sector	Direct jobs	Indirect jobs (supply chain)	Sub-total	Direct jobs	Indirect jobs (supply chain)	Sub-total	
TF1.1	170	210	380	34	42	76	17	55	72	148

Hypothesis 2.0%/year recruitments for retirement compensation

New recruitments needed in the EU27+UK nuclear energy industry (in thousands of jobs, horizon 2035)

It is projected that between 148,000 and 167,000 jobs will need to be recruited by 2035 in the nuclear industry in EU27+UK, 50,000 to 60,000 of those being direct jobs. When considering the full perimeter of Work Package 1, addressing the need to replace retiring workers and maintain the sector’s current capacity, it is projected that between 196,000 and 215,000 jobs will need to be recruited by 2035 in the EU27+UK, 77,000 to 86,000 of those being direct jobs. It appears therefore that the perimeter of Task Force 1.1 (industry) represents the largest contribution to the nuclear sector workforce in 2023 (380,000 out of 500,000 total direct and indirect jobs), as well as for 2035 forecast.

In terms of qualitative outputs, certain roles will be in high demand. Alongside the ongoing strong demand within the “other” category, which includes sought-after roles like welders and boilermakers, and project managers who emerge as the most highly sought-after positions. Additionally, there will be a need for process engineers, operators, and construction engineers. Furthermore, expertise in nuclear-specific areas such as radiation protection continues to be of utmost importance in the industry. Some roles, such as radiochemistry, process engineering, and reactor physics, are witnessing a potential decrease in demand according to the collected data.

Soft skills will also be in high demand in the future and will require education & training providers to adapt their curricula so that they can be both multidisciplinary and emphasise skills such as leadership, communication, problem-solving, to better fit with the industry’s and other stakeholders’ evolving needs.

In terms of summarized recommendations:

- Government policies and plans play a vital role in providing a clear and stable framework for the nuclear sector. By establishing long-term commitments to nuclear energy, governments provide the industry and its supply chain with the confidence needed to make strategic workforce decisions. Clear policies can outline expected future demand, the consideration of small modular reactors (SMRs), and the strategy for fuel cycle management

and waste disposal. This information enables stakeholders to anticipate workforce size, skill requirements, and training timelines.

- Promotion of National Nuclear Workforce Assessments (NWA) emerge as a crucial tool to comprehensively understand current and future human resource demands. The NWAs would enable the monitoring of available skills and competences, identification of potential gaps between supply and demand, and the formulation of an action plan with appropriate remedial measures. Such NWAs should then be streamlined at EU level and periodically updated.
- E&T providers are invited to introduce multidisciplinary curricula to better fit with the evolving needs of the industry. These multidisciplinary curricula should emphasize the integration of technical knowledge with a comprehensive understanding of the broader context in which the nuclear sector operates. In addition, nuclear awareness modules should be promoted in education curriculum and in vocational training and should begin as early as possible in the young people's education in order to make the nuclear sector more attractive.

The following recommendations directly relate to the industry's contributions:

- Systematically provide inputs to update national NWAs.
- Vocational education and training should be further harmonized at the international level in order to adapt to changes in the labour market.
- Preserving and disseminating knowledge within the industry should ensure the transfer of critical expertise and best practices, senior employees' expertise and know-how should be recognized as a key-asset.

Potential shortages in specific critical skills (welders, project managers, automation and control room operations, digital instrumentation and control, quality assurance, research and development, and planning in nuclear waste management, etc.) should be addressed through targeted recruitment, training, and retention strategies.

1 INTRODUCTION

1.1. WP1 General Introduction

Context

Nuclear power and non-power technologies are technically very complex facilities that operate in an increasingly challenging regulatory framework and difficult market conditions. In such a fast-changing world, the nuclear sector can be impacted by many different factors:

- Political change, socio economic situation, country by country,
- Public opinion perception, sensitivity to environment and climate change issues, impact of social media on public information, in particular when facts are wrong
- Energy context including, as the world experienced it painfully recently, a crisis impacting energy supply for EU countries,
- Innovation in technologies (renewables, SMR, etc.), digital transformation (smart grids, digital twins for construction activities, new applications for medical diagnostics and therapies, etc.) and artificial intelligence.

Among context factors which should be considered when analysing the consequences in terms of human resources needs in each specific country, they include:

- Background country by country with respect to nuclear science and technology: Is there already a nuclear history in the country (operation of nuclear power plants, research reactor operated locally, use of nuclear applications in medicine or in any other non-energetic nuclear application, etc.)? Are there structured and degree opportunities for students who wish to embark in the nuclear sector in the country's education system?
- Scenario for the future of nuclear in the energy mix of the country (number and size of nuclear power plants, opportunities to build SMRs, wish to develop a local nuclear value chain or rely on international cooperation including a "plug & light" contractual model, strategy regarding fuel cycle, and waste management, etc.).
- Other initiatives of large projects / energy infrastructures engaged in the country (or to be engaged soon) in other sectors (renewable energies for example) that may interfere (mutualisation or competition) with the nuclear sector in terms of needed skills and available HR on the labour market (identify tension areas for specific skills / skill levels), but also may be used as benchmark for the development of human resources for the nuclear sector.

Challenges

The scope of organizations and stakeholders that are involved in the analysis of HR needs is large. It is essential to keep as the main goal the achievement of a highly resilient organization of the HR capabilities assessment and preparation for the nuclear sector in EU. Consequently, the quantification process for HR needs is to be considered and managed as an iterative process, as well as the definition of HR development solutions. Only such an organization will be able to adapt to the changing environment, evolving needs of the sector, encompassing all stakeholders, while providing attractiveness and sustainable career solutions to the workforce embarked, especially to attract new

talent.

Workforce excellence, including in terms of soft skills, should remain the basic enabler of safe long-term operation of existing facilities and development of future advanced ones. It should be strongly emphasized that, while the focus is usually placed on experts, the nuclear sector does not require only nuclear specialists to be maintained and developed. Experience has shown that the technicians and semi-skilled personnel form a very large portion of the needed workforce.

As a compulsory first step, a skills assessment system should rely on a commonly established skills inventory and jobs / skills mapping using qualitative and quantitative non ambiguous criteria in terms of knowledge, know-how, behaviour, experience and employee turnover frequency. The level of detail can vary from one job to another depending on its sensitivity. Some work has been conducted especially by IAEA Technical Working Group on Training and Qualification of Nuclear Power Plant Personnel (see for instance 2006 publication¹ aiming to provide guidance on the development and implementation of competency assessments for nuclear industry personnel) but deserves to be updated. Moreover, efforts towards harmonization of skills assessment methodologies in the EU27+UK perimeter would be welcome to facilitate future studies on nuclear workforce assessment. Skills assessment system must also define skill levels and know-how needed at the local level for the various jobs and determine the assessment criteria to measure the skills of staff members. Rules and criteria should also need to be established in order to deliver certification / qualification to staff members and facilitate movements of staff members inside, between, and outside stakeholder organizations, thus contributing to people employability within the nuclear sector and more broadly to serve large projects in the country or abroad, especially among EU Member States. The European Qualifications Framework (EQF), as recommended by the Council Recommendation of 22 May 2017, serves as a vital tool for referencing and comparing national qualifications frameworks. In the end, such an analysis for anticipating HR needs (numbers, skills, timing, budget, etc.) and identifying gaps between needs and E&T local capabilities providing solutions might be considered as performing a risk analysis. Compiling the information at the EU level and establishing European wide recommendation (based on the national recommendation, rather than at a country-by-country level only, is clearly a way to minimize and mitigate these risks. It is also a path to consolidate both the EU's low carbon energy strategy, and EU leadership to face international nuclear technologies development opportunities.

1.2. Introduction to Task 1.1 Report on human resources needs in the nuclear industry up to 2035

The deliverable of Task-Force 1.1 aims to provide an overview of the current state of HR and skills in the nuclear sector, with a focus on the industry. The report's primary objective is to identify potential bottlenecks that could arise in the future, up to the year 2035, and recommend strategic planning to address these challenges proactively.

The goals to be reached include providing an overview of the existing HR situation in EU27 + UK, anticipating needs to 2035, providing a suitable level of details by job type according to documented job descriptions, performing a gap analysis between available HR and needs until 2035, and

¹ https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1236_web.pdf

providing recommendations to the industry, policy makers and E&T organizations in order to fill the gaps through the development of targeted actions. These actions will ensure that the sector can meet future demands and maintain its operational efficiency.

The deliverable will emphasize the importance of adequately addressing these different skill levels to ensure a well-rounded workforce capable of meeting the sector's requirements. In order to make results easier to interpret, the report divides the workforce into the following 4 categories (see details in chapter 2) in the often-used nuclear competence pyramid:

- Subject matter experts/domain experts
- Nuclear professionals
- Nuclearised professionals
- Nuclear-aware professionals.



By gaining a deep understanding of the current state of HR and skills in the nuclear sector, the report will provide valuable insights to industry leaders, but also to policymakers, and education institutions.

2 METHODOLOGY

The purpose of this deliverable is to provide an overview of the human resources (HR) situation within the nuclear industry, from front-end fuel cycle to back-end spent fuel management, including nuclear supply chains, with the aim of anticipating needs up until 2035.

The context of this deliverable is driven by the changing energy concerns in the European Union (EU), which will keep evolving in the near future. These concerns include climate change issues (commitments of EU to reduce CO₂ footprint), geopolitics (aiming to reduce EU dependence on imported fossil fuels and more generally to increase EU sovereignty/independence), political uncertainties with war at the frontiers of Europe, and a growing share of electricity in the energy mix (electric vehicles, industrial processes, green H₂, etc.), uncertainties such as pandemics. The public opinion regarding nuclear has also shifted in some countries, which has led to policy changes with announcements for ambitious nuclear new build plans. The development of renewables has

introduced tension on the work market in the EU for some skills, while some innovations (SMR, Gen IV, etc.) might disrupt existing business and impact HR needs in the near future. Long-term operation of existing reactors already decided in some countries might also impact HR needs. Given these changes, it is necessary to update previous studies and provide an up-to-date analysis of the HR situation within the nuclear industry, including dealing with the issue of turnover and replacing retirees. In the following sections, the methodology used to achieve these goals is explained.

The deliverable covers existing nuclear power plant (NPP) owner-operators (utilities), as well as companies in the supply chain, especially SMEs, specific components/subcomponents manufacturers, services providers (engineering, maintenance, digital tools, etc.), and integrators (e.g., engineering, procurement and construction management, civil works, etc., for new build). Other segments of the nuclear sector are covered by TF1.2 (research, regulatory agencies and technical safety organizations, waste management agencies or companies) and TF1.3 (non-energy applications including the medical sector, aeronautics, agriculture, etc. of WP1. By involving all relevant industry stakeholders, the deliverable aims to provide a comprehensive assessment of HR needs and address the challenges faced by the nuclear sector. In order to make results easier to interpret, industrial organizations considered in the deliverable have been categorized according to their activities in the following segments:

- Activity segment: utilities
- Activity segment: fuel fabrication, enrichment, supply, cycle
- Activity segment: design, engineering, manufacturing, and maintenance
- Activity segment: transport
- Activity segment: other

Constraints and limits were acknowledged at the outset of the project and were confirmed during the study development. Data access and quality were potential issues:

- The survey developed in collaboration between Task Forces 1.1 and 1.2 was circulated to the project partners and members of Nucleareurope. Replies to the survey was only received from eight countries (see chapter 4).
- The industrial perimeter of TF1.1, aims to cover the nuclear supply chain, including existing NPP owners/operators, fuel cycle from front end to back end (excluding waste management in the perimeter of TF 1.2), and specific components, subcomponents manufacturers and services providers. Despite having a broad network of potential contributors (Nucleareurope, etc.) to the TF 1.1, only a limited part of the entire sector could be reached directly.
- While direct jobs can be estimated with rather high accuracy, the number of indirect jobs has a higher margin of uncertainty due, among other factors, to variability in job roles within supply chains.
- For the organizations considered in the perimeter of the study, forecasting HR needs up to 2035 appears to be quite challenging.
- Confidentiality is a sensitive issue among the considered industrial perimeter. This is the reason why a disclaimer in the survey sent to all potential contributors (see Annex 1) stated that “the responses to the survey will be kept anonymous and the individual data collected will be kept confidential”. Nevertheless, the observed reluctance to provide data can be understood, considering the strategic value of HR issues.

It must be recognized that partial coverage raises questions about the representativeness of the data collected during the study and its applicability to the broader nuclear sector. To overcome these challenges, and achieve a more complete analysis, complementary approaches were implemented and combined for constructing the databases:

- A literature review was conducted to assess what information is available in the public domain, determine whether the results would differ significantly from those of previous reports, and identify new trends in the present context compared to previous reports.
- A survey (see Annex I for the template of the survey) was conducted to collect data as much as possible from stakeholders. The survey's content was prepared in collaboration with TF1.2, and the general description of skill categories was based on existing literature. The survey was sent to Nucleareurope's members, which includes utilities and companies involved in the fuel cycle (front-end and back-end with waste management covered in the TF1.2 deliverable of the project).
- Modelling was used as a complementary approach to surveying to account for potential gaps in the data, and existing models for HR in the operational phase of NPPs were adapted (references will be provided in following chapters).
- Different scenarios were introduced (details provided in chapter 5) to account for possible evolutions of HR needs for new NPP construction according to policy statements of different countries and the impact of innovative concepts such as small modular reactors (SMRs).

The data analysis process involved assessing the quality and representativity of collected data versus the entire EU industry perimeter theoretically covered, sorting data according to several criteria (country, type of industrial activity, type of job categories/skills, and evolution of forecasted needs over time), and adopting a reader-friendly representation of the results.

In the context of our analysis, skills are defined as the specific abilities and expertise possessed by an individual that enable them to effectively perform the core competencies and functional competencies required for a particular job. Jobs are aligned with EHRO-N's job classification², which means that several functions or functions with similar characteristics can be grouped under a common competence area/job type. This classification system allows for a more comprehensive and standardized approach to categorizing and understanding various roles within the nuclear sector.

The analysis and projections followed the nuclear competence categories described in the 2012 OECD-NEA report "*Nuclear Education and Training: From Concern to Capability*"³ that describes the various degrees of "nuclearisation" within the nuclear industry. The deliverable divides the workforce into the following 4 categories in the nuclear competence pyramid (see Figure 4 in Chapter 3):

a) Subject matter experts/domain experts

This is a small group of high-level experts at the top of the pyramid. These experts have developed their competence, in their specific disciplines, fundamentally through academic and professional training over a long period of practical experience (typically 10-20 years) and after significant immersion in the topic. The subject matter experts can both be within the nuclear field and in non-nuclear fields.

² Nuclear Job Taxonomy Final Report, A competence-oriented classification of jobs in nuclear power plants, Chenel Ramos, C., JRC Technical Report 2018

³ <https://www.oecd.org/publications/nuclear-education-and-training-9789264177604-en.htm>

b) Nuclear professionals

Nuclear professionals hold a specialised formal education in nuclear subjects (e.g., nuclear physics or engineering, radiochemistry, radiological protection, etc.). They are together with subject matter experts important for the research, development and design and employed throughout the sector leading to the safe operation of nuclear installations.

c) “Nuclearised” professionals

"Nuclearised" professionals typically possess formal education and training in relevant non-nuclear disciplines such as mechanical, electrical, chemical, civil engineering, project management, quality control, or welding. However, they often need to acquire additional knowledge of the nuclear environment to effectively apply their competencies within the sector.

d) “Nuclear-aware”

The "nuclear-aware" professionals, including electricians, mechanics, craftspeople, and support personnel, do not require an extensive nuclear knowledge. Instead, they will undergo specific nuclear training and receive tailored information that meets their needs.

Four "clusters" were identified to analyse the workforce for NPP operation:

- Reactor physics, safety, and security
- Nuclear technology, construction, and operation
- Chemistry and environment and decommissioning
- Other (support functions, procurement, administration, management system, etc.)

In addition, three categories of skills have been identified to draft, in a simplified approach, trends in the demand from collected data:

- General engineering
- Nuclear-specific
- Soft skills

3. CURRENT SITUATION

3.1 Literature review

3.1.1 Objectives

This literature review aims to provide an overview of the current situation in terms of Human Resources (HR) numbers and the types of skills required in the sector. The nuclear sector is a highly specialized and technical field, which requires unique skill sets. Thus, it is imperative to identify the current state of HR and skills in this sector to make informed recommendations and decisions regarding future needs. Let's keep in mind though that the largest number of professionals required are those that are "nuclear-aware", including electricians, mechanics, craftspeople, and support personnel.

This review will enable the identification of trends, disparities, and similarities between the findings of the modelling approach and survey responses received from companies. The report seeks to identify potential bottlenecks that could arise in the future and inform strategic planning for addressing them. By understanding the current state of HR and skills in the nuclear sector, the report will facilitate the development of targeted interventions to ensure the sector has the necessary HR and skill sets to meet future demands.

3.1.2 Background

The nuclear sector plays a significant role in the energy mix of the EU27+UK, especially when considering contribution to low-carbon electricity production (see Figure 2): nuclear plants provide almost half of the low-carbon electricity production in the EU.

There are currently 109 reactors (102 GWe) in operation within this perimeter, with the EU accounting for a quarter of the world's nuclear power production. In the UK, nuclear energy represented 14.2% of the country's electricity production in 2022⁴, while in the EU nuclear accounted for 24.57%⁵ (with high variability according to countries: from 0% to 74%) of the electricity production in 2020.

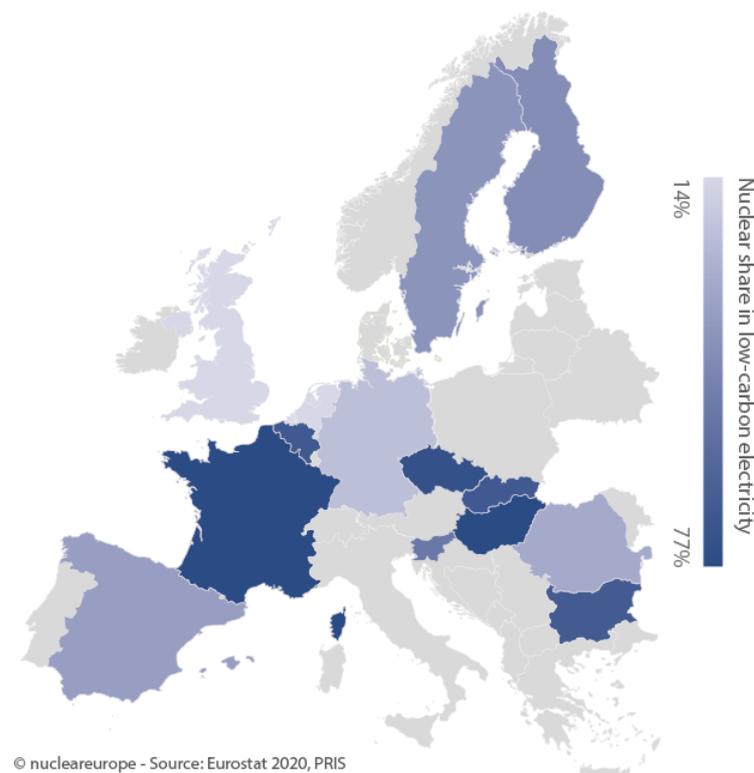


Figure 2: Share of nuclear in the electricity mix in 2020 (EU27+UK)

⁴ 'PRIS - Country Details', accessed 19 May 2023, <https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=GB>.

⁵ Directorate-General for Energy (European Commission), *EU Energy in Figures: Statistical Pocketbook 2022* (LU: Publications Office of the European Union, 2022), <https://data.europa.eu/doi/10.2833/334050>.

The nuclear sector is crucial in enabling energy security and decarbonization goals alongside renewables, providing a strong local supply chain in the EU27+UK and offering high-quality jobs located in Europe. However, the workforce required by the sector is highly specialized and technical, requiring specific knowledge of the sector's particularities and high regulatory standards.

The European nuclear sector is expected to see an increase in capacity in the coming decade, especially following the commitment of some Member States that nuclear power may provide up to 150 GW of electricity capacity in 2050⁶. With the existing fleet's continued operation and new build projects, there will be a strong demand for a highly qualified workforce. In addition, for the countries which have decided to phase out nuclear, there will be a continued demand for a qualified workforce with a specialisation in decommissioning⁷. In some of these countries, companies are contributing to the EU nuclear supply chain and might decide to maintain their activity for export in spite of their national context, therefore they will continue to contribute to HR and skills needs at the EU27+UK level.

Ensuring that the nuclear sector has the right people with the right skills at the right moment is crucial to avoid issues with new build projects, including delays and cost overruns. Avoiding shortages will allow the continuation of operations without tensions in some critical job areas. Additionally, being able to anticipate needs will lead to adapting training offers with sufficient anticipation, ensuring that they correspond to the current and future demands of the sector in terms of skills.

3.1.3 Literature overview

Workforce

The nuclear sector is a significant employer, generating over 1.1 million direct, indirect and induced jobs in the EU 27+UK⁸. These jobs are predominantly filled by highly skilled professionals, with more than half a million employees classified as such (Figure 3).

⁶ 'Nuclear Alliance Statement' (Ministry of Ecological Transition, 16 May 2023).

⁷ This is detailed in the ENEN2+ Work Package 1 Task 1.2 report

⁸ Deloitte, 'Economic and Social Impact Report' (Deloitte, 2019).

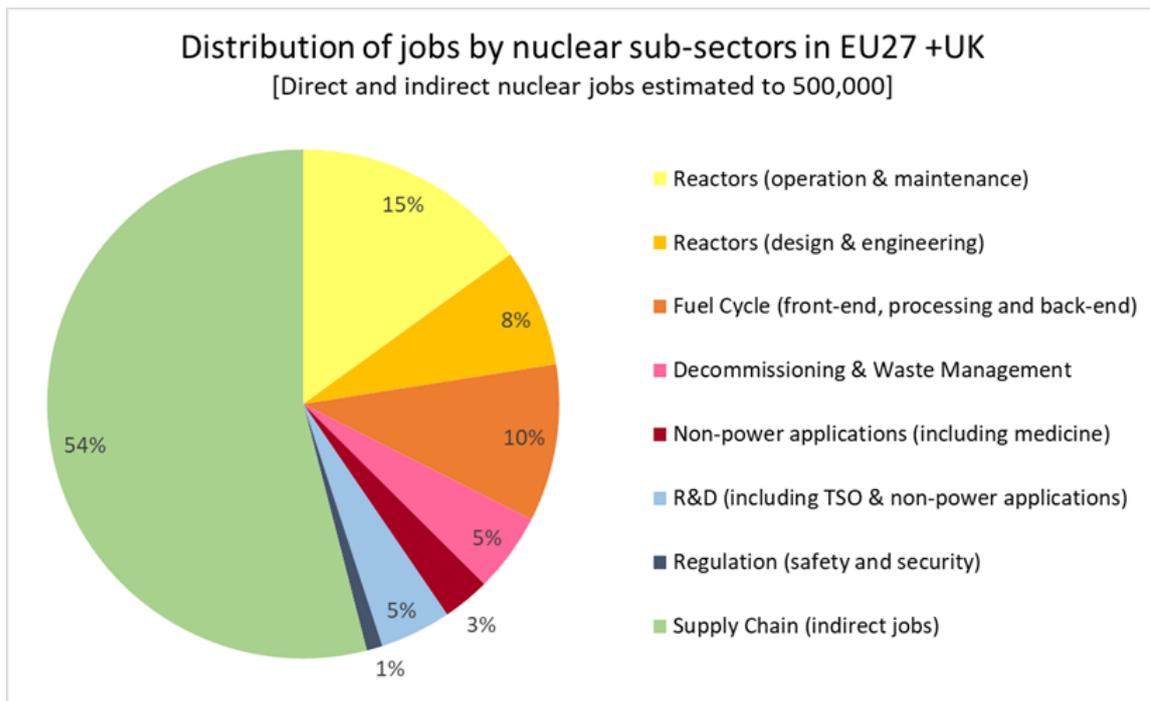


Figure 3: Estimated distribution of Nuclear Jobs (considered as highly skilled) in the EU27 and the United Kingdom in nuclear subsectors (from literature overview as detailed below)

Figure 3 shows the estimated workforce distribution in various sub-sectors of the nuclear industry for direct and indirect jobs. It highlights that the supply chains, which are also supporting other sub-sectors contribute a significant portion (more than half) of the workforce. This is essential when understanding the dynamics of the industry's workforce. While direct jobs can be estimated with greater accuracy, the number of indirect jobs has a higher margin of uncertainty. This uncertainty arises due to factors such as the complexity of tracing indirect employment, variability in job roles within supply chains, and the fluctuation of indirect job creation based on market conditions and project requirements. Recognising this uncertainty is crucial for understanding of the industry's workforce dynamics.

The workforce required in the nuclear sector is diverse and wide-ranging in terms of skills, reflecting the specialized nature of the industry and its high regulatory standards. The European Nuclear Education Network (ENEN)⁹ only lists 53 nuclear master programmes in the EU27+UK. In addition, several companies offer VET training. According to a survey conducted by EHRO-N¹⁰ in 2018, there were:

- On the E&T offer side 2167 nuclear graduates in 2017 (2833 in 2010) in the EU27+UK (the survey was sent to 90 higher education institutions which provide nuclear education nuclear at EQF 6 (BSc), EQF 7 (MSc) and EQF 8 (PhD) levels),
- On the demand side 7181 new students at EQF 6,7,8 levels enrolled in 2017-2018. (119 of the 308 invited nuclear organisations participated in the survey). Respondents reported a total of 16.119 nuclear staff of which 6.949 Nuclear Experts, 5.198 nuclearized STEM professionals and 3.972 nuclear administrative staff.

The discrepancy between supply side and demand side in these numbers could be explained by the assumption that some of the respondents provided the total number of graduated enrolled students rather than the specific number of students graduated in nuclear curricula in 2017-2018.

⁹ 'Nuclear Master Programmes – European Nuclear Education Network', 11 July 2023, <https://enen.eu/index.php/about-enen/nuclear-masters/>.

¹⁰ Brian Eriksen et al., 'Results of Surveys of the Supply of and Demand for Nuclear Experts within the EU-28 Civil Nuclear Energy Sector', JRC Publications Repository, 17 December 2019, <https://doi.org/10.2760/499847>.

Competition for talent within the sector and from other industries, such as the high-tech sector, poses recruitment challenges¹¹. As the European nuclear sector continues to expand¹², both through the operation of existing reactors and the construction of new ones, there is a growing demand for a highly qualified workforce.

Obtaining precise numbers and detailed data regarding the required workforce for operation of the current nuclear reactors in EU27 + UK is challenging. However, there have been some reports addressing the staffing requirements for nuclear power plant operation in recent years.

According to a 2013 EHRO-N report, a single one-gigawatt plant typically necessitates between 300-500 direct jobs for operation and maintenance. The following table provides the detailed distribution of jobs function/competence areas needed for operation of the nuclear power plants, and corresponding EQF qualification levels. The table is based on an IAEA report from 2022 which provides specific job categories and median staffing levels for a single unit. The median staffing numbers for the 43 different staff categories in the IAEA report has been mapped against the 23 job functions/competence areas used in the ENEN2+ survey, based on the EHRO-N classification as it results from more recent JRC work. The figure shows the results of this mapping.

Id.	Job function/competence area	EQF Level	Job distribution [%]
1. Chemistry and environment and decommissioning			
1	Nuclear waste management, decommissioning and dismantling (including R&D and planning)	6-8	2
2	Radiochemistry	6-8	1
3	Water chemistry (incl. corrosion)	6-8	few
2. Nuclear technology, construction, and operation			
4	Construction engineering	6-8	2
4b	Construction engineering	4-5	5
5	Electrical engineering	6-8	2
5b	Electrical engineering	4-5	5
6	Instrumentation and control	6-8	2
6b	Instrumentation and control (automation engineering)	4-5	5
7	Mechanics/mechanical engineering	6-8	2
7b	Mechanics/mechanical engineering	4-5	5
8	Nuclear fuel cycle (R&D, front end, reprocessing, and back-end)	6-8	1
9	Operators	6-8	13
10	Process engineering	6-8	6
10b	Process/chemistry engineering	4-5	1
11	Project management	6-8	1
12	Radiation protection	6-8	1
12b	Radiation protection	4-5	3
13	Reactor and hot lab operation	6-8	1
14	Quality management and inspections	6-8	1
3. Reactor Physics, safety, and security			

¹¹ Chiel Scholten, Veerle Bastiaanssen, Erwin Karsten and Geert van der Veen, 'De Arbeidsmarkt in de Nederlandse Nucleaire Sector. Nu En Verwachtingen Voor 2030/2035', September 2022.

¹² 'Nuclear Alliance Statement'.

15	Organisational and human factors	6-8	0-1
16	Materials science and engineering (nuclear facility materials, failures, component engineering, inspections and lifetime management)	6-8	2
17	Reactor physics and dynamics	6-8	0-1
18	Thermal hydraulics	6-8	0-1
19	Risk analysis (incl. Probabilistic Risk Assessment PRA)	6-8	1
20	Safeguards	6-8	0-1
21	Safety and security (business security and fire safety)	6-8	0-1
21b	Security	4-5	16
22	Severe accidents	6-8	1
4. Other (*)			
23	Others	6-8	13
23b	Others	4-5	11

Table 2: Distribution of individual job functions/competence areas for operation of nuclear power plants using the EHRO-N classification

A more recent OECD-NEA report from 2018 suggests an average of approximately 600 direct jobs for administrative, operational, maintenance, and permanent staff in a single unit nuclear power plant.

The IAEA has made available since a long time a lot of documents online especially dedicated to HR issues in so called “newcomer countries” embarking in building their first nuclear plant¹³. In a more recent one¹⁴, the median staffing levels based on 67 operating North American and European nuclear power plants were provided in an IAEA report from 2022. The report identifies the staffing levels to 732 jobs for a single unit and 506 jobs for a reactor in a double unit plant and further provides the median staffing numbers for 43 specific job categories.

IAEA15 also underlines a specificity in demographics aspects of HR in nuclear sector compared to other sectors: “[...] many of the current nuclear facilities were put in place in the 1970s and 1980s, and the following years saw very little growth in the industry. Thus, the age profile for these

¹³ Among others :

- - ‘Workforce Planning for New Nuclear Power Programmes’, Workforce Planning for New Nuclear Power Programmes (International Atomic Energy Agency, 2011), <https://www.iaea.org/publications/8488/workforce-planning-for-new-nuclear-power-programmes>
- - Managing Human Resources in the Field of Nuclear Energy, IAEA Nuclear Energy Series @ No. NG-G-2.1 (Rev. 1), 2023 https://www-pub.iaea.org/MTCD/Publications/PDF/PUB1958_web.pdf)
- - Commissioning of Nuclear Power Plants: Training and Human Resource Considerations, IAEA Nuclear Energy Series No. NG-T-2.2, IAEA, Vienna (2008)
- - Recruitment, Qualification and Training of Personnel for Nuclear Power Plants, IAEA Safety Standards Series No. NS-G-2.8, IAEA, Vienna (2002)
- - Nuclear Power Plant Personnel Training and Its Evaluation: A Guidebook, Technical Reports Series No. 380, IAEA, Vienna (1996).
- Assessing Behavioural Competencies of Employees in Nuclear Facilities, IAEA-TECDOC-1917, IAEA, Vienna (2020)
- The Nuclear Power Industry’s Ageing Workforce: Transfer of Knowledge to the Next Generation, IAEA-TECDOC-1399, IAEA, Vienna (2004).

¹⁴ Human Resource Management for New Nuclear Power Programmes IAEA Nuclear Energy Series Technical Reports Guides Objectives Basic Principles No. NG-T-3.10 (Rev. 1) 2022 https://www-pub.iaea.org/MTCD/Publications/PDF/PUB1933_web.pdf ,

¹⁵ Managing Human Resources in the Field of Nuclear Energy, IAEA Nuclear Energy Series No. NG-G-2.1 (Rev. 1), 2023 https://www-pub.iaea.org/MTCD/Publications/PDF/PUB1958_web.pdf

facilities is unusual, generally having an older workforce than other major industrial facilities. As many of these facilities are considering life extension up to 50 years or even beyond, this necessitates the replacement, in a relatively short period of time, of much of the experienced workforce. This situation presents particularly difficult challenges, including maintaining the safety and security culture of the organization and transferring knowledge to the next generation.”

In addition to these contributions from international organizations, various reports provide projections for the workforce demands in the nuclear sector at country level.

In France, the Match Programme, a dynamic management tool to ensure that the industry's capacities and needs are in line with its future challenges that includes a gap analysis and action plan. indicates that the civil nuclear workforce is estimated at 220.000 jobs of which 125.000 are direct jobs. The report predicts a 25% increase in workload over the next ten years, requiring approximately 60,000 new full-time equivalent (the Match study evaluates needs in FTE) hires in France, half for growth and half for retirements or movements¹⁶ to other sectors¹⁷, however, for some jobs, the demand is expected to increase much more (e.g. 220% for civil engineering). Most of this growth is expected in the supply chain, particularly due to the construction of EPR2 nuclear reactors, which may create an additional 55,000 jobs in France.

In the Netherlands, a 2022 study estimates that the sector supports 20.000 jobs needing nuclear knowledge and up to 400.000 jobs in organisations with a nuclear licence, with approximately 1,800 FTE employed within the narrow¹⁸ nuclear sector¹⁹. The study anticipates a short-term increase of 20% and a long-term increase of up to 30% in the number of employees in the country, driven by the realization of new medical isotope production facilities (Pallas and Shine) and the overall expansion of the sector. The authors also note the increasing competition not only with other sectors but also among nuclear organizations, which further complicates recruitment efforts.

In the UK, the Nuclear Skills Strategy Group undertakes a regular nuclear workforce assessment, which provides estimates for workforce needs in the UK. The 2021 report²⁰ indicated that the sector will need to recruit a cumulative total of 50,000 (baseline scenario without new build) to more than 100,000 (high scenario, see Annex II.12) FTEs up to 2040. According to a 2019 survey conducted by the Ministry of Economic Affairs and Employment in Finland, the demand for personnel in the Finnish nuclear sector is projected to reach 3,981 by 2030. This represents a 5% increase compared to the number of personnel in 2017²¹.

¹⁶ 'Global Energy Talent Index', 2023, <https://www.getireport.com/>. Page 68.

¹⁷ Gifen, 'Programme MATCH. L'outil de Pilotage de l'adéquation Besoins-Ressources de La Filière Nucléaire Pour Être Au Rendez-Vous de Ses Programmes', April 2023.

¹⁸ COVRA, EPZ, NRG, PALLAS, Reactor Instituut Delft, Urenco, SHINE and the ANVS (Nuclear Safety and Radiation Protection Authority) - "By the narrow nuclear sector, we mean the nuclear organisations represented in Nuclear Netherlands and the ANVS. The ANVS is the Nuclear Safety and Radiation Protection Authority, which ensures that nuclear safety and radiation protection in the Netherlands meet the highest standards. The organisations in the narrow nuclear sector exploit nuclear knowledge for their main activities."

¹⁹ Chiel Scholten, Veerle Bastiaanssen, Erwin Karsten and Geert van der Veen, 'De Arbeidsmarkt in de Nederlandse Nucleaire Sector. Nu En Verwachtingen Voor 2030/2035'.

²⁰ 'Nuclear Workforce Assessments | Nuclear Skills Strategy Group', accessed 19 May 2023, <https://www.nssguk.com/resources/nuclear-workforce-assessments/>.

²¹ Jari Hämäläinen and Vesa Suolanen, 'Survey of Competence in the Nuclear Energy Sector 2017–2018 in Finland', Serial publication (Ministry of Economic Affairs and Employment, 21 March 2019), <https://julkaisut.valtioneuvosto.fi/handle/10024/161464>.

Workforce planning for new nuclear power programmes indicates varying workforce needs depending on the phase and type of project. For a single unit, staffing ranges in orders of magnitude from 500-800 during operation, to several thousand during the construction phase²².

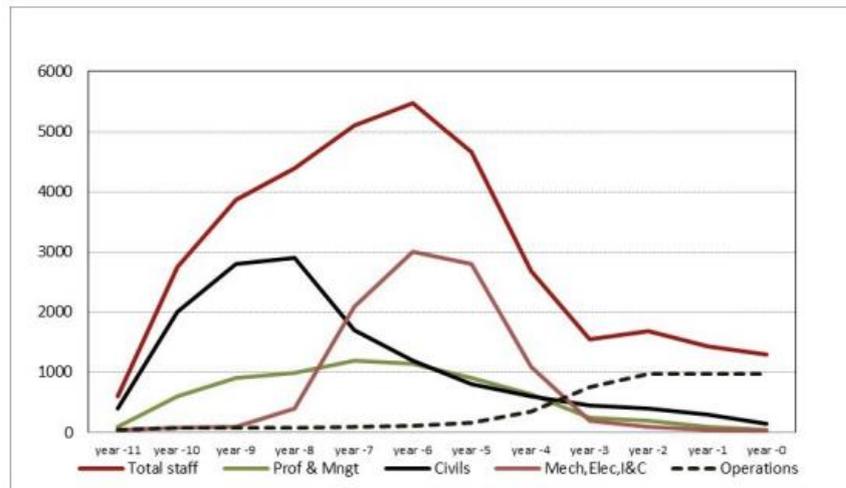


FIG. 12. Workforce for the HPC construction phase.

Figure 4: Example of HR needs during construction phase
(illustration from Nuclear Power Human Resources Modelling Tool Description and User Manual, IAEA TRAINING COURSE SERIES 73, 2021)

While the reports generally agree on the need for a highly skilled workforce and anticipate growth in the nuclear sector, there are some differences in the projected numbers. These differences can be attributed to varying methodologies, scenarios considered, and geographical focus within each report. In a recent report²³, EHRO-N has introduced a proposal for a streamlined job classification system aimed at effectively mapping the national nuclear workforce. The framework organizes the nuclear workforce into 23 distinct job categories or competence areas. The approach aims to promote a simplified mapping tool, while enhancing collection of European wide data.

While the projected numbers vary, the reports generally foresee an increased need in terms of workforce, which ranges from 20 to 30% within the next 10 years. They collectively highlight the need for a robust and skilled workforce in the nuclear sector. In addition, they provide valuable insights into the current state of HR and skills, enabling informed decision-making, strategic planning, and the development of targeted interventions to meet future demands in the nuclear sector.

The reports from the literature review also emphasize the importance of addressing recruitment and attractivity challenges and ensuring an adequate supply of skilled professionals to mitigate potential issues such as project delays, cost overruns, and operational tensions²⁴. Anticipating

²² Ferry Roelofs and ESTORFF Ulrik Von, 'Top Down Workforce Demand from Energy Scenarios: Influence of Long Term Operation', JRC Publications Repository, 7 April 2015, <https://publications.jrc.ec.europa.eu/repository/handle/JRC95213>.

²³ EHRO-N report not yet published

²⁴ Eriksen et al., 'Results of Surveys of the Supply of and Demand for Nuclear Experts within the EU-28 Civil Nuclear Energy Sector', 17 December 2019.

future needs and adapting training programmes are crucial to aligning skill sets with the evolving demands of the nuclear industry.

Tools for skills management

Various organizations have implemented strategies to provide training and education in the nuclear sector, ensuring a skilled workforce for the industry's sustainable growth. The European Qualifications Framework (EQF), as recommended by the Council Recommendation of 22 May 2017, serves as a vital tool for referencing and comparing national qualifications frameworks or systems²⁵. It facilitates the alignment of qualifications across European member states, ensuring compatibility and compliance with quality assurance principles. Vocational education and training is also a tool that was proposed by the by the conclusions of the European Council in 2020 (which define key principles for ensuring that vocational education and training is agile in that it adapts swiftly to labour market needs and provides quality learning opportunities for young people and adults alike. It places a strong focus on the increased flexibility of vocational education and training, reinforced opportunities for work-based learning and apprenticeships and improved quality assurance.). This tool should be further utilised and harmonized to adapt to changes in the labour market²⁶.

In addition to education and training, effective knowledge management is crucial for the long-term success of the nuclear industry. Preserving and disseminating knowledge within the industry ensures the transfer of critical expertise and best practices. The French Presidency's report (2022) emphasizes the significance of knowledge management strategies in the nuclear field²⁷. These strategies involve capturing and preserving institutional knowledge, leveraging advanced technologies for knowledge sharing, tutoring/mentoring and developing mechanisms for continuous learning and improvement.

The Nuclear Job Taxonomy, developed to classify jobs in nuclear power plants, provides a competence-oriented framework for education and training²⁸. By defining job positions and their associated functions and requirements, the taxonomy serves as a valuable resource for designing job-oriented qualifications. This supports targeted skills development initiatives and facilitates the design of tailored learning processes for specific positions and employees. This approach is complemented by the varying degrees of nuclearization within the nuclear industry, as described by the OECD-NEA²⁹, which categorizes the workforce into the following categories (see Figure 4 below):

- Subject matter experts/domain experts

²⁵ 'Council Recommendation of 22 May 2017 on the European Qualifications Framework for Lifelong Learning and Repealing the Recommendation of the European Parliament and of the Council of 23 April 2008 on the Establishment of the European Qualifications Framework for Lifelong Learning', n.d.

²⁶ 'Council Recommendation of 24 November 2020 on Vocational Education and Training (VET) for Sustainable Competitiveness, Social Fairness and Resilience 2020/C 417/01' (2020), <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32020H1202%2801%29>.

²⁷ French Presidency European Council, 'Rapport de la présidence "Pour une dynamique européenne des compétences dans le domaine nucléaire"', 7 June 2022. <https://data.consilium.europa.eu/doc/document/ST-9799-2022-INIT/fr/pdf>

²⁸ RAMOS Rafael Chenel, 'Nuclear Job Taxonomy-Final Report. A Competence-Oriented Classification of Jobs in Nuclear Power Plants', JRC Publications Repository, 14 March 2018, <https://doi.org/10.2760/090414>.

²⁹ 'Nuclear Education and Training: From Concern to Capability' (OECD-NEA, 2012), <https://www.oecd.org/publications/nuclear-education-and-training-9789264177604-en.htm>.

- Nuclear professionals
- Nuclearized professionals
- Nuclear-aware professionals

As illustrated in Figure 4, experts represent only a limited part of the workforce needed. This observation has to be considered with high attention when designing the future education & training offer. It also induces consequences in terms of competition between employment sectors, as Nuclearized or Nuclear-aware professionals might easily be attracted during their careers by non-nuclear companies or organizations. Their experience, technical expertise, as well as the acquired soft skills developed to cope with the high level of excellence required in the nuclear sector, will be considered as added value on their resumes.

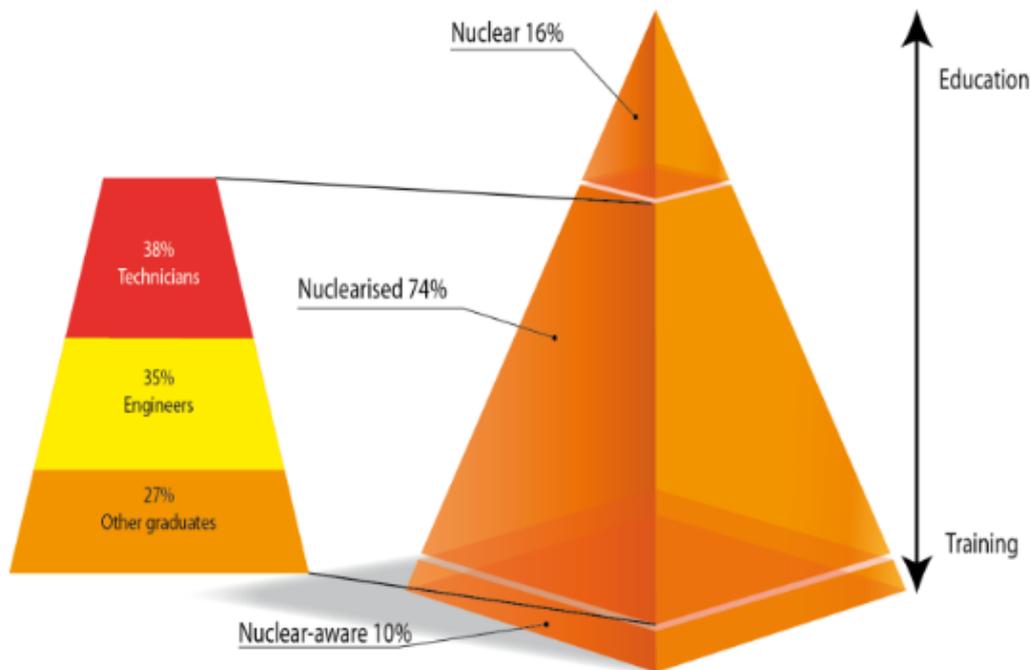


Figure 4: Nuclear Skills Pyramid (Simonovska & Von Estorff, 2012)³⁰

3.1.3.1 Skills needs

The demand for skilled personnel in the nuclear sector is influenced by various factors. The report "The Labour Market in the Dutch Nuclear Sector Now and Expectations for 2030/2035" highlights the need for technical staff with different educational backgrounds, such as MBO (vocational upper secondary education, EQF level 4), HBO (higher vocational education, EQF level 6), and WO (university education, EQF level 7-8)³¹. These staff members are sought after for roles such as operators, operations managers, technicians, and nuclear staff. Anticipating policy changes, the report also indicates an increasing need for WO-educated personnel with a nuclear and technical background.

According to the Finnish survey³², the current supply of experts with bachelor degrees and secondary-level vocational qualifications is expected to meet the demand adequately in Finland.

³⁰ Roelofs and Von, "Top Down Workforce Demand from Energy Scenarios".

³¹ Chiel Scholten, Veerle Bastiaanssen, Erwin Karsten and Geert van der Veen, 'De Arbeidsmarkt in de Nederlandse Nucleaire Sector. Nu En Verwachtingen Voor 2030/2035'.

³² Hämäläinen and Suolainen, 'Survey of Competence in the Nuclear Energy Sector 2017-2018 in Finland'.

However, there is a need for an additional workforce consisting of master's degree-holders. It is estimated that the number of individuals with a master's degree should increase by 190, representing a 10% growth compared to the current level. Looking ahead, the highest demand for experts holding a master's degree is anticipated in specific areas, such as R&D and planning in nuclear waste management, project management, electrical engineering, and process engineering.

Furthermore, the Deloitte report from 2019 indicates that the nuclear industry sustains a greater share of highly skilled employees compared to the electricity sector³³; demonstrating the industry's reliance on a skilled workforce³⁴. To meet the projected employment needs, the industry must take proactive measures to recruit and retain skilled employees, such as resource development, training programme adaptation, and improvements in working conditions³⁵.

Despite the demand for skilled workers in the nuclear sector, there are instances of skill shortages and a need for individuals with rare skills. Reports indicate shortages in specific roles such as project managers, digital instrumentation and controls experts, licensing specialists, and quality assurance professionals³⁶. Other areas mentioned include R&D and planning in nuclear waste management, nuclear and particle physics, automation and control room operations, electrical engineering, process engineering, and operator duties³⁷. Addressing these shortages requires a proactive approach from the industry, including targeted recruitment, training, retention strategies and knowledge management strategy to ensure the availability of a competent workforce. The IAEA³⁸ insists on the inter-relations between these different tools which have to be implemented by industry in a global approach: "Knowledge management is closely aligned with workforce planning and succession and talent management. When an organization identifies that it will lose key skills (e.g. retirements), sufficient lead time is required to allow for recruitment, training and knowledge transfer."

³³ 47% in the nuclear industry, 25-36% in the rest of the electricity sector according to Deloitte.

³⁴ Deloitte, 'Economic and Social Impact Report'.

³⁵ Gifen, 'Programme MATCH. L'outil de pilotage de l'adéquation besoins-ressources de la filière nucléaire pour être au rendez-vous de ses programmes'.

³⁶ Nucnet, 'Nuclear Workforce / Industry "Must Start Preparing Now" For Future Job Shortages :: NucNet | The Independent Nuclear News Agency', The Independent Global Nuclear News Agency, 14 September 2021, <https://www.nucnet.org/news/industry-must-start-preparing-now-for-future-jobs-shortages-12-3-2022>.

³⁷ Hämäläinen and Suolainen, 'Survey of Competence in the Nuclear Energy Sector 2017–2018 in Finland'.

³⁸ Managing Human Resources in the Field of Nuclear Energy, IAEA Nuclear Energy Series No. NG-G-2.1 (Rev. 1), 2023 https://www-pub.iaea.org/MTCD/Publications/PDF/PUB1958_web.pdf

3.1.4 Conclusion of the literature review

In conclusion, the literature review highlights the crucial role played by the nuclear sector in the energy mix of the EU27+UK, helping achieve decarbonisation goals alongside renewables, and offering high-quality jobs. The reports collectively highlight the need for a robust and skilled workforce in the nuclear sector and provide valuable insights into the current state of HR and skills, enabling informed decision-making, strategic planning, and the development of targeted interventions to meet future demands in the nuclear sector.

However, part of the workforce required by the sector is highly specialized and technical, posing recruitment challenges, which requires anticipating future needs and adapting training programmes.

Attractiveness of the nuclear sector in competition with other industrial activities, including other energy sectors under rapid development such as renewables, is also a challenge. The review also emphasizes the importance of effective knowledge management strategies in the nuclear field, ensuring the transfer of critical expertise and best practices.

However, it should be noted that obtaining precise EU-level data for the nuclear workforce appears very challenging due to the low level of participation in European-wide surveys (such as those conducted by EHRO-N or ENEN2+).

The methodologies employed up until now to assess the workforce and future needs of the nuclear industry will deserve some assessment and improvements. Recommendations will be provided in the framework of WP1 final report, both at national and at EU levels.

3.2 National Nuclear Policy / Plans until 2035

3.2.1 Long-term operation

Several countries intend to keep nuclear as part of their national energy mix, with the extension of the lifetime of their current nuclear fleet planned. Other countries intend to extend the lifetime of their nuclear fleet while in addition building new reactors for additional capacity.

- Belgium doesn't have any plans to build new nuclear capacity, but it is currently discussing the future of its nuclear fleet, with the government extending the operational lifespan of Doel 4 and Tihange 3 until 2035, despite previous commitments to phase out nuclear energy by 2025³⁹.
- In Bulgaria, units 5 and 6 of Kozloduy are being extended to run for up to 60 years⁴⁰.

³⁹ Nucnet, 'Belgium Considering Extensions For Three Nuclear Power Plants :: NucNet | The Independent Nuclear News Agency', The Independent Global Nuclear News Agency, 30 January 2023, <https://www.nucnet.org/news/government-considering-extensions-for-three-nuclear-power-plants-2-2-2023>.

⁴⁰ 'IAEA Concludes Long Term Operational Safety Review of Bulgaria's Kozloduy Nuclear Power Plant', Text (IAEA, 16 July 2021), <https://www.iaea.org/newscenter/pressreleases/iaea-concludes-long-term-operational-safety-review-of-bulgarias-kozloduy-nuclear-power-plant>.

- In the Czech Republic, the Dukovany and Temelin plants have undergone uprating and are licensed for continued operation indefinitely, with a recent investment of around US\$100 million in Dukovany to extend the plant's operational lifetime to 60 years (until 2047)⁴¹.
- In Croatia and Slovenia, the Krško nuclear power plant was granted a lifetime extension, allowing it to operate until 2043⁴².
- In Finland, the Loviisa plant has been granted a license to operate until 2050⁴³, while the Olkiluoto 1 and 2 units have had their operating licenses extended until 2038⁴⁴.
- In France, the *Grand Carénage* programme is ongoing to extend the lifetime of the current nuclear fleet⁴⁵.
- Hungary's Paks nuclear power plant has undergone feasibility studies to extend its operational lifetime by up to 50 years, and all four reactors have received permission to operate for additional years⁴⁶.
- The Netherlands is looking into extending the lifetime of Borssele beyond 2033⁴⁷.
- Romania is seeking a lifetime extension of Cernavoda unit 1 to allow it to run until 2060⁴⁸.
- In Slovakia, there are plans to extend the licenses of units 3 and 4 at the Bohunice plant to 2045⁴⁹.

3.2.2 New-build

Several countries in Europe are either planning to build new nuclear power plants or considering the deployment of small modular reactors (SMRs) to meet their growing energy needs.

- Bulgaria's energy strategy includes plans for two new reactors at Kozloduy, and two new reactors at Belene⁵⁰. In addition, Bulgarian Energy Holding has signed an agreement with

⁴¹ Nucnet, 'Czech Republic / ČEZ Plans Further Investment in Long-Term Operation of Dukovany Reactors: NucNet | The Independent Nuclear News Agency', The Independent Global Nuclear News Agency, 18 March 2022, <https://www.nucnet.org/news/cez-plans-investment-in-long-term-operation-of-dukovany-reactors-2-5-2023>.

⁴² 'IAEA Concludes Long-Term Operational Safety Review of Slovenia's Krško Nuclear Power Plant', Text (IAEA, 15 October 2021), <https://www.iaea.org/newscenter/pressreleases/iaea-concludes-long-term-operational-safety-review-of-slovenias-krsko-nuclear-power-plant>.

⁴³ 'The Finnish Government Has Granted a New Operating Licence for Fortum's Loviisa Nuclear Power Plant', Fortum, accessed 19 May 2023, <https://www.fortum.com/media/2023/02/finnish-government-has-granted-new-operating-licence-fortums-loviisa-nuclear-power-plant>.

⁴⁴ 'Finland's TVO Gets New 20-Year License for Olkiluoto 1 and 2 Nuclear Units', *Reuters*, 20 September 2018, sec. Commodities News, <https://www.reuters.com/article/finland-nuclear-tvo-idAFL8N1W631F>.

⁴⁵ 'La R&D et le Grand carénage | EDF FR', 17 February 2022, <https://www.edf.fr/groupe-edf/inventer-l-avenir-de-l-energie/r-d-un-savoir-faire-mondial/toutes-les-actualites-de-la-r-d/la-r-d-et-le-grand-carenage>.

⁴⁶ 'Hungary | ENSREG', accessed 19 May 2023, <https://www.ensreg.eu/country-profile/Hungary>.

⁴⁷ Nucnet, 'Netherlands / IAEA Completes Safety Review at Borssele Nuclear Station: NucNet | The Independent Nuclear News Agency', The Independent Global Nuclear News Agency, 23 January 2023, <https://www.nucnet.org/news/iaea-completes-safety-review-at-borssele-nuclear-station-2-5-2023>.

⁴⁸ 'IAEA Concludes Long-Term Operational Safety Review of Romania's Cernavoda Nuclear Power Plant', Text (IAEA, 19 February 2020), <https://www.iaea.org/newscenter/pressreleases/iaea-concludes-long-term-operational-safety-review-of-romanias-cernavoda-nuclear-power-plant>.

⁴⁹ 'Nuclear Power in Slovakia | Slovakia Nuclear Energy - World Nuclear Association', accessed 19 May 2023, <https://world-nuclear.org/information-library/country-profiles/countries-o-s/slovakia.aspx>.

⁵⁰ 'Bulgaria Energy Strategy Includes Four New Nuclear Reactors : New Nuclear - World Nuclear News', accessed 19 May 2023, <https://www.world-nuclear-news.org/Articles/Bulgaria-sets-out-plans-for-four-new-nuclear-react>.

the company Fluor to investigate the feasibility of replacing coal plants with iPWR SMRs from NuScale⁵¹.

- The Czech Republic has announced plans to build two new 1200 MWe units, Dukovany units 5&6, which are expected to be operational by 2036, and is also considering building Temelin Units 3&4⁵². The country is also exploring various SMR technologies, with a reserved area of land on the Temelin site announced in 2022 for the first SMR⁵³.
- Estonia is considering building its first nuclear power plant by 2035, with Fermi Energia choosing GE Hitachi Nuclear Energy's BWRX-300 SMR technology for deployment in Estonia, subject to regulatory approval⁵⁴.
- Finland is planning to build SMRs for electricity and other applications, with the government currently revising its Nuclear Energy Act to incorporate a legislative framework for SMRs⁵⁵.
- France has ambitious plans to construct up to 14 new reactors by 2035 (six are planned after validation in the Parliament on 16 May 2023, and eight additional reactors are under study, in addition to maintaining its existing reactors, as part of the country's long-term energy strategy aimed at meeting energy needs and reducing carbon emissions. The country is also aiming to build SMRs⁵⁶.
- Hungary is planning to construct two new units, referred to as Paks II, to maintain the capacity of the Paks nuclear power plant and meet future electricity demand. The project was awarded to Rosatom for two VVER-1200 reactors, to be operational in 2032. Despite economic sanctions against Russian companies, the project is proceeding, with the construction license issued in August 2022⁵⁷.
- Italy could potentially look at building new nuclear in the country, including with the SMR option⁵⁸.

⁵¹ 'Bulgaria Enlists Fluor and NuScale : New Nuclear - World Nuclear News', accessed 19 May 2023, <https://www.world-nuclear-news.org/Articles/Bulgaria-enlists-Fluor-and-NuScale>.

⁵² 'France's EDF in the Running to Build New Czech Nuclear Plant', www.euractiv.com, 1 December 2022, <https://www.euractiv.com/section/energy/news/frances-edf-in-the-running-to-build-new-czech-nuclear-plant/>.

⁵³ 'Czech Republic's First SMR Could Be Built at Temelin by 2032 - Nuclear Engineering International', accessed 19 May 2023, <https://www.neimagazine.com/news/newsczech-republics-first-smr-could-be-built-at-temeln-by-2032-10025944>.

⁵⁴ 'Fermi Energia Chooses GE Hitachi's BWRX-300 as the Technology for Planned SMR Nuclear Power Plant in Estonia', Fermi Energia, accessed 19 May 2023, <https://fermi.ee/en/fermi-energia-chooses-ge-hitachis-bwrx-300-as-the-technology-for-planned-smr-nuclear-power-plant-in-estonia/>.

⁵⁵ 'Finland to Reform Nuclear Energy Act - Nuclear Engineering International', accessed 19 May 2023, <https://www.neimagazine.com/news/newsfinland-to-reform-nuclear-energy-act-9316926>.

⁵⁶ Nucnet, 'France / Macron Announces Ambitious Plans For Up To 14 New Nuclear Reactors :: NucNet | The Independent Nuclear News Agency', The Independent Global Nuclear News Agency, 10 November 2021, <https://www.nucnet.org/news/macron-announces-ambitious-plans-for-up-to-14-new-nuclear-reactors-2-4-2022>.

⁵⁷ Nucnet, 'Hungary / Regulator Approves €12.5 Billion Construction Of Two Russian Nuclear Reactors At Paks 2 :: NucNet | The Independent Nuclear News Agency', The Independent Global Nuclear News Agency, 1 July 2022, <https://www.nucnet.org/news/regulator-approves-construction-of-two-russian-nuclear-reactors-at-paks-2-8-5-2022>.

⁵⁸ 'Italy Takes Another Step toward New Nuclear Plants', *Le Monde.Fr*, 11 May 2023, https://www.lemonde.fr/en/economy/article/2023/05/11/italy-takes-another-step-toward-new-nuclear-plants_6026291_19.html.

- The Netherlands is taking steps to build two new nuclear power stations, which would provide 9-13% of the country's electricity production in 2035⁵⁹. The country is also exploring the potential of deploying SMRs in the province of Limburg⁶⁰.
- Poland is planning to commission its first nuclear power reactor in 2033, followed by subsequent units, with an investment of PLN 140 billion (about USD 40 billion). The Polish Nuclear Programme (2014) has announced a plan to build nuclear plants with 6 GWe total capacity, revised in 2018 at 6-10 GWe, with first operational unit in 2033, and finalization of the investment in 2043⁶¹. In addition, the country aims to build SMRs⁶².
- Romania is planning to build two new reactors at Cernavoda NPP, units 3&4, each with a capacity of 720 MWe. The project is expected to be operational by 2030 and is aimed at replacing the old coal-fired plants⁶³. In addition, the country is exploring the possibility of deploying SMRs⁶⁴.
- Slovakia is considering the possibility of building a new unit at Bohunice⁶⁵. The plan is to apply for a construction licence at the end of 2025 with construction work foreseen to start in 2031.
- Slovenia is considering the construction of a second nuclear power plant to meet its growing energy needs⁶⁶.
- Sweden is planning to replace its aging nuclear reactors with new ones to maintain its nuclear power capacity⁶⁷, with Vattenfall considering deploying SMRs in the country⁶⁸.
- The United Kingdom is currently constructing Hinkley Point C, the country's first new nuclear power plant in over 20 years, with a capacity of 3.2 GW. In addition, the country is

⁵⁹ 'Borssele Earmarked for Two New Reactors : New Nuclear - World Nuclear News', accessed 19 May 2023, <https://world-nuclear-news.org/Articles/Borssele-earmarked-for-two-new-reactors>.

⁶⁰ Nucnet, 'Netherlands / Province Of Limburg To Look At SMRs For Industry :: NucNet | The Independent Nuclear News Agency', The Independent Global Nuclear News Agency, 12 December 2022, <https://www.nucnet.org/news/province-of-limburg-to-look-at-smrs-for-industry-3-5-2023>.

⁶¹ Mihajlo Vujasin, 'Poland to Build Three Nuclear Power Plants', Balkan Green Energy News, 1 November 2022, <https://balkangreenenergynews.com/poland-to-build-three-nuclear-power-plants/>.

⁶² 'Polish Plans for Large and Small Reactors Progress : New Nuclear - World Nuclear News', accessed 19 May 2023, <https://www.world-nuclear-news.org/Articles/Polish-plans-for-large-and-small-reactors-progress>.

⁶³ Nucnet, 'Romania / Government Adopts Draft Law On Cernavodă New-Build Plans :: NucNet | The Independent Nuclear News Agency', The Independent Global Nuclear News Agency, 24 July 2020, <https://www.nucnet.org/news/government-adopts-draft-law-on-cernavoda-new-build-plans-12-2-2022>.

⁶⁴ 'NuScale Marks SMR Progress in USA, Romania : New Nuclear - World Nuclear News', accessed 19 May 2023, <https://www.world-nuclear-news.org/Articles/NuScale-marks-SMR-progress-in-USA,-Romania>.

⁶⁵ 'Siting Permit Requested for New Slovak Plant : New Nuclear - World Nuclear News', accessed 19 May 2023, <https://www.world-nuclear-news.org/Articles/Siting-permit-requested-for-new-Slovak-plant>.

⁶⁶ Nucnet, 'Krško / Slovenia To Take Investment Decision On New Unit By 2027, Say Reports :: NucNet | The Independent Nuclear News Agency', The Independent Global Nuclear News Agency, 19 October 2021, <https://www.nucnet.org/news/slovenia-to-take-investment-decision-on-new-unit-by-2027-say-reports-12-4-2021>.

⁶⁷ 'Swedish Government Frees up Legislation on Nuclear Expansion', www.euractiv.com, 12 January 2023, <https://www.euractiv.com/section/politics/news/swedish-government-frees-up-legislation-on-nuclear-expansion/>.

⁶⁸ Nucnet, 'Sweden / Vattenfall Interested In SMRs Because They Offer "Much More Than Just Electricity" :: NucNet | The Independent Nuclear News Agency', The Independent Global Nuclear News Agency, 12 January 2023, <https://www.nucnet.org/news/vattenfall-interested-in-smrs-because-they-offer-much-more-than-just-electricity-3-2-2023>.

considering building eight new reactors⁶⁹ and is also considering the deployment of SMRs to meet its energy needs⁷⁰.

The perspective of nuclear new builds remains subject to uncertainties due to political and economic evolutions in each country. The schedule of the various projects might also be subject to uncertainties. Nevertheless, it deserves attention in terms of HR needs. This is the reason why several scenarios for new nuclear plants in the EU27+UK will be introduced in chapter 5 of this report.

3.2.3 Decommissioning

Germany, Italy, Lithuania,⁷¹ and Spain share the common goal of decommissioning their nuclear power plants in the long term. In Germany, three operating reactors were shut down in April 2023, and a total of 26 reactors are undergoing decommissioning⁷².

- Italy has already announced the decommissioning of all nuclear facilities in the country⁷³.
- Spain has a plan to reduce installed nuclear capacity from 2030 onwards⁷⁴. The responsibility for decommissioning rests with the respective licensees or national agencies, such as Enresa in Spain.
- Belgium will be decommissioning some of its reactors. Indeed, the government announced plans to permanently shut down two older reactors – Doel 1 and Doel 2⁷⁵.
- In the UK, the Nuclear Decommissioning Authority (NDA) has a programme of work to clean-up and decommission the UK's fleet of legacy reactors and facilities across 17 sites. The NDA estate directly employs over 15,000 people and engages with an extensive supply chain of large Tier 2 contractors and SMEs.
- In France, the Fessenheim plant's two reactors are permanently shut down and will be decommissioned/dismantled once all the spent fuel is removed.

⁶⁹ 'Energy Strategy: UK Plans Eight New Nuclear Reactors to Boost Production', *BBC News*, 6 April 2022, sec. Business, <https://www.bbc.com/news/business-61010605>.

⁷⁰ 'UK Launches Funding to Encourage Nuclear New Build : Nuclear Policies - World Nuclear News', accessed 19 May 2023, <https://www.world-nuclear-news.org/Articles/UK-launches-funding-to-encourage-nuclear-new-build>.

⁷¹ Central Office Belgium NucNet a s b l, Brussels, 'Lithuania / Consortium Chosen to Plan Dismantling and Waste Management at Ignalina: NucNet | The Independent Nuclear News Agency', The Independent Global Nuclear News Agency, 21 April 2022, <https://www.nucnet.org/news/consortium-chosen-to-plan-dismantling-and-waste-management-at-ignalina-1-4-2023>.

⁷² Nucnet, 'Germany's Nuclear Shutdown / Last Three Plants To Go Offline, Despite Last-Minute Appeals For Extensions :: NucNet | The Independent Nuclear News Agency', The Independent Global Nuclear News Agency, 30 January 2023, <https://www.nucnet.org/news/last-three-plants-to-go-offline-despite-last-minute-appeals-for-extensions-4-4-2023>.

⁷³ 'Italy 2022', accessed 19 May 2023, <https://cnpp.iaea.org/countryprofiles/Italy/Italy.htm>.

⁷⁴ Vladimir Spasić, 'Spain on Track to Phase out Nuclear Power, Coal by 2035', *Balkan Green Energy News*, 22 October 2021, <https://balkangreenenergynews.com/spain-on-track-to-phase-out-nuclear-power-coal-by-2035/>.

⁷⁵ Nucnet, 'Belgium Considering Extensions For Three Nuclear Power Plants'.

4. DATA ANALYSIS

4.1. Introduction to the data analysis

This chapter aims to analyse the data collected directly from the survey sent to job providers in the nuclear industry. This analysis is crucial for understanding the current state of the workforce, anticipating future skill requirements, and formulating strategies to address potential challenges. However, it is important to acknowledge certain limitations in the data collection process, as these limitations may impact the comprehensiveness of the findings.

The survey (see Appendix 1) sent to 39 organizations within Nucleareurope's network. Anonymization of data collected was stated as a basic principle in conducting the survey. The survey yielded only 19 responses, some of which weren't fully complete, resulting in a 48% response rate. These responses only covered eight countries (Belgium, Bulgaria, Estonia, France, Hungary, Romania, Spain, and UK) whereas the report aims to encompass the EU27+UK. For France and the Netherlands, the answers were provided based on a detailed parallel study conducted at the national level (respectively the Match report and Technopolis Group report).

The organisations who answered were involved in the following activities (some were involved in multiple activities):

- utilities (20%)
- fuel fabrication, enrichment, supply, cycle (19%)
- design, engineering, manufacturing, and maintenance (42%)
- transport (11%)
- other (8%)

This limited response rate can be a cause for concern as it may not provide a representative sample of the entire nuclear sector. Consequently, the findings and conclusions drawn from the analysis should be interpreted with caution: in the following figures in this chapter, we analyse answers to the survey as they are, even if it represents a very limited number of respondents.

In France, the information for the data analysis was centralized through the Gifen (the nuclear trade association) and used data from the Match programme. This means that through the Gifen, seven answers were taken into account, and these answers are considered representative of the entire nuclear sector in France, covering all segments of activity.

One potential reason for the limited response rate could be the sensitivity of the data being collected. HR numbers, particularly related to workforce composition and skill requirements, are often considered confidential and proprietary information. Organizations may be hesitant to share this information due to concerns about competitive advantage or other factors, in spite of the fact that it was clearly stated that responses to the survey shall be anonymized.

Despite the limited response rate to the survey, it is encouraging to note that the open-ended questions received more answers, and these answers were often more comprehensive. These open-ended questions focused on identifying the types of jobs currently in highest demand, forecasting the jobs expected to be in highest demand in 10 years, and determining the necessary skills for these jobs in the future. This highlights the importance of qualitative insights in complementing the quantitative data gathered. The analysis will leverage these open-ended responses to gain valuable perspectives and deepen our understanding of the HR and skills needs for the sector up to 2035.

In this analysis, skills are defined as the specific abilities and expertise possessed by an individual that enable them to effectively perform the core competencies and functional competencies required for a particular job. The jobs can be defined as a specific position or role within an organization that encompasses a set of duties, responsibilities, and requirements assigned to an individual employee. In the context of this analysis, jobs are aligned with EHRO-N's job classification, which means that several functions or functions with similar characteristics can be grouped under a common job type. This classification system allows for a more comprehensive and standardized approach to categorizing and understanding various roles within the nuclear sector, considering the diverse functions and responsibilities that may fall under a specific job type.

4.2. Activity of the respondents

The majority of survey respondents were working in the design, manufacturing, and maintenance sector of the nuclear industry. In this sector, the majority of companies provide services covering the complete lifecycle of nuclear power, including new construction, operations, and decommissioning or backend activities. Respondents who identified themselves as utilities were primarily engaged in operations, but some also participated in other areas, such as new build, decommissioning, and fuel cycle management. As some companies (10) were involved in several activities, the companies are counted as one for each segment of activity they are involved in, in the graph below.

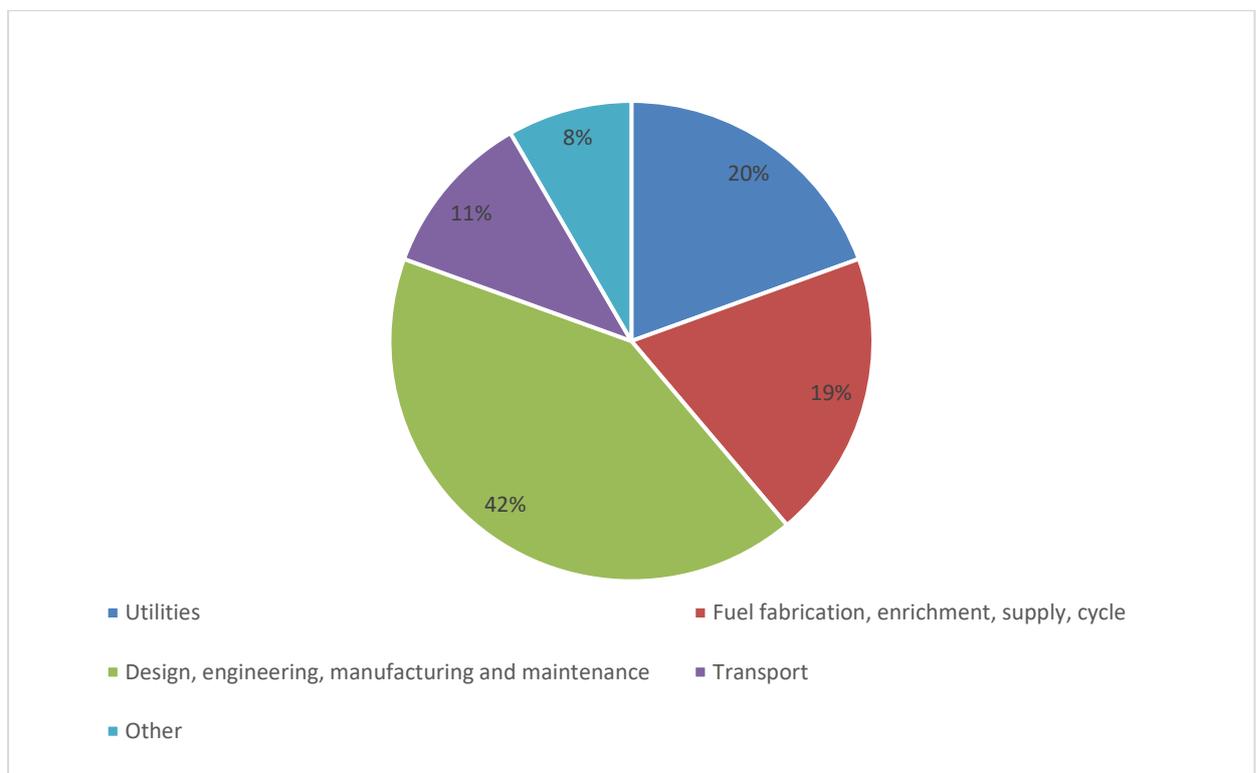


Figure 5: Activity of the survey respondents

4.3. Staff and European Qualification Framework (EQF) levels forecasts

The majority of respondents (63%) anticipate an increase in staff levels within both the next five and ten years. The highest increase in staff is foreseen in France (+51%), while Hungary and Bulgaria foresee that their staff levels will remain stable across all EQF levels over the next 10 years. Some companies foresee a decrease in staff, especially those located in countries with nuclear policies aimed at reducing nuclear capacity and decommissioning existing nuclear facilities. For instance, Spain foresees an overall decrease in staff of 20%. This suggests that efforts will have to be made to recruit new employees in most countries, while considering the time required for education to have an operative staff and retaining employees.

It was observed that some companies, both utilities and design/engineering firms, have a higher proportion of their staff in the lower EQF levels. However, most respondents reported having the majority of their staff in the higher EQF levels (7-8). This indicates that a considerable number of organizations in the nuclear sector prioritize hiring and retaining personnel with advanced qualifications and specialized expertise, likely in roles that demand greater technical proficiency and seniority.

Furthermore, the survey responses shed light on the future skill requirements of the nuclear sector. According to the respondents' predictions, there is a noteworthy forecasted increase in the demand for staff possessing EQF 4-5 qualifications. The projected surge in demand indicates a remarkable 204% increase in the need for professionals with qualifications at these specific EQF levels.

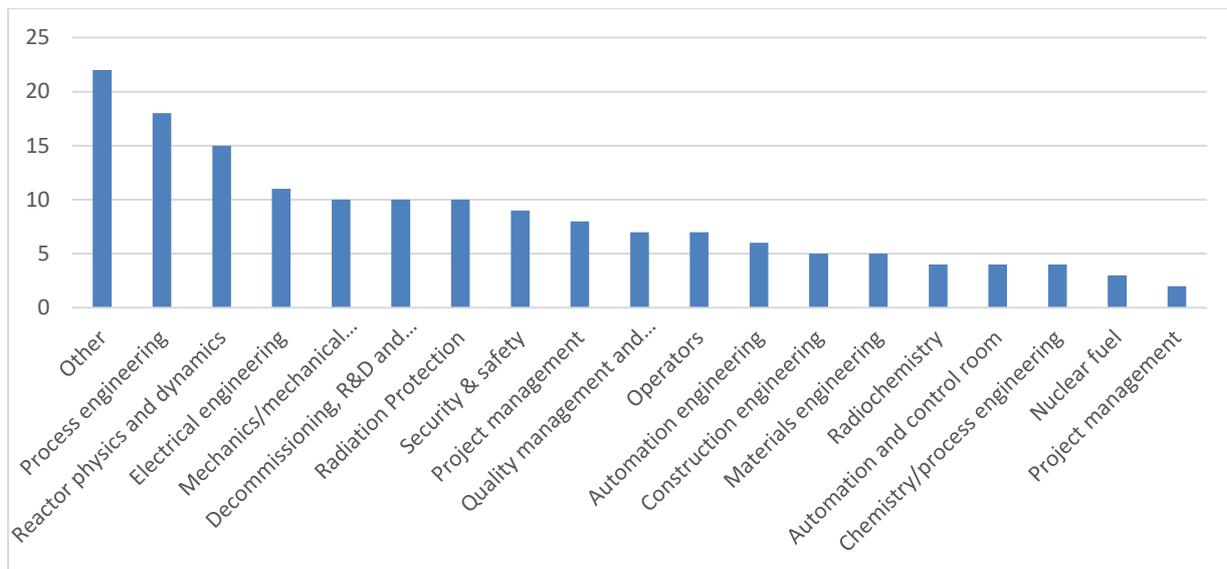
4.4. Trends in job demand

According to the survey respondents, the current job market in the nuclear sector is presenting significant challenges for companies in terms of recruiting qualified engineers. The demand for professionals in various engineering disciplines is particularly high, with process engineers, nuclear engineers, electrical engineers, and mechanical engineers being in great demand. These specialized engineering roles play crucial roles in the design, operation, and maintenance of nuclear facilities and processes, making them essential for the industry's growth and development.

In addition to engineering roles, individuals with expertise in nuclear-specific fields, such as radiation protection, nuclear and reactor physics, and nuclear chemistry are also experiencing a surge in demand.

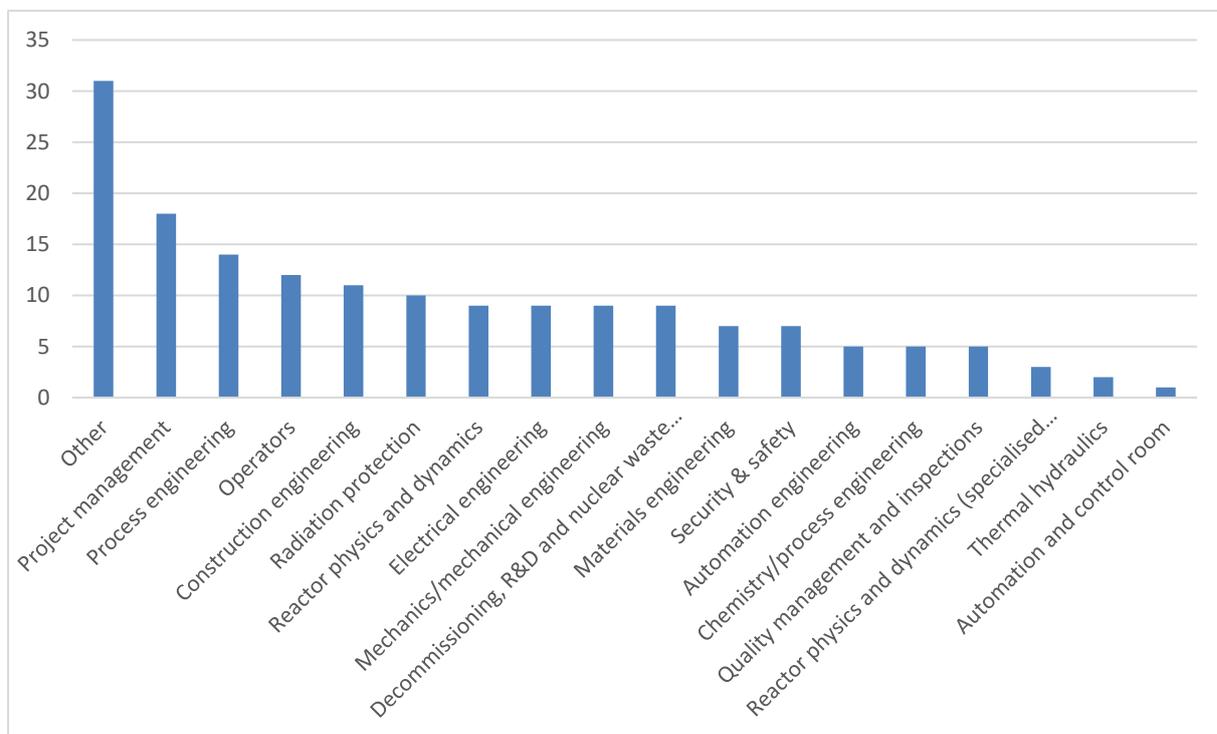
Moreover, the "other" category is witnessing a strongest demand for skilled employees with diverse technical capabilities (figure 6). Boilermakers, fitters, welders, and other trade professionals are in high demand as they play critical roles in construction, maintenance, and repair activities within nuclear facilities. In terms of methodology for future studies, criticality of some of these skills (especially welders) should lead to consider them more specifically and not in a general "others" category. In general, attention should be paid to more "standardized" skills description. One possible way in this improvement effort could take advantage of previous work conducted by some

major industrial players (especially utilities) for their own HR planning needs, provided they agree on sharing such information at the EU level.



*Figure 6: Types of jobs in demand now
(number of occurrences among answers to the survey)*

The respondents foresee a significant demand for various nuclear jobs in the coming decade (figure 7). Alongside the ongoing strong demand within the “other” category, which includes sought-after roles like welders and boilermakers, project managers emerge as the most highly sought-after positions. Additionally, there is a notable need for engineers (of all disciplines), operators, and construction personnel. Furthermore, expertise in nuclear-specific fields such as radiation protection and reactor physics continues to be of utmost importance in the industry.



*Figure 7: Types of jobs in demand in the following 10 years from 2023
(number of occurrences among answers to the survey)*

Overall, the data suggests that while some roles like project management and those falling under the “other” category are experiencing increased demand, roles such as radiochemistry, process engineering, and reactor physics are witnessing a potential decrease in demand (table 3). These trends highlight the evolving needs and priorities of the nuclear sector as it continues to grow and adapt to changing circumstances. The job categories highlighted in green in the table below are the ones that appear in both the responses for types of jobs in demand now and for those in 10 years. The job categories in white indicate categories that are found only either in the types of jobs in demand now or in 10 years.

Type of job	Trend
Project management	10
Other	9
Construction engineering	6
Operators	5
Reactor physics and dynamics (specialised in SMRs)	3
Materials engineering	2
Chemistry/process engineering	1
Thermal hydraulics	0
Radiation Protection	0
Mechanics/mechanical engineering	-1
Decommissioning, R&D and nuclear waste management	-1
Security & safety	-1
Automation engineering	-1
Electrical engineering	-2
Quality management and inspections	-2
Human Factor	-2
Automation and control room	-3
Nuclear fuel	-3
Radiochemistry	-4
Process engineering	-4
Reactor physics and dynamics	-6

Table 3: Trend for job demand (based on number of occurrences among answers to the survey)

In addition, based on the data provided for different activity segments within the nuclear sector, we can observe certain trends and shifts in the demand for various job roles over the current period and the next 10 years.

Activity Segment: Utilities

Currently, the most sought-after jobs in the utilities segment are found in the "other" category, which includes roles like welders, fitters, boilermakers, etc. Additionally, process engineers, reactor physics and dynamics specialists, and other types of engineers (electrical, mechanical, etc.) are in high demand. Looking ahead to the next decade, the respondents foresee that the demand for jobs in the "other" category will continue to increase. Alongside this, operators, process engineers, and construction engineers will also be highly sought after. A possible explanation for this trend towards the "Other" category is the ability (and wish) of utilities to train their new personnel in-house through VET (Vocational Education and Training), relying on quite general initial skills.

Activity Segment: Fuel Fabrication, Enrichment, Supply, Cycle

In the fuel fabrication, enrichment, supply, and cycle segments, the most sought-after jobs currently align with the "other" category, along with process engineers, reactor physics and dynamics specialists, and security and safety roles. Looking ahead to the next 10 years, the demand for jobs in the "other" category is expected to increase further. Process engineers, operators, and project managers will also be in high demand in this segment. The possible explanation suggested for the utilities activity segment also applies here.

Activity Segment: Design, Engineering, Manufacturing, and Maintenance

For the design, engineering, manufacturing, and maintenance segments, the most sought-after jobs currently include process engineers, roles falling under the "other" category, reactor physics and dynamics specialists, as well as positions related to decommissioning, R&D, and nuclear waste management. Looking ahead to the next decade, the demand for jobs in the "other" category will remain high. Additionally, project management roles, process engineers, and construction engineers will also be in demand.

Activity Segment: Transport

In the transport segment, the most sought-after jobs currently involve roles in the "other" category, process engineering, and radiation protection. Looking ahead to the next 10 years, the demand for jobs in the "other" category will continue to rise. Project management and radiation protection roles will also be highly sought after.

Other Segment of Activity

For companies falling under the "other" segment of activity, the most important roles currently are found in the "other" category, along with process engineering and electrical engineering positions. Over the next 10 years, these companies anticipate that the demand for jobs in the "other" category will remain significant, alongside the continued importance of process engineering and electrical engineering roles.

Overall, the trends suggest that the "other" category, which comprises various technical and trade professionals, is experiencing an increased demand across multiple activity segments within the nuclear sector. Project management and specific engineering roles, such as process engineers and reactor physics specialists, are also expected to be in demand in the coming decade.

4.5. Trends in skills demand

Three categories of skills have been identified in order to draft in a simplified approach trends in the demand:

- General engineering
- Nuclear specific
- Soft skills

In the next 10 years, companies are anticipating a significant demand for specific skills, particularly in the nuclear industry. As some countries seek to expand their nuclear fleet, large project management skills will be highly valued.

In the engineering domain, companies will highly value professionals with general engineering skills (figure 8). These skills will be crucial in the design, engineering, manufacturing and maintenance activity segment, making up 38.3% of the overall skills demand. Additionally, they will be essential in the transport (57.1% of skills demand) and other (60% of skills demand) activity segments. Among engineering disciplines, expertise in electrical and process engineering will be particularly important, as they directly relate to the nuclear industry's requirements.

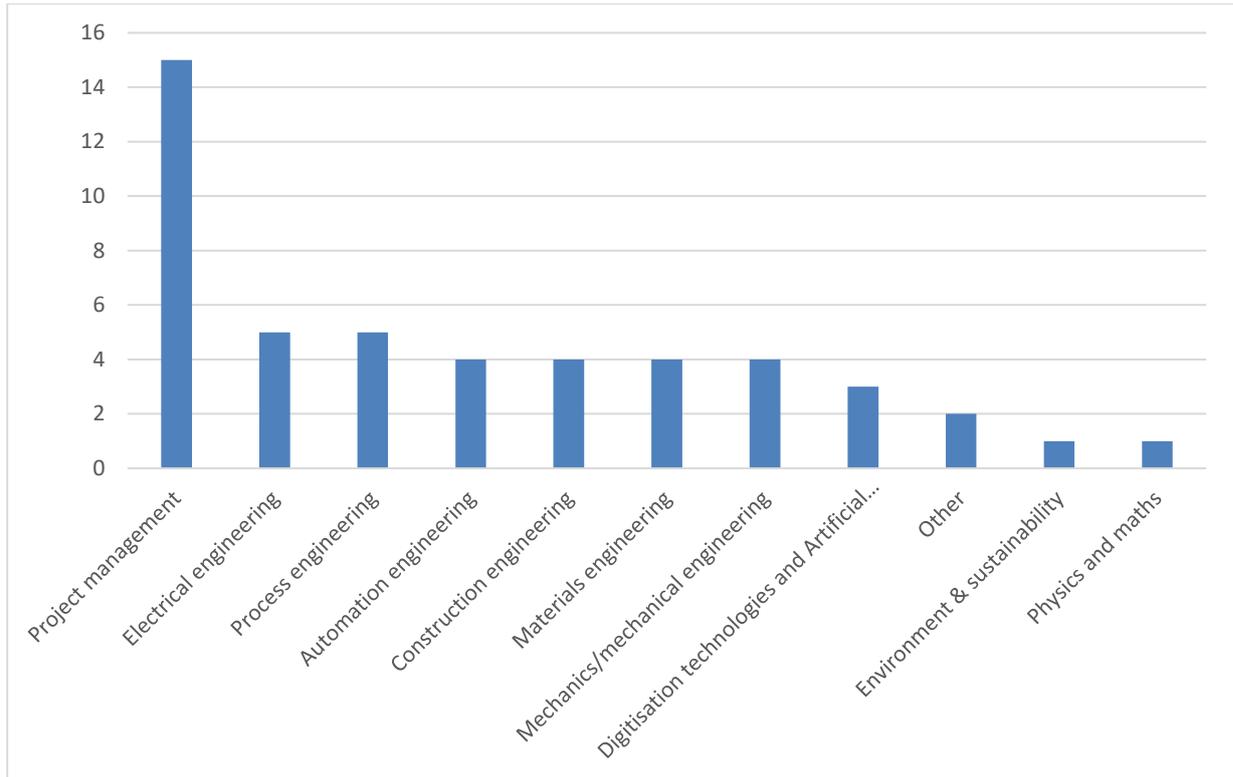
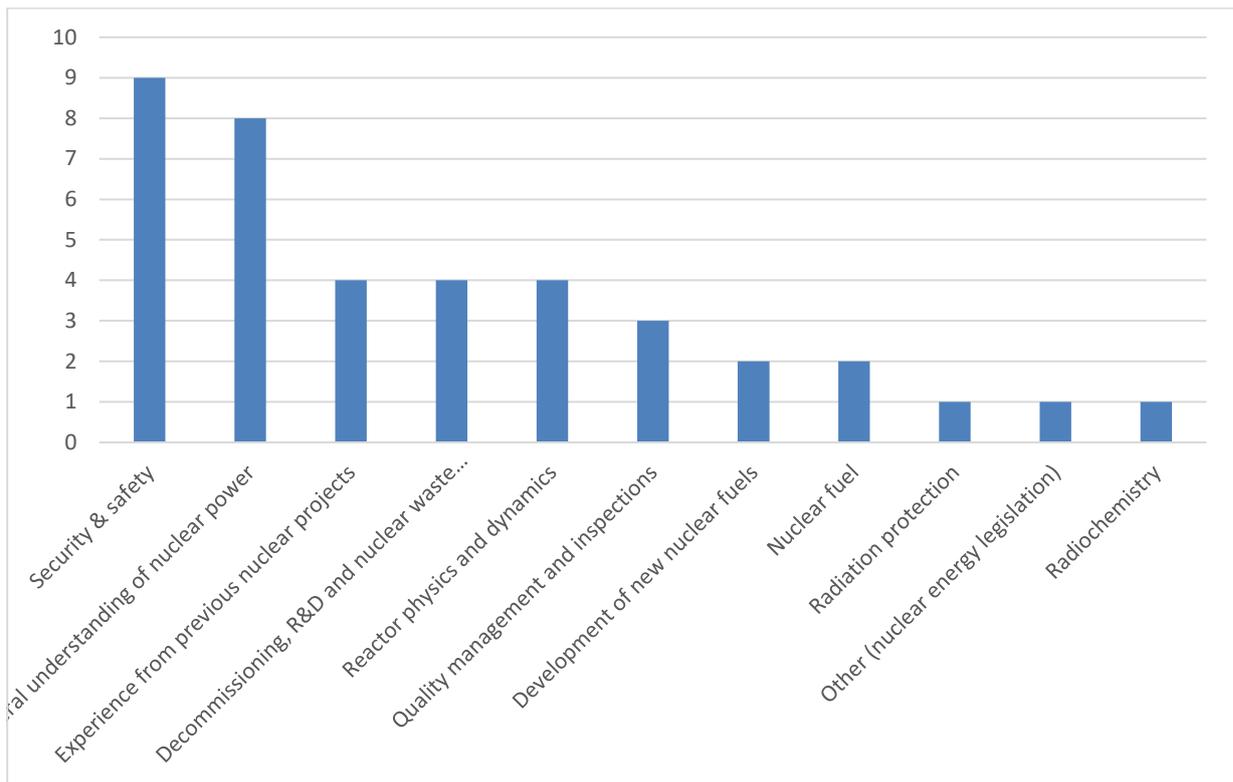


Figure 8: General engineering skills demand in the following 10 years from 2023 (number of occurrences among answers to the survey)

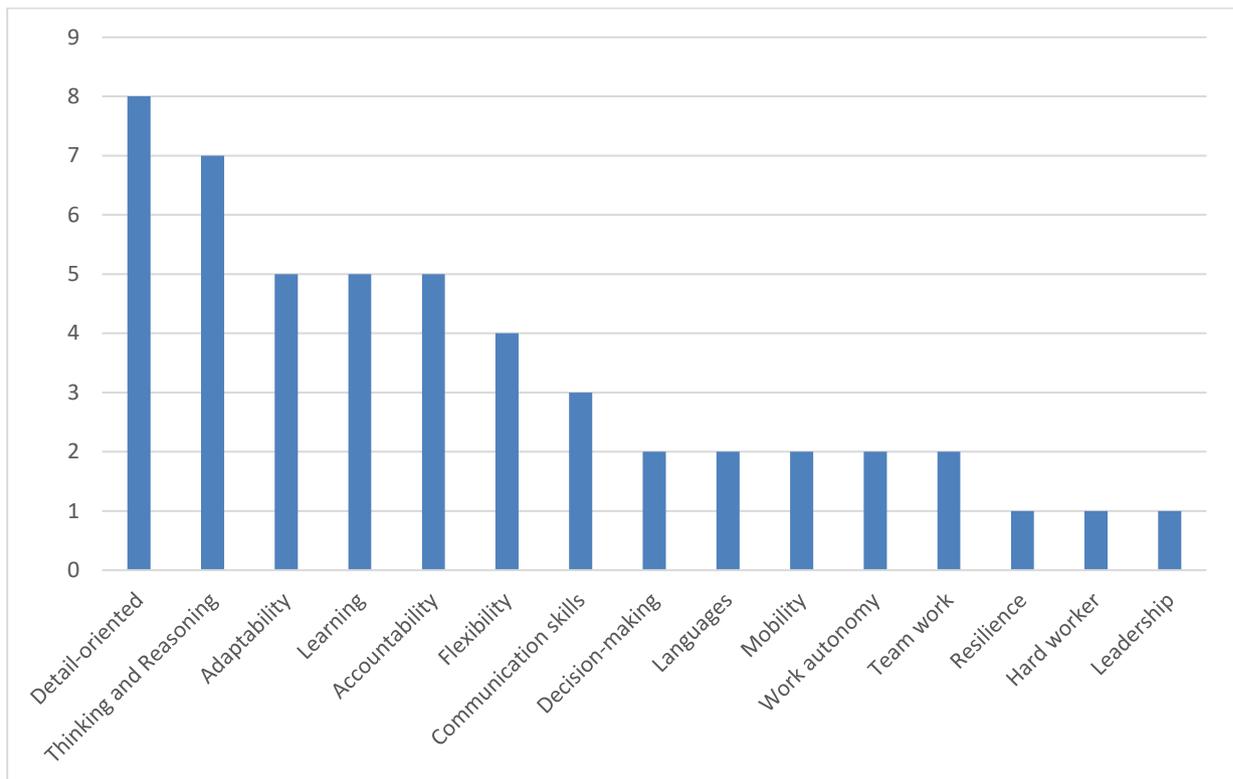
A general understanding of nuclear science and nuclear safety will be highly regarded, indicating that companies are actively seeking candidates with nuclear-specific skills (figure 9). This is especially true for utilities, where 48.1% of their skills needs will pertain to nuclear-specific knowledge. Given the critical nature of nuclear operations, companies will prioritize professionals who possess expertise in areas such as decommissioning, research and development (R&D), nuclear waste management and reactor physics and dynamics.

As experienced personnel approach retirement age, there will be a need to preserve and transfer knowledge to ensure a seamless transition of expertise. Mentoring or shadowing could be possible ways to improve in industry attention paid to expertise and know-how, including tacit ones, of senior employees, whatever their EQF level.



*Figure 9: Nuclear-specific skills demand in the following 10 years from 2023
(number of occurrences among answers to the survey)*

Apart from technical competencies, soft skills will play a pivotal role within the nuclear industry (figure 10). Companies will highly value professionals who possess strong attention to detail, adaptability, ease of learning, effective communication, critical thinking abilities, accountability, and leadership qualities. These soft skills will be particularly sought after by companies involved in the design, engineering, manufacturing, and maintenance activity segment (38.3% of skills needs), and in fuel fabrication, enrichment, supply, cycle (45.8% of skills needs) activities. For utilities, soft skills will make up 33.3% of their overall skills requirements.



*Figure 10: Soft skills demand in the following 10 years from 2023
(number of occurrences among answers to the survey)*

4.6. Conclusions of the data analysis

This data analysis provides some insights into the HR and skills landscape of the nuclear sector up to 2035. However, there are certain limitations in the data collection process that need to be considered when interpreting the findings. Limited response rate from the survey, partial coverage of countries among the EU27+UK perimeter, partial coverage of the industrial sector even in countries covered may impact the representativeness of the data and its applicability to the broader nuclear sector.

One key takeaway from the survey is the anticipated increase in staff levels within the next five to ten 10 years. This trend is positive for the nuclear sector as it indicates potential growth and expansion. However, certain countries, like Spain, foresee a decrease in staff due to nuclear policies aimed at reducing capacity. In light of this, it is essential for companies and policymakers to collaborate and formulate strategies to address potential labour market imbalances in different regions.

Another key takeaway is the "Other" category of skills coming at the top of demand for most of the activity segments considered. Several explanations might be considered:

- Priority given by industrial players to in-house E&T after initial academic E&T (importance of VET).
- Difficulty in anticipating jobs and roles and how they fit with initial skills to fulfil operational demands.

- Evolution of nuclear technologies towards more intense integration of generic non-nuclear technologies (digital tools especially).

The data also sheds light on the future skill requirements of the nuclear sector. Engineering roles, particularly process engineers, nuclear engineers, electrical engineers, and mechanical engineers, are in high demand, and companies are likely to face challenges in recruiting and retaining talents. This highlights the continued importance of ensuring the attractiveness of science, technology, engineering and mathematics (STEM) subjects and of the nuclear industry. It is crucial for educational institutions and training programmes to align their curriculum with these specific skill needs to produce a highly skilled workforce capable of meeting industry demands.

Furthermore, the demand for nuclear-specific skills, such as radiation protection and reactor physics, is also noteworthy. The nuclear industry's unique safety and operational requirements necessitate a specialized skill set, and companies should actively invest in training and development programmes to ensure the availability of qualified personnel for critical roles.

Soft skills are of utmost importance in the nuclear industry, with companies placing high value on professionals who possess a range of essential qualities. These qualities include strong attention to detail, adaptability, a quick learning ability, effective communication, critical thinking, accountability, and leadership capabilities. Therefore, prioritizing investments in soft skills training, creating a culture of continuous learning and adapting curricula to be more multidisciplinary will be key for nuclear organizations.

5. FORECAST

Gaining a comprehensive understanding of the size and skills of the European nuclear workforce is essential for effective industry planning, policy development, workforce transition, addressing skill requirements, supporting education and training initiatives, and enhancing competitiveness.

This chapter will examine the required nuclear workforce for the safe operation of current nuclear power plants in the EU27+UK. It will analyse these needs and provide predictions for future requirements up to 2035. Additionally, it will aim to establish a connection between these figures and the broader nuclear sector.

5.1. Estimation of the workforce needed for the operation of nuclear power plants in the EU27 + UK

For the purpose of this estimation, the staffing level for a single unit from the IAEA report is being used. This estimation suggests a **workforce of just under 80,000 workers for the operation of the current operating nuclear reactors in EU27 + UK**. It is important to note that the estimated workforce number mentioned only relate to the operation and daily maintenance of nuclear reactors. It does not encompass the broader aspects of the nuclear industry, such as supply chains,

design, and manufacturing. In the assumed definition of our study, these are 80,000 “direct jobs” in the utilities category of activity.

The following figure shows the distribution of the workforce between the four job clusters in the ENEN2+ survey. The median staffing numbers for the 43 different staff categories in the IAEA report has been aligned with the 23 job functions/competence areas used in the ENEN2+ survey.

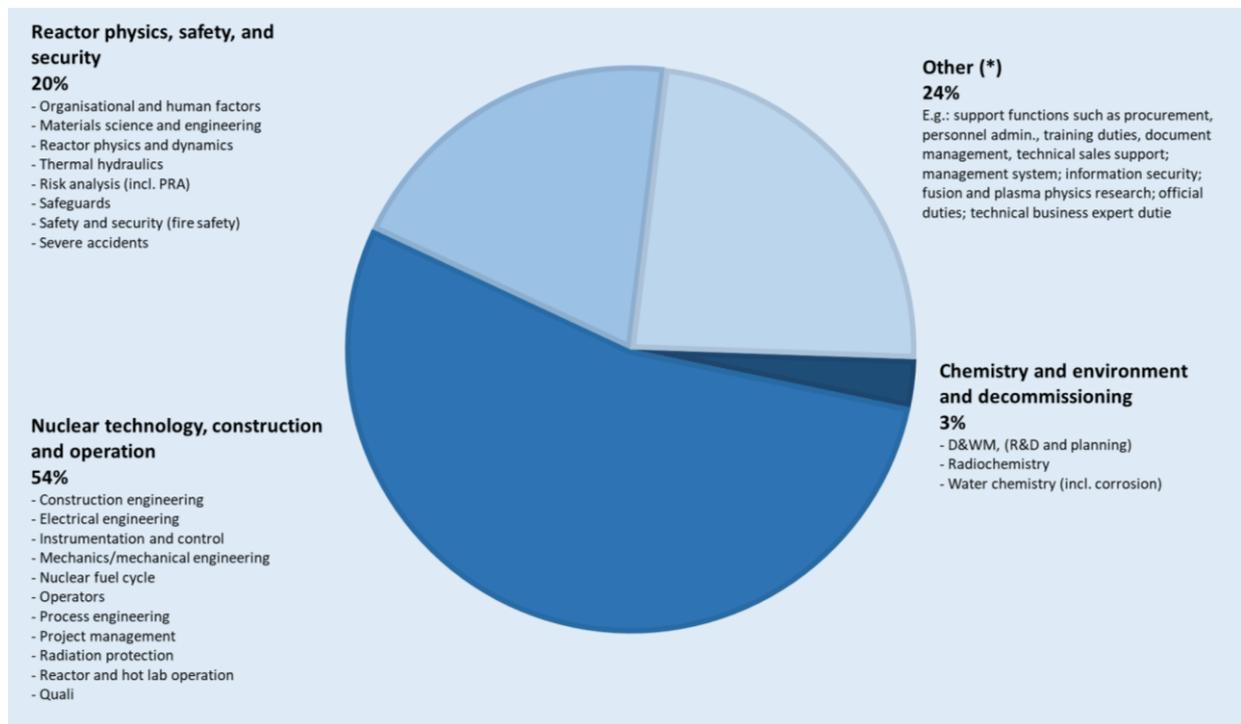


Figure 11: Distribution of workforce for NPP operation in the four clusters used in the ENEN2+ survey

5.2. Possible scenarios workforce needed to build & operate nuclear power plants in the EU27 + UK

In the EU27+UK, there are currently plans underway for the construction or development of 13 new reactors even if subject to geopolitical uncertainties. This significant expansion in nuclear infrastructure is expected to have a notable impact on the workforce requirements within the industry both during the construction phases and during operation.

Workforce needed in Construction phase:

The size of the workforce during construction of a nuclear power plant varies depending on several factors such as the size and complexity of the plant, the contractual scheme between technology provider and plant owner, the construction method used, the level of automation and technology used, and the availability of skilled workers. For illustration, if SMRs are to be developed, required skills for construction might be focused more on components industrial manufacturing sites and less on construction sites.

According to industry estimates, the construction of a single unit can create anywhere from a few thousand to tens of thousands of jobs during the construction phase, depending on the specific circumstances of the project. For example, the construction of the Hinkley Point C twin unit EPR nuclear power plant in the UK is estimated to have employed up to 8,500 workers at its peak, while the Vogtle Electric Generating Plant in the US is estimated to have employed up to 9,000 workers at its peak for a double unit.

The workforce required to construct a nuclear power plant typically includes a large range of specialised personnel, such as project managers, several types of engineers (design, civil, mechanical electrical, instrument and control, and nuclear), construction workers, electricians, pipefitters, welders, health and safety professionals, etc. These workers may be employed directly by the nuclear power plant owner and/or future operator, the construction contractor, or subcontractors working on specific aspects of the construction project.

An estimated 13 nuclear units are currently planned or under construction in the EU27 + UK, which could require up to 50,000 additional jobs for their construction in the relatively short term if built simultaneously. It is important to note that the construction of a nuclear power plant is a complex and long-term process that can take several years to complete. As a result, the size of the workforce required may vary over time depending on the stage of the construction process. Estimation of the required workforce may also vary taking into account mobility of workers from one site to another if constructions are planned in sequence.

Workforce needed for NPP Operation:

As these new nuclear power plants in the EU27+UK become operational, there will be a corresponding increase in the demand for specialized personnel to handle plant operation, maintenance, and safety, including safety authorities and technical safety organizations. Additionally, there will be a continuous need for the influx of skilled workers to replace the workforce that is retiring.

Currently, there are 109 operating nuclear reactors in the EU27+UK, with 13 reactors either being planned or under construction. To illustrate the workforce requirements, we can consider three different scenarios.

1. In the first scenario, which represents the present situation with 109 nuclear power plants, there will be a need for recruitment to replace retiring personnel and account for any capacity expansions until 2035.
2. In the second scenario, assuming a moderate increase to 115 nuclear power plants, there will be an additional demand for specialized personnel due to capacity growth and retirement replacements.
3. The third scenario takes into account all the planned and under-construction nuclear units, totalling 122. This scenario projects the highest requirement for workforce recruitment to manage the increased capacity and address retirements.

A larger number of new reactors (large and SMR) should be built to reach the 150 GW by 2050 mentioned in the policy statement previously quoted in the present report. The third scenario among the three introduced above is the only one that could be in line to prepare in 2035 this electricity production level for 2050. However, it appeared to the members of the task force that

conservative approach should be prioritized in order to produce achievable recommendations in terms of HR and E&T capabilities.

In any case, the relevant indicator in a first approach is “new recruitments needed/GWe operation of new nuclear” and our approach allows to produce such an estimation.

It should be noted that for all scenarios, some countries will need human resources and skills dedicated to the end of the lifecycle of nuclear power plants. Some detailed information can be found in the ENEN2+ Work Package 1 TF 1.2 report⁷⁶.

These three scenarios provide an overview of the recruitment needs based on different levels of nuclear power plant capacity. They highlight the importance of workforce planning and the continuous need for skilled professionals to ensure the safe and efficient operation of both existing and upcoming nuclear power plants in the EU27+UK.

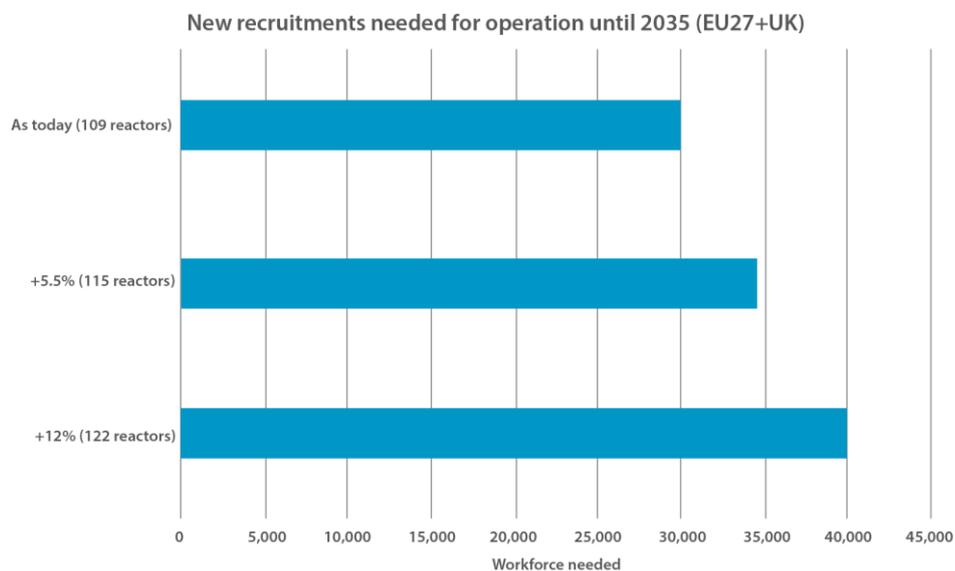


Figure 12: New recruitments needed by the power plants for operations based on three scenarios

The data highlights a significant workforce demand in the power plant industry, even without an increase in nuclear capacity. It indicates that approximately 30,000 workers will need to be recruited by 2035. However, in the third scenario where additional capacity of 13 units are considered, the workforce requirement by 2035 rises to 40,000, representing 50% of the current workforce.

Key output is that 770 new recruitments per new unit should be envisaged. Assuming only large reactors among these new builds (in the 1.5GW power range) this means roughly 500 new recruitments/GWe for new builds operation. This figure is a little bit lower than the average staffing for operating we have considered for reactors of the existing fleet. It seems reasonable taking into account some mutualization effects and feedback from acquired operating experience.

A similar workforce requirement can be anticipated within the power plant supply chain, potentially doubling the number of workers needed.

⁷⁶ Katarzyna Deja et al., ‘ENEN2+ - Report on Human Resources Needs in Research, Safety and Waste Management’, Deliverable, n.d.

These figures emphasize the need for a proactive approach to workforce planning and recruitment within the power plant sector. With a substantial number of retirements, attrition, and the potential for industry growth, it is crucial to develop strategies to attract and train a sufficient number of qualified individuals to meet the future workforce demand.

Let’s remind here that we could find in the literature review⁷⁷ some modelling tools of this attrition effect, with rather in-depth level of details: “The model uses two attrition factors, general attrition rate which applies to all workers and nuclear workforce attrition rate which applies to workers in the nuclear organizations. The reasons workers leave an organization, or the workforce, vary with age. Retirement becomes a larger reason for older workers, while job changes are more common for younger workers. Because of this, the attrition rates are defined by age bands.”

Further studies could take advantage of such existing models in the literature and develop benchmarking approach to check and complete results of the present simplified approach.

5.3. The EU27+UK nuclear workforce

The presented workforce numbers specifically focus on the personnel required for the operation of nuclear power plants. However, this represents only a portion of the overall workforce within the broader nuclear sector, which encompasses various subsectors.

ENEN2+ and EHRO-N has by a collaborative effort in the framework of TF1.1 and more widely of WP1 established a best estimate of the current workforce in the nuclear sector. These estimated figures will be discussed further in the overall WP1 report. It is estimated that the European Nuclear Sector, including the United Kingdom, supports approximately 500,000 jobs. Out of these, around 230,000 are direct jobs, while approximately 270,000 are indirect jobs, supporting the nuclear industry in various indirect capacities.

Sub-sector	Direct jobs	Indirect jobs	Percentage of total jobs
Reactors (operation & maintenance)	75000		15
Reactors (design & engineering)	37500		8
Fuel Cycle (front-end, processing, back-end)	50000		10
Decommissioning & Waste Management	25000		5
Non-power applications (including medicine)	15000		3
R&D (including TSO & non-power applications)	22500		5
Regulation (safety and security)	5000		1
Supply chain (indirect jobs)		270000	54
Total	230000	270000	100

Table 4: EU27 and the United Kingdom estimated nuclear workforce distribution in nuclear sub-sectors

⁷⁷ Nuclear Power Human Resources Modelling Tool Description and User Manual, IAEA TRAINING COURSE SERIES 73, 2021

While a best estimate may not provide the same level of accuracy as comprehensive data, it can still offer insights and can support decision-making processes in the absence of detailed European-wide data.

This data compared against the aforementioned scenarios highlights the need for the nuclear sector to recruit between 148,000 (if the retirement rate is assumed to be 2.0%/year) and 167,000 (if the retirement rate is assumed to be 2.5%/year) jobs in the perimeter of Task Force 1.1, out of which between 51,000 and 60,000 are direct jobs (between 34,000 and 43,000 for retirement compensation), in order to sustain its current level of operations until 2035. These figures signify the magnitude of workforce demand and the importance of attracting and retaining skilled professionals within the nuclear industry. To ensure the continued functioning and growth of the nuclear sector, it is crucial to address the workforce requirements in a timely manner. This entails implementing targeted recruitment strategies, investing in education and training programmes, and fostering collaborations among academia, research institutions, and industry stakeholders.

5.4. Discussion

The nuclear sector is complex and requires a diverse range of high-level skills, but also significant number of technicians and semi-skilled staff. Among factors which should be further analysed in the future:

- Workforce in the supply chain supported by export activities. Supply chain companies located in countries phasing out from nuclear should be considered in this deeper analysis,
- Competition for talents from other industrial sector, including in the energy sector in general (renewable, energy efficiency, etc.)
- Question of induced jobs: estimations of the EU27+UK nuclear workforce as it is nowadays may vary by a factor of 2 (between 500,000 and 1 million, depending on whether or not induced jobs are taken into account).

Methodologies to assess existing workforce should be also questioned, especially considering the limits we have observed (low rate of response to surveys). Predicting the precise workforce needs in this sector up to 2035 appears to be even more challenging than assessing existing workforce, as it is influenced by various factors, including the political environment and decisions regarding the installation of new power plants.

This chapter has used the example of nuclear power plants in 2023 to estimate the projected workforce needs until 2035 for the EU27+UK region. Through this analysis, insights have been provided regarding the broader workforce requirements of the nuclear sector. The findings indicate that in order to maintain its current capacity by replacing retired workers; the industry in nuclear sector (TF 1.1 perimeter) will need to recruit between 76,000 (if the retirement rate is assumed to be 2.0%/year) and 95,000 (if the retirement rate is assumed to be 2.5%/year) jobs, with between 34,000 and 43,000 of them being direct jobs.

The nuclear sector relies heavily on a highly skilled and educated workforce across various subsectors. Among these subsectors, and as highlighted in the ENEN2+ Work Package 1 Task 1.2 report, R&D plays a particularly critical role. The R&D sector is essential for driving technological advancements, ensuring the best design of nuclear reactors, and exploring non-power applications. It is instrumental in maintaining the safe operation of existing plants and facilities while also spearheading the development of innovative solutions for nuclear waste management and decommissioning. The R&D sector acts as the driving force behind a competitive and safe European

nuclear industry. Therefore, it is crucial to invest in this subsector, especially considering the emergence of new advanced reactor technologies and the significant growth of non-power applications. In addition to the specific perimeter covered by TF1.1, an analysis of the three Task-Forces reports considered simultaneously is necessary. The WP1 report will aim to progress in this direction. Some recommendation could be strengthened as they are common to the three WP1 task forces. Some additional recommendations might emerge from a broader point of view considering the nuclear sector as a whole. Finally, some recommendations might deal with the methodology in itself, as it was for the three task forces very similar (survey complemented by literature review).

Another challenge facing the European nuclear workforce is the continued retirement of highly specialised and experienced personnel. Ensuring the effective transfer of knowledge and expertise to the next generation is crucial for maintaining a skilled workforce and organisational knowledge.

This challenge is against the backdrop of the nuclear competences pyramid⁷⁸ and the time needed for the education and mastery of the different jobs which will need to be replaced. The respondents from ENEN2+ survey anticipated highest demand in the nuclear sector in the coming 10 years to be the following skills and competences:

- project managers
- operation (engineering)
- radiation safety
- decommissioning and waste management
- mechanical engineering
- nuclear engineering

Further, the Gifen report⁷⁹ highlights the skills and competencies that will be crucial for the French nuclear sector in the upcoming years:

Direct jobs:

- project manager
- mechanical design engineer
- operations technician
- maintenance technician
- design studies,

Intellectual/consultancy services:

- project management in client and contractor roles
- commissioning tests
- logistics, transport, handling & lifting
- nuclear processes

It is important to recognize that the anticipated skills and competence needed in the nuclear sector are not only nuclear professionals, but also “nuclearized” or “nuclear-aware” staff (the proportion can exceed 80% on construction site during phases where civil works are the main tasks) coming from possible non-nuclear backgrounds, along with professionals which have developed soft-skills.

⁷⁸ Nuclear Education and Training: From Concern to Capability 2012 OECD-NEA report
<https://www.oecd.org/publications/nuclear-education-and-training-9789264177604-en.htm>

⁷⁹ Gifen, ‘Programme MATCH. L’outil de pilotage de l’adéquation besoins-ressources de la filière nucléaire pour être au rendez-vous de ses programmes’.

The measures to address the skills and competence shortage might be different for the different professionals. However, to overcome the skills and competence challenges faced by the EU nuclear sector, it is crucial to prioritise and focus efforts for any categories of professionals on the following three principles:

1. **Attracting New Talent:** Implement targeted recruitment campaigns and initiatives to attract young professionals, students, and individuals with diverse backgrounds to the nuclear sector. Highlight the industry's importance, career opportunities, and advancements in technology. Collaborate with educational institutions to promote nuclear-related programmes and create awareness among students about the benefits of pursuing a career in the nuclear field. Reinforce the flexibility in career development and address the mobility of nuclear employees in order to help with the necessity of having the right resources at the right place, at the right time. In addition, more efforts need to be made to recruit women into the industry, as having a diverse workforce is key to success. Bringing together more diverse views would allow a different approach to problem-solving and innovation.
2. **Developing Current Talent:** Invest in the continuous development and upskilling of the existing nuclear workforce. Provide training programmes, workshops, and professional development opportunities to enhance their knowledge, competencies, and adaptability to evolving technologies and industry standards. Foster a culture of lifelong learning and innovation within the sector to ensure that professionals stay at the forefront of advancements in the field.
3. **Retaining Skilled Professionals:** Create a supportive work environment that values and rewards the contributions of nuclear professionals. Offer competitive compensation packages, opportunities for career advancement, and a healthy work-life balance. Implement retention strategies such as mentorship programmes, employee recognition, and a strong organizational culture that promotes job satisfaction, professional growth, and work-life balance.

Prioritizing the attraction, development, and retention of talent entails implementing targeted recruitment strategies, investing in academic and professional development programmes, and fostering a supportive and engaging work environment. Here again, IAEA literature deserve attention⁸⁰.

6. CONCLUSION

Performing a National Nuclear Workforce Assessment is critical for ensuring that the nuclear sector has an adequate number of skilled professionals with the right qualifications and experience to meet the industry's needs in due time. The steps of an NWA are the following:

- Mapping of current Nuclear Workforce
- Predicting future Nuclear Workforce needs
- Mapping of supply of workforce to the Nuclear Sectors

⁸⁰ Managing Human Resources in the Field of Nuclear Energy, IAEA Nuclear Energy Series No. NG-G-2.1 (Rev. 1), 2023 https://www-pub.iaea.org/MTCD/Publications/PDF/PUB1958_web.pdf

- Gap Analysis
- Develop a nuclear skills strategy
- Implementation of skills strategy
- Review of the nuclear NWA process



Effective planning involves collaboration between governments, industry stakeholders, and education and training providers to align policies, plans, and educational offerings. This collaborative approach is essential to address the complex and specialized requirements of the nuclear power industry. To facilitate effective workforce planning, collaboration among governments, industry stakeholders, and education and training providers should be ongoing. Regular dialogue and information sharing can help identify emerging trends, challenges, and opportunities in the nuclear sector.

Strong cross-party political engagement and government policies and plans play a crucial role in providing a clear and stable framework for the nuclear sector. In parallel, coordinated actions in the framework of EU must be promoted among supportive countries. By establishing long-term commitments to nuclear energy, governments provide the industry and its supply chain with the confidence needed to make strategic workforce decisions. Clear policies can outline the expected future demand for nuclear energy, the number and size of nuclear power plants, the consideration of SMRs, and the strategy for fuel cycle management and waste disposal. This information enables industry stakeholders to anticipate the required workforce size, skill sets, and timelines for training and recruitment.

Education and training providers play a vital role in meeting the workforce needs of the nuclear sector. They must develop and deliver courses and programmes that align with the industry's requirements, ensuring that the workforce has the necessary training, knowledge, and skills. Collaboration between industry and educational institutions is crucial to identify the specific competencies and qualifications needed for various job roles in the nuclear sector. This partnership can help shape the curricula, update course content to reflect technological advancements, and establish practical training opportunities to bridge the gap between theory and practice. International networks gathering E&T providers and industrial organizations could play a significant positive role in enhancing attractiveness of the sector by promoting and facilitating mobility across countries in EU.

Furthermore, workforce planning should consider the lifecycle of nuclear facilities. Different stages, such as construction, operation, maintenance, and decommissioning, require specific skill sets at different times. Anticipating these changing workforce needs is essential to avoid potential delays

and disruptions. It requires a comprehensive understanding of the industry's evolving demands and technological advancements to align training programmes and ensure the availability of skilled professionals when they are needed.

In addition, the nuclear sector faces significant challenges in attracting, recruiting and retaining skilled professionals to meet its evolving demands. Addressing these recruitment and attractiveness challenges is crucial to ensure an adequate supply of skilled workforce and mitigate potential issues. While salary is an important consideration for attracting talent, it is essential to recognize that it is not the sole determining factor. The nuclear sector offers unique opportunities for professionals to contribute to the development of low-carbon energy solutions, address environmental concerns, and make a positive impact on global energy security. Emphasizing these intrinsic motivations and the long-term benefits of working in the nuclear sector can enhance its attractiveness.

To attract and retain skilled professionals, it is crucial to highlight the challenging and intellectually stimulating nature of the work, the potential for career growth, and the opportunity to work with cutting-edge technologies and innovative solutions. Creating a positive work environment that fosters collaboration, professional development, and work-life balance is equally important in attracting top talent.

Furthermore, the nuclear sector must proactively engage with educational institutions and training programmes to ensure that the curricula align with the industry's evolving needs. Anticipating future skill requirements and adapting training programmes accordingly will help bridge the gap between the supply and demand of skilled professionals. This can be achieved through partnerships, internships, and apprenticeship programmes that provide hands-on experience and practical training opportunities. Mentoring programmes provide valuable opportunities for knowledge transfer, skill development, and career guidance. Establishing mentoring initiatives can help bridge the gap between experienced professionals nearing retirement and emerging talents entering the field. This transfer of expertise not only enhances the skills and capabilities of the workforce but also should help the retention of personnel within the sector.

Additionally, efforts should be made to promote diversity and inclusivity within the nuclear sector to harness a wide range of perspectives and experiences. Promoting nuclear careers with women for instance, will not only contribute to a more diverse workforce but also bring new ideas and innovation to the industry.

In order to take advantage of international positive impact on careers and attractiveness, some practical initiatives might be tested by industrial companies such as promoting international curriculum vitae for application, harmonization of skills certification processes, grants for transboundary residence for professional, international VET seminars, etc. And foreign language learning and practicing, not only English... even if this sounds trivial, it is easier to cooperate when intercultural aspects are mastered through shared native languages.

To this point, European Commission through its EURATOM program heavily supported the attraction, creation and maintaining the skilled workforce in Europe. It is of utmost importance that this support continues to be provided especially in the actual context.

7. RECOMMENDATIONS

7.1. Recommendations for Industry

The future success of the European nuclear industry relies heavily on a skilled and well-trained workforce. With numerous nuclear new build projects and the ongoing decommissioning of reactors, there is a pressing need for new staff. To address this demand effectively, it is essential to have a comprehensive overview of the HR situation in the European nuclear sector. Additionally, promoting research and development (R&D) investment, strengthening education and training support, and encouraging collaboration among industry stakeholders are vital for sustained growth and innovation.

1. **Support national nuclear workforce assessment:** To ensure a robust HR planning process, it is recommended that the nuclear industry actively supports comprehensive national NWAs. All industry stakeholders, including education and training providers, should contribute to this process. By providing comprehensive workforce data, such as demographic information, competences, and future workforce needs, a clearer understanding of the industry's requirements can be obtained.
2. **Utilize a streamlined job classification:** To facilitate workforce planning and coordination, the nuclear industry should adopt the streamlined job classification proposed by EHRO-N (European Human Resources Observatory in the Nuclear Sector). This classification system will promote consistency in job descriptions and facilitate better understanding of required competences across organizations, ensuring a more efficient allocation of human resources.
3. **Increase R&D investment:** To drive innovation and enhance safety measures, the nuclear industry should allocate dedicated resources to increase research and development investment. This investment should focus on nuclear technology advancements, safety improvements, waste management, and other relevant areas. By strengthening R&D efforts, the industry can improve operational efficiency, develop advanced nuclear technologies, and contribute to the long-term sustainability of the sector.
4. **Strengthen education and training support:** Closer collaboration between education and training providers and the industry is essential to meet the evolving needs of the nuclear sector. The industry should actively support education and training initiatives by offering scholarships, grants, and other forms of financial support to students pursuing nuclear-related degrees. Moreover, embracing the concept of lifelong learning and providing industry-specific training programmes, workshops, and seminars will enhance the knowledge and skills of the workforce.
5. **Offer mobility and career flexibility:** To attract and retain top talent, among young people but also among professional who would like to switch to nuclear during their career, the industry should provide opportunities for mobility and career flexibility. Promoting job rotation programmes and cross-functional training will not only enhance employee skillsets but also provide valuable experiences that contribute to professional growth. By fostering a culture of career development and mobility, the nuclear industry can position itself as an attractive and dynamic sector.
6. **Encourage diversity and promote nuclear careers with women:** To address gender imbalances and promote diversity within the nuclear industry, concerted efforts should be made to encourage women to pursue nuclear careers. The industry should actively promote female role models, create mentorship programmes, and establish initiatives to support and

empower women in the sector. By fostering an inclusive environment, the industry can tap into a broader talent pool and benefit from diverse perspectives and contributions.

7. **Foster collaboration to avoid unnecessary competition for talent and HR:** To optimize talent acquisition and retention, companies within the nuclear industry should collaborate rather than compete unnecessarily for skilled individuals. Sharing best practices, collaborating on workforce development initiatives, and creating platforms for knowledge exchange will enable organizations to address HR challenges collectively and establish a supportive ecosystem.

7.2. Recommendation for Policymakers

Approximately half of the low-carbon electricity in the EU is produced by the nuclear sector. Considering the significance of climate policies, nuclear power has the capacity to enhance its role as a dependable, secure, and clean energy source, offering stable supply with affordable prices. Moreover, during geopolitical crises, nuclear power can provide increased independence and resilience. Strategic planning both at Member State and EU-wide levels is crucial to ensure the conditions maintain sufficient workforce levels and expertise in nuclear as a precondition to fulfil nuclear safety, as an absolute priority for the EU. The diversity of the contexts (new developments, new investments, long-term operation, phase out) introduces different objectives at Member States level, but education and training remain a key component to ensure the necessary knowledge for the operational purpose of the nuclear installations, radioactive waste management, decommissioning, R&D activities, etc.

The efforts for an effective implementation of a European competences framework in nuclear should be supported for many years to create a robust framework for the mobility of workers with high specialization. The national efforts to prepare specialists may vary strongly between different national contexts. On the other hand, an important loss of workforce in the nuclear sector may appear by migration outside of the EU into regions with a high rate of implementation of new nuclear projects. In such conditions, the policymakers should develop a resilient action plan to ensure sufficient and performant workforce, and to take into consideration the dynamic and contextuality of the attractiveness. They should take into consideration a multitude of aspects such as increased attractiveness of other technological areas for young people (artificial intelligence, advanced robotics, big data, block chains, additive manufacturing, etc.), the preferences for more flexible and easier jobs, and the high specialization. Due to the long duration to establish appropriate expertise, the importance of the implementation plans is greater than for other sectors.

Since rapid action at national level, especially for the countries implementing a nuclear programme is necessary, improved and more coordinated international cooperation is crucial. Networking in nuclear education (educational open access in nuclear R&D facilities, summer schools, common courses for experimental and computer simulation, etc.), integrating a European competence framework and involving cooperation between academia, government and industry should be stimulated by long-term support.

Special attention should be paid to the loss of knowledge (mainly the tacit knowledge) due to retirement and associated knowledge transfer challenges. Moreover, decrease in the interest of the young generation for nuclear, especially in Member States where the phase-out was already

declared and the need to prepare the workforce by vocational education should be considered as well.

In a summary it is recommended to:

1. **Publish clear policies and plans for nuclear energy:** Governments should publish clear policies and plans regarding their stance on nuclear energy. Transparent and well-defined policies will provide industry stakeholders, investors, and the workforce with a clear understanding of the government's intentions and expectations. These policies should address aspects such as the role of nuclear energy in achieving climate goals, the development of new nuclear projects, the long-term operation of existing plants, and the management of nuclear waste. Clear policies will provide stability and certainty, which are essential for attracting investments and maintaining a skilled workforce in the nuclear sector. These national statements should be reinforced through EU level coordination.
2. **Facilitate national nuclear workforce assessment and disclose this data:** It is crucial for policymakers to take the lead in facilitating the process of establishing a national nuclear workforce assessment. This involves coordinating efforts and ensuring the availability of necessary resources and data to conduct the assessment effectively. All countries should undertake a thorough nuclear workforce assessment on a regular basis to identify current and future workforce needs. At present, the UK is the only country that regularly publishes a nuclear workforce assessment. Other countries should follow suit and make their assessments publicly available to ensure transparency and informed decision-making.
3. **Increase R&D investment:** Policymakers should recognize the importance of research and development (R&D) in the nuclear sector and increase investment in relevant initiatives. Allocating dedicated resources to nuclear technology, safety, waste management, and other relevant areas will drive technological advancements and support the growth and innovation of the nuclear industry. Increased R&D investment will also contribute to the development of advanced nuclear technologies and improved safety measures.
4. **Support education and infrastructure for training:** Policymakers should prioritize the allocation of necessary resources to enhance the education and training infrastructure required to support nuclear programmes. This includes providing the required facilities, equipment, and expertise to ensure high-quality education and training in the nuclear sector. Investing in education and training will help maintain a skilled workforce and ensure the necessary knowledge for the safe operation of nuclear installations, radioactive waste management, decommissioning, and R&D activities.
5. **Funding and financing:** Policymakers should explore possibilities and good practices under existing initiatives and funding programmes, such as the Euratom R&T Programme, Horizon Europe Framework Programme, Erasmus+ Programme, the European Social Fund Plus, NetZero Academies and the Recovery and Resilience Facility. Strengthening collaborations, mobility, and exchanges among students, doctoral candidates, and post-docs will foster knowledge sharing and skill development in the nuclear sector. Building on existing initiatives will ensure the availability of funding and resources to support education, training, and research in nuclear-related fields.

7.3. Recommendation for Education & Training providers

Education and training providers should establish stronger connections with the nuclear industry, ensure that their curricula meet the industry's evolving needs, offer multidisciplinary programmes, and enhance the development of soft skills among students. These actions will contribute to a well-prepared and adaptable workforce that can effectively support the growth and safety of the nuclear sector.

1. **Foster closer collaboration between education and training providers and the industry:** Education and training providers should establish stronger partnerships and collaborations with the nuclear industry. This collaboration can be achieved through joint initiatives, industry advisory boards, and regular dialogue to ensure that the educational programmes and training courses align with the industry's evolving needs. By working closely together, education and training providers can stay updated on industry trends, technological advancements, and emerging skill requirements. Finally, ensure that a fair number of professors and instructors are currently employed by the industry, transferring their know-how directly to the students that will soon enter the job market.
2. **Align curricula with industry's evolving needs:** Education and training providers should regularly review and update their curricula to ensure they align with the industry's evolving needs. This can be achieved through close collaboration with industry professionals, who can provide valuable insights into the skills and knowledge required by the nuclear sector. By incorporating industry input into the curriculum development process, education and training providers can ensure that graduates possess the relevant skills and knowledge needed to meet industry demands.
3. **Introduce multidisciplinary curricula:** To better fit with the evolving needs of the industry, education and training providers should propose more multidisciplinary curricula. Nuclear energy involves various aspects, including engineering, physics, chemistry, environmental sciences, policy, and economics. By offering multidisciplinary programmes, education and training providers can equip students with a broader skill set, enabling them to tackle complex challenges in the nuclear industry effectively. These multidisciplinary curricula should emphasize the integration of technical knowledge with a comprehensive understanding of the broader context in which the nuclear sector operates. **Promotion of nuclear awareness modules** in education curriculum including in vocational training (technicians, computer technology, health professionals, etc.) should begin as early as possible in the young people's education and might help make the nuclear sector more attractive as a whole.
4. **Enhance training that promotes soft skills:** In addition to technical knowledge, education and training providers should enhance the focus on soft skills that are essential for success in the nuclear industry. Soft skills, including leadership, communication, teamwork, problem-solving, and adaptability, are crucial for professionals working in complex and high-stakes environments. By incorporating training modules or courses that promote the development of these soft skills, education and training providers can ensure that graduates are well-rounded and equipped to excel in their careers. Such training can include practical exercises, simulations, case studies, and workshops to provide hands-on experience and foster the development of leadership skills.

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ANNEXES

ANNEX I – SURVEY TEMPLATE



ENEN2+ survey on HR and skills needs in the nuclear sector

Survey objective

To determine the current and future nuclear Human Resources needs of the European nuclear sector up to 2035.
To determine the current and future vocational educational needs of the European nuclear industry.

Disclaimer

The responses to this survey will be kept anonymous and the individual data collected will be kept confidential. The results of the survey will be aggregated in a manner neither allowing for the identification of individual respondents nor for the attribution of individual responses to a respondent.

Content

Section 1: General information

Section 2: Human Resources (Utilities/ Fuel fabrication, enrichment, supply, cycle/ Design, engineering, manufacturing and maintenance/ Transport/Other)

Section 3: Human Resources (Waste management and decommissioning/ R&D institute/ TSO - Technical safety organisation/Regulatory Authorities)

Section 4: Skills and jobs

Section 5: SMRs

Section 6: Training

Section 7: Contact information

Section1: General information

1. Name of your organisation

2. In which country is your organisation based?

3. Your organisation is a (please choose the appropriate answer):

	New Build	Operations	Decommissioning/ back-end
Utilities	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fuel fabrication, enrichment, supply, cycle	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Waste management and decommissioning	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Design, engineering, manufacturing and maintenance	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Transport	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
R&D institute	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
TSO - Technical safety organisation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Regulatory Authority	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other(*)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

(*) Please Specify

4. What is the total number of employees in your organisation globally (nuclear & non-nuclear)?

- 1-9
- 10-99
- 100-499
- 500-999
- 1000-9999
- <10000

If you selected the category Utilities/ Fuel fabrication, enrichment, supply, cycle/ Design, engineering, manufacturing and maintenance/ Transport/Other: go to section 2

If you selected the category Waste management and decommissioning/ R&D institute/ TSO - Technical safety organisation/Regulatory authority: go to section 3

Section 2: Human Resources (Utilities/ Fuel fabrication, enrichment, supply, cycle/ Design, engineering, manufacturing and maintenance/ Transport/Other)

5. How many 'nuclear' staff do you currently employ and how many do you foresee will be required in the future? What is/should be their educational level?

	EQF ¹ 4-5	EQF 6	EQF 7-8
Current			
Forecast for the total number of employees in 5 years			
Forecast for the total number of employees in 10 years			

Go to section 4

Section 3: Human Resources (Waste management and decommissioning/ R&D institute/ TSO - Technical safety organisation/Regulatory authority)

6. How many employees do you currently employ and how many do you foresee will be required in the future? What is their educational level?

Applicable?		NUMBER OF EMPLOYEES			EMPLOYMENT PROJECTION (IN 10 YEARS)					
		EQF 6	EQF 7-8	Total	Decrease more than 10%	Decrease less than 10%	No change	Increase less than 10%	Increase more than 10%	
1. Chemistry and environment and decommissioning										
<input type="checkbox"/>	Nuclear waste management, decommissioning and dismantling (including R&D and planning)				<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>	Radiochemistry				<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>	Water chemistry (incl. corrosion)				<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

¹ [European Qualification Framework](#)

Applicable?		NUMBER OF EMPLOYEES			EMPLOYMENT PROJECTION (IN 10 YEARS)					
		EQF 6	EQF 7-8	Total	Decrease more than 10%	Decrease less than 10%	No change	Increase less than 10%	Increase more than 10%	
2. Nuclear technology, construction and operation										
<input type="checkbox"/>	Construction engineering				<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>	Electrical engineering				<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>	Instrumentation and control				<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>	Mechanics/mechanical engineering				<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>	Nuclear fuel cycle (R&D, front-end, reprocessing and back-end)				<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>	Process engineering				<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>	Project management				<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>	Radiation protection				<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>	Reactor and „hot“ lab operation				<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>	Quality management and inspections				<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
3. Reactor physics, safety, and security										
<input type="checkbox"/>	Organisational and human factors				<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>	Materials science and engineering (nuclear facility materials, failures, component engineering, inspections and lifetime management)				<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>	Nuclear and particle physics				<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>	Reactor physics and dynamics				<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>	Thermal hydraulics and coolants				<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>	Risk analysis (incl. probabilistic risk assessments)				<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>	Safeguards				<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>	Safety and security (business security and fire safety)				<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>	Severe accidents				<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

Applicable?		NUMBER OF EMPLOYEES			EMPLOYMENT PROJECTION (IN 10 YEARS)					
		EQF 6	EQF 7-8	Total	Decrease more than 10%	Decrease less than 10%	No change	Increase less than 10%	Increase more than 10%	
4. Other (*)										
<input type="checkbox"/>					<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>					<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>					<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>					<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>					<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>					<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>					<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>					<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>					<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>					<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>					<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<input type="checkbox"/>					<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

(*) Others = E.g.: support functions such as procurement, personnel admin., training duties, document management, technical sales support; management system; information security; fusion and plasma physics research; official duties; technical business expert duties; management duties; duties related to financial profitability; strategic planning; extensive licensing-related functions; legal duties; environmental control.

Go to section 4

Section 4: Skills and jobs

7. What nuclear profiles are difficult to recruit today?

1.
2.
3.
4.
5.

8. Why?

--

9. Which do you consider will be the top 5 nuclear jobs that will be most in demand in the next 10 years?

1.
2.
3.
4.
5.

10. What do you consider will be the most important knowledge, skills and competences for these roles?

1.
2.
3.
4.
5.

Utilites: go to section 5

Other organisations: go to section 6

Section 5: SMRs

11. Which job categories do you think will be needed to construct and operate SMRs in the future?

12. Which skills do you think the workforce will need in order to meet the needs of these job categories?

13. Do you believe the 'knowledge needs' are met by existing courses/training?

- Yes No

14. What additional 'knowledge' do you believe needs to be developed?

Go to section 6

Section 6: Training

15. Which main areas of nuclear education & training are the most important for your organisation?
And which method of delivery do you prefer?

	1 week short course	Series of 1 day course	Distance learning	e-learning ²	Hands-on training	Other (please specify)	Desired learning outcomes
Nuclear engineering	<input type="checkbox"/>						
Radioprotection	<input type="checkbox"/>						
Nuclear chemistry	<input type="checkbox"/>						
Decommissioning	<input type="checkbox"/>						
Other...							
	<input type="checkbox"/>						
	<input type="checkbox"/>						
	<input type="checkbox"/>						
	<input type="checkbox"/>						
	<input type="checkbox"/>						
	<input type="checkbox"/>						
	<input type="checkbox"/>						

16. What type of VET training would your organisation/employees prefer?

- Taught lectures with notes
- Laboratory practicals
- Worked assignments and tutorials
- Formal examinations and assessments
- Other – please specify

17. What level of recognition of VET training does your organisation prefer?

- National
- International

Go to section7

Section 7: Contact information

18. Do you agree to be contacted for further information?

- Yes No

Name:

Surname:

Phone:

e-mail:

ANNEX II – LITERATURE REVIEW: DOCUMENT SUMMARIES

1. Report of the French Presidency "For a European dynamic of skills in the nuclear field"⁸¹

The report describes the challenges and strategies related to nuclear education, knowledge management, and infrastructure in the European Union.

It discusses the current and future workforce needs in the nuclear industry, the challenges of attracting and retaining talent, and the importance of a diverse workforce. It also highlights the initiatives taken by different organizations to address these challenges, such as promoting STEM education, creating networking opportunities, and supporting diversity and inclusion.

In addition, the report focuses on the importance of promoting education and training in the nuclear sector, as well as the strategies used by various organizations to provide such training. It highlights the role of different organizations, in promoting nuclear education, training, and knowledge management. It also discusses the importance of effective knowledge management for the long-term success of the nuclear industry, and the strategies used to preserve and disseminate this knowledge.

Finally, it discusses the importance of having sufficient infrastructure and resources in the nuclear industry, particularly in fields like nuclear medicine and research. It describes the efforts made by the European Union to guarantee the availability and proper functioning of nuclear infrastructure.

2. Council Recommendation of 22 May 2017 on the European Qualifications Framework for lifelong learning and repealing the recommendation of the European Parliament and of the Council of 23 April 2008 on the establishment of the European Qualifications Framework for lifelong learning⁸²

The council recommendations urge member states to use the European Qualifications Framework (EQF) to reference and compare national qualifications frameworks or systems, ensure qualifications with an EQF level comply with quality assurance principles, and make qualification documents with EQF levels publicly available. They also encourage the use of EQF by social partners, education providers, and public authorities to support the transparency of learning outcomes. The Council recommends the Commission to support consistency in EQF implementation, develop methodologies for the use of learning outcomes, and establish peer learning and best practice exchanges between Member States. The Commission should ensure that the implementation of these recommendations is supported through relevant Union programmes and report on progress following the adoption of these recommendations.

⁸¹ European Council, 'Rapport de La Présidence "Pour Une Dynamique Européenne Des Compétences Dans Le Domaine Nucléaire"'.
⁸² 'Council Recommendation of 22 May 2017 on the European Qualifications Framework for Lifelong Learning and Repealing the Recommendation of the European Parliament and of the Council of 23 April 2008 on the Establishment of the European Qualifications Framework for Lifelong Learning'.

The annexes to the Council recommendations provide – among others – definitions of terms used in the recommendations, including a definition of competence, skills, learning outcomes, etc, as well as a descriptor of levels in the EQF.

3. The labour market in the Dutch nuclear sector. Now and expectations for 2030/2035⁸³

This report discusses the potential impact of different policy scenarios on the employment and labour market in the Dutch nuclear sector. The authors analyse two scenarios: one with unchanged policy and one with planned policy changes. The former scenario would mean that the government does not commit to building new nuclear power plants and that the existing nuclear power plants will close by 2033. In the latter scenario, two new nuclear power plants will be constructed, and the life of the existing ones will be extended. For the purpose of the ENEN2+ report, the narrow nuclear sector, which includes the nuclear organizations represented in Nuclear Netherlands and the Nuclear Safety and Radiation Protection Authority (ANVS) examined in this report is the most relevant.

Based on data collected in the study, the authors estimate that the total staff size of the nuclear sector is around 0.4 million full-time equivalent (FTE), of which about 1,800 FTE are employed within the narrow nuclear sector. Technical staff at MBO (vocational upper secondary education, EQF level 4)- and HBO-level (higher vocational education, EQF level 6) are mainly sought for roles such as operators, operations manager, and technician. In the short term, the authors expect an increase in the number of employees by about 20% due to the realization of two new medical isotope production facilities (PALLAS and SHINE), while in the long term, the increase may reach 30%. In the scenario with planned policy changes, the authors expect an increase in the number of employees at organizations in the narrow nuclear sector to a maximum of around 3,000 FTE in the period 2030-2035.

The authors highlight that there is a growing need for labour in the narrow nuclear sector and a demand for technically skilled personnel. The main jobs in demand are MBO- and HBO-educated staff with a technical background, with vacancies mainly targeting nuclear staff. In the scenario with planned policy changes, the authors also expect a greater need for WO (university education, EQF level 7-8)-educated personnel with a nuclear and technical background. The authors note that competition with other sectors, such as the high-tech sector, is fierce, and that increasing competition among nuclear organizations makes recruitment for nuclear roles increasingly difficult. Finally, the authors expect that the realization of PALLAS, SHINE, and two new nuclear reactors will involve a maximum of some 5,500 FTE of external nuclear-aware labour in the period 2030-2035.

⁸³ Chiel Scholten, Veerle Bastiaanssen, Erwin Karsten and Geert van der Veen, 'De Arbeidsmarkt in de Nederlandse Nucleaire Sector. Nu En Verwachtingen Voor 2030/2035'.

4. Programme MATCH : L'outil de pilotage de l'adéquation besoins-ressources de la filière nucléaire pour être au rendez-vous de ses programmes⁸⁴

The Match programme is a French initiative aimed at addressing the employment needs of the nuclear industry from 2023 to 2033. The programme aims to ensure the industry's adequacy between needs and capacities by focusing on around twenty operational activity segments and their significant professions. The industry projects a 25% increase in workload over the next ten years, which will require around 60,000 new FTE hires, half of which will be for growth and half for retirements or movements to other sectors.

In 2023, it is estimated that over 125,000 jobs are required in the core segments of the industry, with a particular demand for project managers, mechanical design engineers, and maintenance technicians. The most significant employment growth is expected to be in the areas of intellectual services, logistics, transportation, handling, lifting, and nuclear processes. By 2033, an additional 30,000 jobs will be needed, with half of those for new growth and half for replacing retirees.

The majority of this growth will be in the supply chain, as the operators have already established their workforces. This growth is mainly due to the construction of EPR2 nuclear reactors, with an estimated need for an additional 55,000 jobs, with an acceleration of 10,000 jobs per year by 2028-2029. There may be additional growth beyond 2030 due to activities not yet integrated into the data, such as the construction of additional EPR2 pairs, investments in fuel cycle facilities, and export projects in the EU and the rest of the world.

Overall, the nuclear industry in France is facing a significant need for skilled employees over the next decade, with an estimated 100,000 jobs to be created. The industry will need to take action immediately to achieve the necessary rhythm of recruitment, including developing resources, adapting training programmes, and improving working conditions to attract and retain skilled employees. The industry must also anticipate the recruitment of FTEs by at least one to two years and take a proactive approach to recruitment and training to meet the projected employment needs.

5. Survey of Competence in the Nuclear Energy Sector 2017–2018 in Finland⁸⁵

The Ministry of Economic Affairs and Employment established a working group in 2010 to examine long-term competence development in Finland's national nuclear energy sector. In 2019, the results of a survey for 2017-2018 providing insights into the employment situation in the nuclear sector in Finland were published.

According to the survey, the number of nuclear energy experts increased by 16% from 2010, reaching a total of 3,807 individuals. Among them, 50% held a master's degree, 32% had a bachelor's degree, and 18% possessed a secondary education qualification.

⁸⁴ Gifen, 'Programme MATCH. L'outil de pilotage de l'adéquation besoins-ressources de la filière nucléaire pour être au rendez-vous de ses programmes'.

⁸⁵ Hämäläinen and Suolanen, 'Survey of Competence in the Nuclear Energy Sector 2017–2018 in Finland'.

Looking ahead, the demand for personnel in the nuclear energy sector is estimated to be 5% higher in 2030 compared to 2017. While the current number of personnel with a bachelor's degree or secondary qualification is deemed sufficient, there is a need for a 10% increase in the number of individuals holding a master's degree.

Based on the survey results and previous trends, it is expected that Finland will have an adequate supply of personnel in the future. However, special attention should be given to the training and development of junior experts in specific competence areas.

6. Economic and Social Impact Report ⁸⁶

The present study aims to evaluate the contribution of the nuclear power sector to the European Union's overall economy. The analysis assesses the current and future economic and social benefits of the nuclear industry, including its impact on Gross Domestic Product (GDP), job creation, disposable household income, public revenues, and trade balance. The study uses the Computable General Equilibrium (CGE) Model, which simulates the macroeconomic linkages within the EU and measures the impacts in several areas of the economy. The assessment is divided into two impact dimensions, namely direct and indirect dimensions. The direct dimension translates into effects generated directly through operators of nuclear power plants and the supply chain affiliated to the nuclear industry, while the indirect dimension comprises the effects created through economic activities between the nuclear sector and suppliers from other industries and through the expenses of nuclear industry employees and suppliers' employees.

According to the report, the nuclear industry provides over 1.1 million jobs in the European Union, with more than half a million staffed by highly skilled professionals. Each year, the industry sustains 351,900 direct jobs and indirectly supports an additional 777,900 jobs through supplier activities and expenditures. This means that one job in the nuclear industry generates 2.2 indirect jobs in the EU labour market. The industry is considered to be labour-intensive and consists of three major phases: construction, operation, and decommissioning, with different types of supplied labour in each phase. During the operation phase, job activities include engineering, operations, maintenance, and management. The industry sustains a greater share of highly skilled employees (47%) compared to the electricity sector (25-36%).

7. Top-down workforce demand from energy scenarios: Influence of Long-Term Operation⁸⁷

For a selected nuclear energy demand scenario, the influence of long-term operation (LTO) on the HR requirements in the EU28 and enlargement and integration countries were analysed using a top-down approach. The scenario taken into account is officially called the "Delayed Carbon Capture and Storage" or "20% nuclear electricity scenario" from the EC Energy Roadmap 2050.

The reactor fleet was simulated with the Daness tool. The lifetime of the existing reactor park and the potential lifetime extension resulting from possible LTO were also determined. The results have shown that depending on the assumed size of the Generation III reactors (1000 MWe or 1400 MWe)

⁸⁶ Deloitte, 'Economic and Social Impact Report'.

⁸⁷ Roelofs and Von, 'Top Down Workforce Demand from Energy Scenarios'.

to be constructed to meet the energy demand, approximately 95-130 reactors would need to be built between 2010 and 2050 if no LTO is foreseen. However, if LTO is taken into account, this number may decrease to 80-115 reactors. Clearly, LTO delays the need for the construction of new reactors, with the workforce for construction being shifted from 2020-2030 to 2040-2050.

Workforce models were used to calculate the workforce required for the construction and operation of a nuclear power plant (NPP), as well as for LTO. For operation, the workforce in FTE was calculated using a model based on electric power and model constants. This equation can be applied for NPPs smaller than 2000 MWe. The model predicted a workforce in the range of 300 to 500 FTE for a 1000 MWe NPP. By considering a construction time of about 6 years and data from literature, it was possible to estimate the workforce demand for the construction of nuclear reactors. The estimated workforce included high-grade professionals, professionals, technicians, and craftsmen who correspond to nuclear-educated employees, nuclearized engineers, nuclearized technicians, and nuclear-aware workforce from the nuclear skills pyramid. The largest part of the construction workforce will not require specific nuclear skills. The absolute peak demand corresponds to 2500 FTE, with around 2000 FTE corresponding to craftsmen.

For LTO, a model was developed by comparing the investment costs for LTO and new build, considering that LTO activities are closer to new build than to maintenance and operation activities. Therefore, the number of jobs created for LTO is estimated to be around 166 jobs/GWe. The total effort for LTO is allocated over a time span of 15 years, starting 8 years before the original end of life is reached. The manpower required for LTO was determined, and the employment (FTE/MWe) took into account the nuclear skills pyramid.

The influence of LTO was assessed by comparing scenarios with and without LTO. The workforce demand (nuclear, nuclearized technicians, engineers, graduates, and nuclear-aware) for operation and construction indicated that the peak shifts from 2020 to 2040. Additionally, the absolute peak demand slowly decreases when LTO is assumed. The analysis concluded that the workforce for LTO is negligible in comparison to the total workforce required for operation and construction activities. Regarding the effects of LTO on the requirements of "new workforce" (referring to the workforce that will partially replace the aging workforce and meet the total workforce demand) for operation and construction, the peak demand for new personnel will be in 2040 when the existing workforce retires.

8. Measuring Employment Generated by the Nuclear Power Sector⁸⁸

Many nuclear projects are at different stages of development, and existing Nuclear Power Plants (NPPs) are reaching the end of their operational lifetimes. Some NPPs are scheduled for decommissioning, while others are considering extending their lifetimes. In all these varied contexts, it is evident that corresponding jobs are needed.

The OECD Nuclear Energy Agency and the International Atomic Energy Agency collaborated to measure direct, indirect, and induced employment in the nuclear sector in several national economies (USA, Korea, and France) using the Input/Output (I/O) macroeconomic model. Direct

⁸⁸ 'Measuring Employment Generated by the Nuclear Power Sector', Nuclear Energy Agency (NEA), accessed 13 April 2023, https://www.oecd-nea.org/jcms/pl_14912/measuring-employment-generated-by-the-nuclear-power-sector?details=true.

employment refers to jobs at NPPs during construction, operation, decommissioning, and waste management phases. Indirect employment encompasses jobs that supply products and services to these NPP activities, while induced employment includes all employment in the relevant economy generated by direct and indirect expenditures.

The results indicate that in the USA, direct employment during the site preparation and construction of a single 1,000 MWe (net) advanced light water reactor (APR1000) over a 10-year construction period is approximately 1,200 professional and construction staff or about 12,000 labour-years. The construction workforce comprises 70%-75% field craft labour (civil, electrical, mechanical, piping, and instrumentation personnel involved in installation and unit start-up) and 25%-30% non-manual labour (field management, field supervision, field engineers, quality assurance/quality control, environmental-safety and health, and administrative/clerical staff). During 50 years of operation, there are approximately 600 administrative, operation and maintenance, and permanently contracted personnel annually, resulting in about 30,000 direct labour-years. For a 10-year decommissioning period, there are approximately 500 employees annually or about 5,000 direct labour-years. Finally, managing nuclear waste for 40 years requires about 80 employees or around 3,000 direct labour-years. Consequently, the total direct labour-years amount to about 50,000 (excluding labour expenditures in the supply chain). The total employment in the nuclear power sector of a given national economy is therefore estimated to be around 200,000 labour-years over the life cycle of a gigawatt of nuclear generating capacity.

In Korea, the number of full-time equivalent jobs directly created by the nuclear industry was estimated to be around 29,400 persons in 2009 (9,000 persons for the construction of four nuclear power units and 20,400 for the operation of 20 units). Indirect employment was approximately 36,700 (9,400 dedicated to NPP construction and 27,300 to NPP operation). The number of jobs created through induced effects was estimated to be approximately 27,400, including 9,000 in the NPP construction supply chain and 18,400 in NPP operation. The indirect/direct multiplier was 1.25, resulting in 36,700 indirect employees ($1.25 * \text{direct employment}$). The (direct + indirect)/induced multiplier was 0.41, yielding 27,400 induced employees ($0.41 * (\text{direct} + \text{indirect employment})$). With these values, the total employment associated with the nuclear industry as a whole in 2009 was estimated to be 93,500 persons, representing 0.5% of Korean employment.

In France, direct employment was estimated at 125,000 employees, approximately 4% of industrial employment. This total included 23,000 in the front end of the fuel cycle, 27,500 in the construction sector, 47,000 in operation and maintenance, 20,500 in the back end of the fuel cycle, and 7,000 directly employed by the French state.

9. Workforce Planning for New Nuclear Power Programmes⁸⁹

The document provides guidance for workforce planning for both member states (MS) initiating a National Nuclear Programme (NNP) and those updating an existing one. Recommendations regarding the size, type, and quality of the workforce at the country/organizational level are introduced. Workforce planning is considered an integral part of human resources (HR) strategy and plan development. A set of prerequisites for NNP workforce planning includes the definition of clear roles, responsibilities, and functions for all organizations involved. The NEPIO (Nuclear

⁸⁹ IAEA, 'Workforce Planning for New Nuclear Power Programmes'.

Energy Implementation Organization) should establish the basis for these roles, responsibilities, and functions, as well as for coordination. The publication also includes details about the establishment of an appropriate knowledge management (KM) system within the NNP to ensure long-term sustainability. At the organizational level, the needs of NEPIO, regulatory bodies, and operators are exemplified. The approach is based on the IAEA Milestone methodology.

Separate sections are devoted to the competencies and HR needs of the various responsible organizations during each of the three phases (preparation, construction, operation). Practical guidance on recruitment and staffing is provided for the main organizations. The role of education and training organizations is discussed in a separate chapter. Additionally, the publication addresses the concept of KM in the NNP. The guidance offered provides valuable elements on how to initiate the workforce planning process. A final section includes a set of case studies from selected Member States (China, Korea, India, UAE, Armenia).

In terms of quantitative data, the publication provides illustrations of workforce planning cases, with the maximum number obtained during the peak phase: (1) 20-50 staff members for NEPIO, (2) 100-150 for regulatory bodies, (3) 500-1000 for the operation of a single unit, and potentially several thousand for a multiple unit plant. An example of NPP staffing by functions is presented in a separate appendix. For technical safety organizations (TSOs), research, development, and innovation (RDI) organizations, and education and training (E&T) organizations, the document only introduces qualitative considerations. In terms of the level of qualification, the document indicates, based on current experience, that more than 50% of the NPP workforce consists of technical staff with vocational qualifications. Establishing a systematic approach to training (SAT) at an early stage will ensure effective E&T in accordance with the needs of the nuclear sector.

10. Results of surveys of the Supply of and Demand for Nuclear Experts within the EU-28 Civil Nuclear Energy Sector⁹⁰

Two stakeholder surveys were performed in 2018 by EHRO-N: one with higher education institutions (HR supply side) and one from nuclear stakeholders (HR demand side).

In total 36 higher education institutions responded to the survey (a response rate of 40%). Owing to questionable data on new students they were unable to identify trends. The total number of graduates in 2017 reported in the survey is 2,167. Once again, they were not able to identify trends from the data when comparing it to previous surveys.

Just 119 nuclear stakeholders responded to the survey (a response rate of 38%). They reported a total of 16,119 nuclear staff of which 6,949 was reported as Nuclear Experts, 5,198 as nuclearized STEM professionals and 3,972 as nuclear administrative staff.

Nuclear Experts groups "between 45 and 55" and "above 55" amounted to just above 50% in 2010, 52% in 2014 and increased to 56% in 2018. This suggests that there is still a strong need for additional Nuclear Experts in the next decades to replace the aging workforce in the EU-28.

⁹⁰ Brian Eriksen et al., 'Results of Surveys of the Supply of and Demand for Nuclear Experts within the EU-28 Civil Nuclear Energy Sector', 17 December 2019, <https://doi.org/10.2760/499847>.

For Nuclear Decommissioning Staff the survey indicated that the number will remain stable until 2025 but will increase by 30% by 2030. However, the reported workforce for decommissioning in the survey was very low (about 7,000). Published data from the UK indicated a decommissioning workforce of 10,000.

For the Nuclear Power Sector 2015-17 responses indicated that 18% more experts were recruited than departed.

The three most needed positions identified in the case of business enlargement were: nuclear engineer, chemical scientist /chemist, and nuclear technician.

11. Nuclear Job Taxonomy Final Report: A competence-oriented classification of jobs in nuclear power plants⁹¹

The Nuclear Job Taxonomy was prepared via six workshops attended by experts in nuclear education and training and nuclear power plant operations. The overall aim being to provide a tool for organizations and consortia developing activities on nuclear education and training.

The job taxonomy covers the typical job positions in a nuclear power plant during its three life cycle phases: design and construction; operation; and decommissioning. It does not include related areas not carried out in NPP premises such as research, regulatory activities and fuel and waste treatment or nuclear occupations not related with electricity production.

Job profiles are described by their relevant functions and job requirements. The job requirements are meant to be the basic component for the design of learning processes tailored for the specific positions and employees. The primary purpose of the taxonomy is helping in the design of job-oriented qualifications.

12. Nuclear Workforce Assessment⁹² 2021 – UK

The UK Nuclear Workforce Assessment uses a scenario-based approach to provide a comprehensive forecast of skills supply and demand across the nuclear sector – including new build, current operations, decommissioning, research and development and defence activities.

The total demand is formed from the sub-sectors, defence, decommissioning, fuel processing, electricity generation and the civil electricity new build programme. The figure below shows the nuclear timeline.

⁹¹ Chenel, 'Nuclear Job Taxonomy-Final Report. A Competence-Oriented Classification of Jobs in Nuclear Power Plants'.

⁹² 'Nuclear Workforce Assessments | Nuclear Skills Strategy Group'.

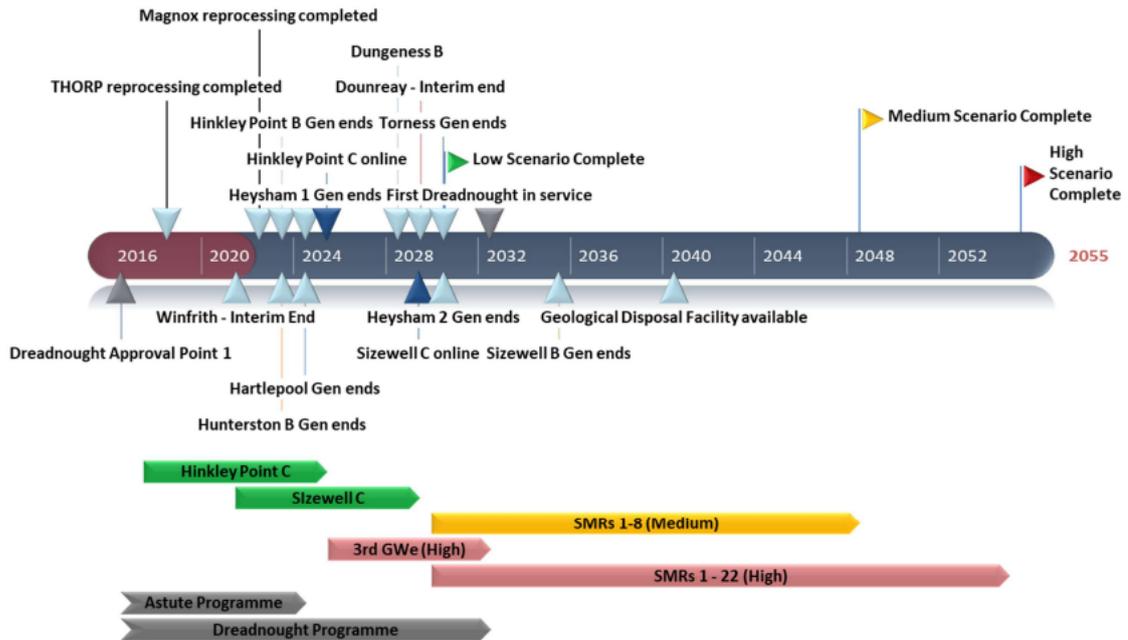


Figure 3 Nuclear timeline

Three scenarios were considered with a mix of large scale and SMR covering High (18.4 GWe – 19.9 GWe, Medium (9.6 GWe – 10.2 GWe) and Low (3.2 GWe). The table gives the workforce projections.

	Inflow per annum	Cumulative total to 2040
Baseline (no new civil newbuild)	3,200 to 2026 – decreasing in the longer term	50,000
High	6,000 – 7,200 except for short period before 2030	>100,000
Medium	6,500 to 2025 with three distinct phases thereafter	~100,000
Low	6,500 to 2025	~65,000

13. Nuclear Workforce / Industry ‘Must Start Preparing Now’ for Future Job Shortages⁹³

According to Thomas Thor Associates the nuclear job market is “fairly stable” largely due to people who have reached retirement age and have remained employed in the sector. The industry needs to think ahead and act now to build a pipeline of talent. Thomas Thor currently sees shortages for project managers and those with rare skills such as digital instrumentation and controls, licensing and quality assurance.

⁹³ Central Office Belgium NucNet a s b l, Brussels, ‘Nuclear Workforce / Industry “Must Start Preparing Now” For Future Job Shortages :: NucNet | The Independent Nuclear News Agency’, The Independent Global Nuclear News Agency, 14 September 2021, <https://www.nucnet.org/news/industry-must-start-preparing-now-for-future-jobs-shortages-12-3-2022>.

14. Five major developments that are setting the stage for 2023 and beyond⁹⁴

Major developments that will affect the demand for the European nuclear workforce include:

Deploying SMRs: Around Europe, companies have signed deals related to all stages of SMR development and deployment.

New Build: According to the International Atomic Energy Agency, around 30 countries are considering or embarking on the construction of new reactors. They include established nuclear nations such as the UK, France, Sweden, the Netherlands, the Czech Republic, Slovakia, China and India, and newcomers such as Poland, Ghana, Kazakhstan, Kyrgyzstan, Saudi Arabia, the Philippines and Indonesia.

Poland's nuclear programme: Poland has ambitious plans to build from 6,000 to 9,000 MW of installed nuclear with commercial operation of a first nuclear unit in a proposed set of six is planned for 2033, with the rest to follow throughout the 2030s and into the early 2040s.

Repowering coal: Countries are looking at repowering existing coal plant infrastructure with small modular reactors. In Poland Korea Hydro & Nuclear Power began investigating the site of a coal plant in southern Poland for the construction of APR1400 nuclear power plants. The Polish private sector is considering SMRs at former coal sites to power industry.

⁹⁴ Nucnet, 'Nuclear Energy / Five Major Developments That Are Setting The Stage For 2023 And Beyond :: NucNet | The Independent Nuclear News Agency', The Independent Global Nuclear News Agency, 27 October 2022, <https://www.nucnet.org/news/five-major-developments-that-are-setting-the-stage-for-2023-and-beyond-1-1-2023>.

ANNEX III – COUNTRY PROFILES

National plans for nuclear and energy in general are detailed in the National Energy and Climate Plans⁹⁵.

1. Belgium

Number of operation reactors: 5

Nuclear capacity: 3,928 MWe

The future of nuclear energy in Belgium is currently under discussion by the government⁹⁶. Recent reports suggest that the government is considering extending the operational lifespan of three nuclear reactors until 2035, despite previous commitments to phase out nuclear energy by 2025^{97,98,99}. Additionally, the government has announced plans to permanently shut down two older reactors - Doel 1 and Doel 2 - by 2025, as part of the country's commitment to phase out nuclear power^{100,101}.

However, the decision to extend the operational lives of the three reactors until 2035 is still subject to public consultation, and the government is expected to make a final decision in the coming months^{102,103}. Recent polls have shown that a majority of the Belgian population supports keeping the nuclear plants online, citing concerns about energy security and the need to reduce carbon emissions¹⁰⁴. The debate over Belgium's nuclear policy has been complex and has involved various stakeholders. SMRs are a technology which the country will continue investigating from a research point of view, but there are currently no plans to develop SMRs in the country¹⁰⁵.

⁹⁵ 'National Energy and Climate Plans (NECPs)', accessed 19 May 2023, https://energy.ec.europa.eu/topics/energy-strategy/national-energy-and-climate-plans-necps_en.

⁹⁶ 'Le gouvernement souhaite prolonger trois autres réacteurs nucléaires', L'Echo, 6 February 2023, <https://www.lecho.be/dossiers/nucleaire/le-gouvernement-souhaite-prolonger-trois-autres-reacteurs-nucleaires/10444922.html>.

⁹⁷ 'Nucléaire : La volte-face du gouvernement belge', accessed 19 May 2023, https://www.lemonde.fr/economie/article/2023/02/06/nucleaire-la-volte-face-du-gouvernement-belge_6160689_3234.html.

⁹⁸ 'Nucléaire : le gouvernement belge envisage la prolongation temporaire de trois réacteurs', LEFIGARO, 3 February 2023, <https://www.lefigaro.fr/flash-eco/nucleaire-le-gouvernement-belge-envisage-la-prolongation-temporaire-de-trois-reacteurs-20230203>.

⁹⁹ 'Belgium Considers Extended Use of Older Reactors : Nuclear Policies - World Nuclear News', accessed 19 May 2023, <https://www.world-nuclear-news.org/Articles/Belgium-considers-extended-use-of-older-reactors>.

¹⁰⁰ 'Nucléaire : La volte-face du gouvernement belge'.

¹⁰¹ 'Nucléaire'.

¹⁰² 'Le gouvernement souhaite prolonger trois autres réacteurs nucléaires'.

¹⁰³ 'Prolongation du nucléaire : Opposition et organisations environnementales dénoncent un accord "qui n'en est pas un" - Rtbf.Be', accessed 19 May 2023, <https://www.rtbf.be/article/prolongation-du-nucleaire-opposition-et-organisations-environnementales-denoncent-un-accord-qui-n-en-est-pas-un-11133689>.

¹⁰⁴ 'Energie en Belgique : le gouvernement décide d'étudier la prolongation d'autres réacteurs nucléaires', RTBF, accessed 19 May 2023, <https://www.rtbf.be/article/energie-en-belgique-le-gouvernement-decide-detudier-la-prolongation-dautres-reacteurs-nucleaires-11147257>.

¹⁰⁵ 'Belgian Government Confirms Closure Plans, Looks to SMRs : Nuclear Policies - World Nuclear News', accessed 19 May 2023, <https://www.world-nuclear-news.org/Articles/Belgian-government-confirms-closure-plans-looks-t>.

2. Bulgaria

Number of operation reactors: 2

Nuclear capacity: 2,006 MWe

The current energy strategy in Bulgaria includes plans for two new reactors at Kozloduy and two at Belene.

In Bulgaria, the share of nuclear power in total electricity production is 34.6% (2021), based on the two operational units (Unit 5 and 6) of Kozloduy NPP, VVER-1000 (V-320). In the past, the share was larger, reaching a maximum of 47.3% in 2002. The four old units (VVER-440 V230) were closed as part of an agreement by the G7 in Munich in 1992, which was implemented as part of the agreement to join the European Union in 2007.

The currently operational units, Unit 5 (1987) and Unit 6 (1991), are included in the ongoing Long-Term Operation (LTO) relicensing programme, with the aim to extend their lifetime from 30 to up to 60 years¹⁰⁶.

The construction of a new plant (Belene plant) with six large units started in 1987 but was halted in 1990. It was then suspended in 1991, work officially resumed in 2008, abandoned again in 2012, and restarted in 2019. However, it has now been definitively abandoned (2021) with the announcement of a new unit to be built in Kozloduy (Unit 7, 1000 MWe) involving the relocation of equipment from Belene¹⁰⁷. Some long-term strategies are discussing the possibility of Kozloduy, Unit 8 (1000 MWe), but a timeline is not clear.

In 2021, a preliminary agreement was signed by Bulgarian Energy Holding with Fluor to investigate the feasibility of replacing coal plants with iPWR SMR (NuScale) in possible configurations of 4/6/12 modules (each of 77 MWe)¹⁰⁸.

Due to the geopolitical crisis, Bulgaria is making new arrangements for licensing and implementing alternative nuclear fuel in order to reduce dependence on Russian nuclear fuel.

Bulgaria is a net exporter of electricity, with a net export of 5.8 TWh in 2022¹⁰⁹. In 2019, the average electricity consumption per capita was 4300 kWh¹¹⁰

¹⁰⁶ 'Nuclear Power in Bulgaria | Bulgarian Nuclear Energy - World Nuclear Association', accessed 19 May 2023, <https://world-nuclear.org/information-library/country-profiles/countries-a-f/bulgaria.aspx>.

¹⁰⁷ djysrv, 'Bulgaria Bids Bye Bye to Belene Again', *Neutron Bytes* (blog), 31 January 2021, <https://neutronbytes.com/2021/01/31/bulgaria-says-bye-bye-to-belene-again/>.

¹⁰⁸ 'Bulgaria Enlists Fluor and NuScale : New Nuclear - World Nuclear News'.

¹⁰⁹ 'Nuclear Power in Bulgaria | Bulgarian Nuclear Energy - World Nuclear Association'.

¹¹⁰ 'Bulgaria Energy Information | Enerdata', 6 March 2023, <https://www.enerdata.net/estore/energy-market/bulgaria/>.

3. Czech Republic

Number of operation reactors: 6

Nuclear capacity: 3,934 MWe

The energy policy in the Czech Republic includes a major increase in nuclear power capacity to 13.9 GWe. CEZ has plans to build four new large-scale reactors and install small modular reactors (SMRs) on existing nuclear and coal-fired power plant sites¹¹¹.

Currently, there are two operational nuclear plants in the Czech Republic, namely Dukovany and Temelín, with a total of six units (4 VVER-440 V213 and 2 VVER-1000 V320). The share of nuclear power in total electricity production was 36.6% in 2021¹¹².

The Dukovany units, which started up between 1985 and 1987, were uprated to 525 MWe as part of a programme completed in 2012. The Long-Term Operation (LTO) project for the Dukovany plant, initiated in 2009, aimed to extend the plant's lifetime by 20 years. All units were licensed for continued operation indefinitely, subject to ongoing reporting, in 2016-2017. The Temelín plant also underwent uprating, with Unit 1 reaching 1125 MWe and Unit 2 reaching 1086 MWe. In 2020, the regulator confirmed the renewal of Unit 1's license for 10 years, while Unit 2 is currently undergoing the renewal process. In February 2023, an investment of approximately USD 100 million was announced for Dukovany to extend the plant's operational lifetime to 60 years, until 2047¹¹³.

The government and industry have announced initiatives to build new reactors, including Dukovany Units 5 and 6, each with a capacity of 1200 MWe (EPR, APR, or AP), expected to be operational by 2036. There is also a possibility of building Temelín Units 3 and 4, also with a capacity of 1200 MWe. Furthermore, the implementation of SMRs is envisaged, with various alternatives being explored, such as WCR, fluoride, and HTR. In 2022, a reserved area of land on the Temelín site was announced for the first SMR¹¹⁴.

The Czech Republic is a net exporter of electricity, with a net export of 11.1 TWh in 2021¹¹⁵. In 2019, the average electricity consumption per capita was 5700 kWh¹¹⁶.

¹¹¹ 'Czech Republic's First SMR Could Be Built at Temelín by 2032 - Nuclear Engineering International'.

¹¹² 'Nuclear Power in the Czech Republic | Nuclear Power in Czechia - World Nuclear Association', accessed 19 May 2023, <https://world-nuclear.org/information-library/country-profiles/countries-a-f/czech-republic.aspx>.

¹¹³ 'Nuclear Power in the Czech Republic | Nuclear Power in Czechia - World Nuclear Association'.

¹¹⁴ 'Czech Republic's First SMR Could Be Built at Temelín by 2032 - Nuclear Engineering International'.

¹¹⁵ 'Nuclear Power in the Czech Republic | Nuclear Power in Czechia - World Nuclear Association'.

¹¹⁶ 'Energy Consumption in Czechia', Worlddata.info, accessed 19 May 2023, <https://www.worlddata.info/europe/czechia/energy-consumption.php>.

4. Croatia

Number of operation reactors: 0

Nuclear capacity: 0 MWe

Croatia co-owns the Krško nuclear power plant with Slovenia and is considering the construction of a new unit on the site.

Croatia does not have a nuclear power plant within its territory, but the country owns half of the Krško nuclear power plant located in Slovenia. The plant consists of one unit with a total capacity of 688 MWe, using a Pressurized Water Reactor (PWR) technology. The reactor began operation in 1981 with an initial operational lifespan of 40 years. In 2015, a decision was made to extend the plant's operational life to 60 years, until 2043, following an investment of approximately €50 million¹¹⁷. Austria has raised objections against the plant's life extension and any new nuclear developments, as reflected in resolutions and petitions from the Austrian Parliament.

In Croatia's National Energy and Climate Plan (NECP), the focus is on decarbonization through increased use of renewable energy sources (RES) and energy efficiency measures. The plan also emphasizes the importance of interconnectivity to ensure energy security. Nuclear power is not envisioned in the NECP, and there is no other information suggesting an interest in nuclear energy for the future. The current energy mix in Croatia (2021) is predominantly composed of oil (37.47%) and gas (28.83%), followed by hydroelectric power (18.83%) and renewable energy sources (9.10%).

Croatia is a net importer of electricity, with a net import of 2.12 TWh in 2021¹¹⁸. In 2020, the average electricity consumption per capita in Croatia was 3,232 kWh¹¹⁹.

5. Estonia

Number of operation reactors: 0

Nuclear capacity: 0 MWe

Estonia is currently considering the possibility of building its first nuclear power plant by 2035, according to a working group established by the Estonian government¹²⁰. The working group,

¹¹⁷ 'Krško Completes IAEA Review of Long-Term Operation : Regulation & Safety - World Nuclear News', accessed 19 May 2023, <https://www.world-nuclear-news.org/Articles/Krsko-completes-IAEA-review-of-long-term-operation>.

¹¹⁸ Balkan Green Energy News, 'Croatia Could Fully Replace Electricity Imports with 1 GW of New Wind Capacity', Balkan Green Energy News, 16 January 2023, <https://balkangreenenergynews.com/croatia-could-fully-replace-electricity-imports-with-1-gw-of-new-wind-capacity/>.

¹¹⁹ Hannah Ritchie, Max Roser, and Pablo Rosado, 'Energy', *Our World in Data*, 27 October 2022, <https://ourworldindata.org/energy/country/croatia>.

¹²⁰ Central Office Belgium NucNet a s b l, Brussels, 'Estonia / Baltic Country Could Have First Nuclear Reactor By 2035, Says Working Group :: NucNet | The Independent Nuclear News Agency', The Independent Global Nuclear News Agency, 16 September 2022, <https://www.nucnet.org/news/country-could-have-first-nuclear-reactor-by-2035-says-working-group-10-3-2022>.

which consists of experts from different fields, has been tasked with assessing the feasibility of nuclear power as an energy source for Estonia in the long term.

In February 2023, Fermi Energia announced that it had chosen GE Hitachi Nuclear Energy's (GEH) BWRX-300 small modular reactor technology for deployment in Estonia¹²¹. The company said that it aims to have the reactor operational by 2031, subject to regulatory approval. This decision came after a competitive selection process involving several nuclear reactor vendors.

To prepare for the potential deployment of nuclear power, Estonia has begun developing legislation for a nuclear programme¹²². The legislation will cover all aspects of the nuclear fuel cycle, including nuclear safety, radiation protection, waste management, and decommissioning.

6. Finland

Number of operation reactors: 5

Nuclear capacity: 4,394 MWe

The current energy policy includes the recent commissioning of a nuclear power reactor and the support of operating lifetime extensions for existing reactors. The country is exploring opportunities for the deployment of SMRs.

Finland has set ambitious goals for decarbonizing its energy sector by 2035. The country's National Energy and Climate Plan (NECP) outlines a vision to phase out coal power by 2029 and increase the use of renewable energy sources to 50% of total energy consumption by 2030. To achieve this, nuclear energy is seen as an essential part of the energy mix, as it provides stable and low-carbon baseload power. Finnish officials have emphasized the importance of nuclear energy in achieving the country's net-zero ambitions¹²³.

Fortum, a Finnish energy company, has signed a memorandum of understanding (MoU) with Rolls-Royce on the possible construction of small modular reactors (SMRs) in Finland and Sweden¹²⁴. The company is also investigating the financial viability of building new reactors in Finland¹²⁵¹²⁶.

¹²¹ 'Fermi Energia Chooses GE Hitachi's BWRX-300 as the Technology for Planned SMR Nuclear Power Plant in Estonia'.

¹²² Toomas Pott ERR ERR |, 'Estonia Could Get Nuclear Power Plant by 2035', ERR, 17 October 2022, <https://news.err.ee/1608754744/estonia-could-get-nuclear-power-plant-by-2035>.

¹²³ 'Nuclear Needed for Net-Zero Ambitions, Finnish Minister Says : Nuclear Policies - World Nuclear News', accessed 19 May 2023, <https://www.world-nuclear-news.org/Articles/Nuclear-needed-for-net-zero-ambitions,-Finnish-min>.

¹²⁴ Nucnet, 'Fortum / Company Signs MOU With Rolls-Royce On Possible Reactors In Finland And Sweden :: NucNet | The Independent Nuclear News Agency', The Independent Global Nuclear News Agency, 17 February 2023, <https://www.nucnet.org/news/company-signs-mou-with-rolls-royce-on-possible-reactors-in-finland-and-sweden-3-2-2023>.

¹²⁵ Nucnet, 'Finland / Fortum To Carry Out "Thorough Investigation" Into Financial Viability Of New Reactors : NucNet | The Independent Nuclear News Agency', The Independent Global Nuclear News Agency, 19 October 2022, <https://www.nucnet.org/news/fortum-to-carry-out-thorough-investigation-into-financial-viability-of-new-reactors-2-5-2023>.

¹²⁶ Nucnet, 'Finland / Fortum Signs MOU To Explore SMRs For Steel Decarbonisation : NucNet | The Independent Nuclear News Agency', The Independent Global Nuclear News Agency, 17 February 2023.

Nuclear energy is viewed as a necessary component of Finland's plan to achieve net-zero emissions by 2035¹²⁷. The CEO of Teollisuuden Voima (TVO), the company that operates three of Finland's nuclear reactors, has stated that the significance of nuclear power has reached new heights since the invasion of Ukraine¹²⁸. The candidate likely to be the next prime minister of Finland has also called for increased focus on nuclear energy¹²⁹.

In addition to producing electricity, SMRs are being considered for other applications, such as steel decarbonization. Fortum has signed an MoU with Outokumpu to explore the use of SMRs for this purpose¹³⁰.

Finland is currently revising its Nuclear Energy Act to incorporate a legal framework for SMRs¹³¹.

7. France

Number of operation reactors: 56

Nuclear capacity: 61,370 MWe

France has ambitious plans to expand its nuclear power capacity by constructing up to 14 new reactors by 2035¹³². President Emmanuel Macron has announced these plans, which are part of the country's long-term energy strategy, aimed at meeting energy needs and reducing carbon emissions. The government's push for nuclear energy has been driven by concerns about energy security and the need to reduce the country's reliance on imported energy sources.

In line with these plans, the French National Assembly has voted to abolish previous proposals to reduce the country's nuclear share to 50% by 2035¹³³. The Senate has also passed a nuclear bureaucracy bill that will streamline the regulatory process for nuclear power plant construction, further paving the way for a nuclear renaissance in France¹³⁴.

<https://www.nucnet.org/news/fortum-signs-mou-with-outokumpu-to-explore-smrs-for-steel-decarbonisation-3-5-2023>.

¹²⁷ 'Nuclear Needed for Net-Zero Ambitions, Finnish Minister Says : Nuclear Policies - World Nuclear News'.

¹²⁸ Nucnet, 'Finland / Significance Of Nuclear Has "Reached New Heights" Since Ukraine Invasion, Says TVO Boss :: NucNet | The Independent Nuclear News Agency', The Independent Global Nuclear News Agency, 3 April 2023, <https://www.nucnet.org/news/significance-of-nuclear-has-reached-new-heights-since-ukraine-invasion-says-tvo-boss-4-3-2023>.

¹²⁹ Nucnet, 'Finland / Candidate Likely To Be Next Prime Minister Calls for Increased Focus on Nuclear :: NucNet | The Independent Nuclear News Agency', The Independent Global Nuclear News Agency, 21 March 2023, <https://www.nucnet.org/news/candidate-likely-to-be-next-prime-minister-calls-for-increased-focus-on-nuclear-4-1-2023>.

¹³⁰ Nucnet, 'Finland / Fortum Signs MOU To Explore SMRs For Steel Decarbonisation'.

¹³¹ 'Finland to Reform Nuclear Energy Act - Nuclear Engineering International'.

¹³² Nucnet, 'France / Macron Announces Ambitious Plans for Up to 14 New Nuclear Reactors'.

¹³³ Nucnet, 'France / National Assembly Votes To Abolish Plans To Reduce Nuclear Share: NucNet | The Independent Nuclear News Agency', The Independent Global Nuclear News Agency, 1 March 2023, <https://www.nucnet.org/news/national-assembly-votes-to-abolish-plans-to-reduce-nuclear-share-3-4-2023>.

¹³⁴ Nucnet, 'France / Senate Passes "Nuclear Bureaucracy" Bill As Country Gears Up For Nuclear Renaissance :: NucNet | The Independent Nuclear News Agency', The Independent Global Nuclear News Agency, 20 December 2022, <https://www.nucnet.org/news/senate-passes-nuclear-bureaucracy-bill-as-country-gears-up-for-nuclear-renaissance-1-4-2023>.

Overall, France's nuclear policy up to 2035 involves expanding nuclear power capacity through the construction of new reactors while maintaining the country's existing reactors¹³⁵. The government's plans have faced some opposition, but recent polling suggests that they have public support¹³⁶. The government's decision to streamline the regulatory process for nuclear power plant construction is expected to facilitate the implementation of its nuclear plans¹³⁷. In addition, the country is aiming to build SMRs.

8. Germany

Number of operation reactors: 0

Nuclear capacity: 0 MWe

Germany no longer has any operating nuclear reactors since April 2023¹³⁸.

A total of 33 nuclear power reactors are undergoing decommissioning, four nuclear power reactors have been taken out of operation and are in different stages of receiving a licence for decommissioning, and three nuclear power plants have already been fully dismantled. Licensees are responsible for the decommissioning of nuclear power plants. The exception is the decommissioning of the NPPs Greifswald and Rheinsberg in the former East Germany and several research reactors for which EWN GmbH, a state-owned company is responsible.

A 2022 survey showed that, owing to the energy crisis, 41% of Germans are currently in favour of building new nuclear plants¹³⁹.

9. Hungary

Number of operation reactors: 4

Nuclear capacity: 1,916 MWe

Hungary has one operational nuclear power plant located in Paks. The plant consists of four VVER-440 V213 reactors that provided a reliable source of 16.1 TWh, accounting for 46% of the country's electricity production in 2020. The Paks Nuclear Power Plant (NPP) is owned and operated by MVM Paks Nuclear Power Plant Ltd, a subsidiary of the state-owned MVM Hungarian Electricity Ltd¹⁴⁰.

¹³⁵ Nucnet, 'France / Macron Announces Ambitious Plans For Up To 14 New Nuclear Reactors'.

¹³⁶ 'Sondage : Les Français plébiscitent un mix renouvelable et nucléaire – EURACTIV.Fr', accessed 19 May 2023, <https://www.euractiv.fr/section/energie/news/sondage-les-francais-plebiscitent-un-mix-renouvelable-et-nucleaire/>.

¹³⁷ Nucnet, 'France / Senate Passes "Nuclear Bureaucracy" Bill As Country Gears Up for Nuclear Renaissance'.

¹³⁸ Nucnet, 'Germany's Nuclear Shutdown / Last Three Plants To Go Offline, Despite Last-Minute Appeals For Extensions'.

¹³⁹ Isabeau van Halm, 'Weekly Data: Shift in Germany's Perception of Nuclear Energy', *Energy Monitor* (blog), 22 August 2022, <https://www.energymonitor.ai/policy/weekly-data-shift-in-germanys-perception-of-nuclear-energy/>.

¹⁴⁰ 'Nuclear Power in Hungary | Hungarian Nuclear Energy - World Nuclear Association', accessed 19 May 2023, <https://world-nuclear.org/information-library/country-profiles/countries-g->

The reactors at Paks began operation in the following years: Paks 1 (1982), Paks 2 (1984), Paks 3 (1986), and Paks 4 (1987). Initially designed for a service life of 30 years, a feasibility study conducted to extend their operational lifetime by 20 additional years found no issues, allowing for operation of up to 50 years. Permissions to operate for another 20 years were granted to each unit, with Paks 1 receiving permission in 2012, Paks 2 in 2014, Paks 3 in 2016, and Paks 4 in December 2017. These extensions enable operation until 2032, 2034, 2036, and 2037, respectively. Upgrades to the secondary circuit and turbine have increased the electrical output of each unit to approximately 470 MW(e). By the end of 2009, the uprating process was successfully completed on all four units. As a result, the nominal electrical power outputs of the units are 508.6 MW, 506 MW, 506 MW, and 506 MW, respectively¹⁴¹.

To maintain the capacity of the Paks NPP and meet future electricity demands in the country, the construction of two new units, referred to as Paks II, is planned. In March 2009, the Parliament approved a government decision to build additional reactors, and a tender was prepared in compliance with European rules. In 2014, the Paks II project was awarded to Rosatom (Russia) for the construction of two VVER-1200 reactors, which are expected to be operational by 2032. An environmental permit was issued in September 2016, followed by a site license issued in March 2017 by the Hungarian Atomic Energy Authority (HAEA)¹⁴². A license application for Paks 5 and 6 was submitted to the regulator in July 2020. In August 2022, the HAEA issued the construction license for the two VVER-1200 PWRs at Paks II, which will be built by Rosatom. Despite the economy-wide sanctions against Russian companies, both Hungarian and Russian authorities have confirmed that the Paks II project is proceeding. In May 2022, Rosatom provided reassurances to Hungarian authorities regarding their technological capability to complete the project¹⁴³.

10. Italy

Number of operation reactors: 0

Nuclear capacity: 0 MWe

Currently, Italy does not have any operational nuclear reactors. All reactors were shut down, with the last one ceasing operation in 1990 due to public reactions following the Chernobyl disaster. In 2008, there was a government intention to introduce a new nuclear programme with a target of achieving a 25% share of nuclear energy in the total electricity generation by 2030¹⁴⁴. However, in 2011, a national referendum rejected this policy proposal.

In 2022, it was announced that all nuclear facilities in the country, including power reactors and nuclear fuel facilities, would be decommissioned.

n/hungary.aspx#:~:text=Hungary%20has%20four%20nuclear%20reactors,has%20been%20signed%20fo
r%20these.

¹⁴¹ 'Hungary 2022', accessed 19 May 2023, <https://cnpp.iaea.org/countryprofiles/Hungary/Hungary.htm>.

¹⁴² 'Nuclear Power in Hungary | Hungarian Nuclear Energy - World Nuclear Association'.

¹⁴³ 'Hungary and Rosatom Push Ahead on Paks II Nuclear Project: New Nuclear - World Nuclear News', accessed 19 May 2023, <https://www.world-nuclear-news.org/Articles/Hungary-and-Rosatom-push-ahead-on-Paks-II-nuclear>.

¹⁴⁴ 'Nuclear Energy in Italy: Italian Nuclear Power - World Nuclear Association', accessed 19 May 2023, <https://world-nuclear.org/information-library/country-profiles/countries-g-n/italy.aspx>.

It is worth noting that higher education institutions in Italy have shown constant interest and efforts to maintain nuclear engineering in their university curricula. However, most graduates in this field tend to seek opportunities abroad in countries with operational nuclear installations.

Currently, there is no national policy in Italy specifically targeting the development of nuclear power. However, there is a possibility of renewed interest from the government that could potentially lead to changes in this regard¹⁴⁵. However, a motion for the possible return of nuclear power to Italy was approved by the lower house of parliament on 9 May 2023.

Italy is a net importer of electricity, with a net import of 32.2 TWh in 2020¹⁴⁶. The energy consumption per capita in 2020 was approximately 4600 kWh¹⁴⁷.

11. Lithuania

Number of operation reactors: 0

Nuclear capacity: 0 MWe

Lithuania is currently decommissioning the two reactors at Ignalina¹⁴⁸.

12. Netherlands

Number of operation reactors: 1

Nuclear capacity: 482 MWe

Nuclear power is at the heart of its climate and energy policy. It is taking steps to build two new nuclear power stations¹⁴⁹. The two reactors would provide 9-13% of the Netherlands' electricity production in 2035. They are currently exploring the potential of deploying SMRs in the province of Limburg¹⁵⁰.

The Netherlands has one nuclear power reactor in operation - Borssele - 3.9 TWh which accounts for about 3.2 % of electricity generation, one nuclear power plant (NPP) in safe enclosure - Dodewaard with final decommissioning due to start in 2045 and two research reactors.

All aspects of decommissioning are the responsibility of the nuclear operator.

Public support for nuclear power is strong¹⁵¹.

¹⁴⁵ 'Italy Takes Another Step toward New Nuclear Plants'.

¹⁴⁶ 'Nuclear Energy in Italy : Italian Nuclear Power - World Nuclear Association'.

¹⁴⁷ 'Italy Energy Information | Enerdata', 10 May 2023, <https://www.enerdata.net/estore/energy-market/italy/>.

¹⁴⁸ Belgium, 'Lithuania / Consortium Chosen to Plan Dismantling and Waste Management at Ignalina.

¹⁴⁹ 'Netherlands Plans to Build Two Nuclear Power Plants by 2035 | Reuters', accessed 19 May 2023, <https://www.reuters.com/business/energy/netherlands-plans-build-two-nuclear-power-plants-by-2035-2022-12-09/>.

¹⁵⁰ Nucnet, 'Netherlands / Province Of Limburg To Look At SMRs For Industry'.

¹⁵¹ 'The Netherlands, Facing Energy And Climate Crises, Bets On A Nuclear Revival | HuffPost Impact', accessed 19 May 2023, https://www.huffpost.com/entry/netherlands-nuclear-energy_n_62aba4d2e4b04a61735a273a.

13. Poland

Number of operation reactors: 0

Nuclear capacity: 0 MWe

Energy policy in Poland includes the commissioning of the country's first nuclear power reactor in 2033, followed by subsequent units, with an investment of PLN 140 billion (approximately USD 40 billion).

Currently, Poland is planning to introduce nuclear power as part of its strategy to reduce heavy dependence on coal in the energy portfolio. In the past, there were some attempts to initiate the development of a series of nuclear power plants on the Baltic Sea coast, including potential participation in the Visaginas nuclear power plant project in Lithuania. The Polish Nuclear Programme, announced in 2014, outlined plans to build nuclear plants with a total capacity of 6 GWe. This plan was revised in 2018 to a range of 6-10 GWe, with the first operational unit expected in 2033 and completion of the investment by 2043¹⁵².

In 2021, PEJ, a public company responsible for the Polish nuclear programme, announced Choczewo as the site for the first unit. In 2022, PEJ submitted the Environmental Impact Assessment report for the project, and the selection of technology is currently underway.

Poland has expressed its intention to introduce small modular reactors (SMRs) and has signed cooperation agreements with U.S. SMR developers¹⁵³.

Poland is a net importer of electricity, with a net import of 13.3 TWh in 2020¹⁵⁴. The average energy consumption per capita is approximately 3500 kWh¹⁵⁵].

14. Romania

Number of operation reactors: 2

Nuclear capacity: 1,300 MWe

Romania currently operates one nuclear power plant (NPP) with two pressurized heavy water reactors (PHWR) of Candu-6 type, each with a net capacity of 650 MWe. Cernavoda NPP Units 1 and 2 started operating in 1996 and 2007 respectively. In 2020, they contributed approximately 11.4 TWh, accounting for about 18% of the total energy generated in the country. These reactors are the only Candu reactors in operation in Europe.

As Cernavoda NPP Unit 1 approaches its design lifetime of 30 years, the Romanian nuclear utility Nuclearelectrica (SNN) is considering a refurbishment project to extend its operation for an additional 30 years. The Unit 1 refurbishment project, initiated in 2017, is being implemented in three phases: project definition (2017-2022), project implementation (February 2022 - 2026), and

¹⁵² Vujasin, 'Poland to Build Three Nuclear Power Plants'.

¹⁵³ 'Polish Plans for Large and Small Reactors Progress : New Nuclear - World Nuclear News'.

¹⁵⁴ 'Nuclear Power in Poland - World Nuclear Association', accessed 19 May 2023, <https://world-nuclear.org/information-library/country-profiles/countries-o-s/poland.aspx>.

¹⁵⁵ 'Poland Energy Information | Enerdata', 21 April 2023, <https://www.enerdata.net/estore/energy-market/poland/>.

refurbishment outage (estimated at 24 months between December 2026 and December 2028). The recommissioning of Cernavoda NPP Unit 1 for another lifecycle of 30 years is expected after 2029¹⁵⁶.

Cernavoda NPP Units 3 and 4, also Candu 6 type reactors with a gross capacity of 720 MWe each, are currently under preservation, with plans to resume their construction. The implementation is divided into three phases. Phase 1 (preparatory phase) started at the end of 2021 and will last for 2 years. Phase 2 (preliminary works) involves site preparations and is expected to take 1.5 to 2 years. Phase 3 (construction phase) is estimated to last 6.5 years, leading to the commissioning of Unit 3 in 2030 and Unit 4 a year later¹⁵⁷.

In November 2021, SNN signed an agreement with U.S. small modular reactor (SMR) vendor NuScale to build a 12-module NuScale SMR plant at a former coal plant in Romania, with construction anticipated to begin in 2027-2028¹⁵⁸. In May 2022, Doicești in Dâmbovița County, Muntenia region, was selected as the reference site for Romania's first SMR. A contract for front-end engineering and design work for a Voygr-6 power plant at Doicești was signed in December 2022¹⁵⁹.

Romania is also involved in the development of Lead-cooled Fast Reactor (LFR) technology. As per the Government Memorandum in 2013, Romania will host the Alfred (Advanced Lead-cooled Fast Reactor European Demonstrator) with a capacity of 125 MWe, serving as a demonstrator for LFR technology to prove its economic and technical viability. The Alfred implementation is currently in the preparatory phase, with a pre-licensing step initiated in 2017. In this context, six large facilities to support the licensing process and future LFR technology development are proposed to be built on the Mioveni nuclear platform. Two facilities (Athena and ChemLab) are under construction and scheduled to be completed by December 2023, while the remaining four facilities (Helena2, ELF, HandsON, Meltin'Pot) are planned to be operational in 2026¹⁶⁰.

15. Slovakia

Number of operation reactors: 5

Nuclear capacity: 2,308 MWe

In Slovakia, there are currently five pressurized water reactors (PWR) of the VVER-440 V213 model in operation: two units at the Bohunice site and three units at the Mochovce site. In 2020, these

¹⁵⁶ MarketScreener, 'S N Nuclearelectrica S A : Nuclearelectrica Advances Cernavoda NPP Unit 1 Refurbishment Project through New Agreement with SNC-Lavalin Group | MarketScreener', accessed 19 May 2023, <https://www.marketscreener.com/quote/stock/S-N-NUCLEARELECTRICA-S-A-16239843/news/S-N-Nuclearelectrica-S-A-Nuclearelectrica-advances-Cernavoda-NPP-Unit-1-Refurbishment-Project-thro-43179522/>.

¹⁵⁷ 'Units 3 and 4 – Nuclearelectrica', accessed 19 May 2023, <https://www.nuclearelectrica.ro/project-development-activities/units-3-and-4/?lang=en>.

¹⁵⁸ 'Newbuild: Romania Talks of Building "Europe's First SMR" | Energy Intelligence', accessed 19 May 2023, <https://www.energyintel.com/0000017c-ebe8-df56-a57f-ffe2c400000>.

¹⁵⁹ 'Nuclear Power in Romania | Romanian Nuclear Energy - World Nuclear Association', accessed 19 May 2023, <https://world-nuclear.org/information-library/country-profiles/countries-o-s/romania.aspx>.

¹⁶⁰ Marin Constantin, Daniela Diaconu, Daniela Gugiu, Ilie Turcu, Minodora Apostol, Mirela Nitoi, Giacomo Grasso, Mariano Tarantino, Michele Frignani, Marco Caramello, 'Experimental Infrastructure in Support of Alfred Licensing Process and of Lead Fast Reactor Technology Development' (Journal of Nuclear Research and Development, May 2023).

reactors produced a stable 28.6 TWh or 54% of the country's electricity¹⁶¹. The state utility responsible for operating and owning the reactors is Slovenské Elektrárne (SE).

At the Mochovce plant, Units 1 and 2 were connected to the grid in 1998 and 1999, respectively. These units have undergone significant upgrades, including the replacement of instrumentation and control (I&C) systems with assistance from Western companies. Upgrades were implemented, increasing the net capacity of Mochovce 1 and 2 from 405 to 436 MWe. Further upgrades of turbines are planned to bring them to about 466 MWe net (500 MWe gross)¹⁶².

Units 3 and 4 at the Bohunice plant were connected to the grid in 1984 and 1985, respectively. SE carried out a modernization programme for these units from 2005 to 2008, improving their seismic resistance, cooling systems, and I&C systems. As a result, the capacity of each unit was increased from 440 MWe gross to 505 MWe gross. Plans also exist to extend the licenses of these two units until 2045¹⁶³.

Construction of Mochovce 3 (VVER 440 V213) began in 1987 but was suspended in 1993 and resumed in 2009. It was connected to the grid on January 31, 2023. Additionally, another VVER 440 V213 unit is currently under construction at Mochovce, with a commercial date expected in October 2024¹⁶⁴.

Slovakia also has three permanently closed reactors at the Bohunice site. Bohunice A-1, a small 93 MW unit (Heavy Water Gas-Cooled Reactor), started operation in 1972 but was closed in 1977 due to several accidents. The other two VVER-440 V230 reactors (Bohunice 1 & 2) were closed in 2006 and 2008, respectively, as part of Slovakia's agreement to join the European Union in 2004¹⁶⁵.

The decommissioning process for the Bohunice A-1 reactor is ongoing, with spent fuel already returned to Russia by 1990. Preparation for decommissioning Bohunice 1 and 2 began in 2012, and these reactors were fully dismantled by the end of July 2022. The remaining equipment and systems at the site will be dismantled and processed by 2025, and the power plant buildings will be demolished, making the site ready for new use by 2027¹⁶⁶.

Plans for new nuclear construction were outlined in Slovakia's Energy Security Strategy in October 2008. It mentioned the construction of a new reactor block at the Jaslovské Bohunice site by 2025, with a gross capacity of 1200 MWe, possibly utilizing Western technology to enable the use of MOX fuel. However, the 2019 Integrated National Energy and Climate Plan for 2021 to 2030 stated that the proposed 1200 MWe reactor at Bohunice would not be commissioned until after 2035. Jadrová Energetická Spoločnosť Slovenska (Jes), a joint venture between Slovak radioactive waste management company Javys and Czech utility ČEZ, has requested a siting permit from the Slovak nuclear regulator UJD for this new reactor block. According to reports, Jes plans to apply for a construction license at the end of 2025, with construction work expected to start in 2031¹⁶⁷.

¹⁶¹ 'Nuclear Power in Slovakia | Slovakia Nuclear Energy - World Nuclear Association'.

¹⁶² 'Nuclear Power in Slovakia | Slovakia Nuclear Energy - World Nuclear Association'.

¹⁶³ 'Nuclear Power in Slovakia | Slovakia Nuclear Energy - World Nuclear Association'.

¹⁶⁴ 'Slovakia 2022', accessed 19 May 2023,

<https://www.pub.iaea.org/MTCD/Publications/PDF/cnpp2022/countryprofiles/Slovakia/Slovakia.htm>.

¹⁶⁵ 'Nuclear Power in Slovakia | Slovakia Nuclear Energy - World Nuclear Association'.

¹⁶⁶ 'Nuclear Power in Slovakia | Slovakia Nuclear Energy - World Nuclear Association'.

¹⁶⁷ Nucnet, 'Slovakia / Regulator Receives Siting Permit Request For New Reactor At Bohunice :: NucNet | The Independent Nuclear News Agency', The Independent Global Nuclear News Agency, 23 January 2023, <https://www.nucnet.org/news/regulator-receives-siting-permit-request-for-new-reactor-at-bohunice-2-4-2023>.

16. Slovenia

Number of operation reactors: 1

Nuclear capacity: 688 MWe

The Krško nuclear power plant (NEK), which is jointly owned by Slovenia and Croatia, accounts for over 30% of Slovenia's electricity production. In 2019, NEK generated 5.8 TWh or 36% of Slovenia's electricity¹⁶⁸.

The Krško nuclear power plant, a 688 MWe Westinghouse pressurized water reactor (PWR), was connected to the grid in 1981 with an initial operational life of 40 years, scheduled to end in 2023. In 2001, the steam generators were replaced, and the plant underwent a 6% uprate followed by an additional 3% uprate. The Slovenian and Croatian state-owned energy firms GEN Energija and HEP, which manage the Krško NPP, have decided to extend its lifespan by 20 years until 2043, as approved by Nuklearna Elektrarna Krško, the plant operator¹⁶⁹. In January 2023, after completing the environmental impact assessment, the Ministry of the Environment approved the extension of Krško's operating lifetime. Krško NPP initiated an ageing management programme in 2008 as a prerequisite for the extension. The plant also underwent periodic safety reviews, with the third review scheduled between 2021 and 2023.

Following the Fukushima Daiichi accident, Krško NPP developed a Safety Upgrade Programme (SUP) approved by the Slovenian Nuclear Safety Administration (SNSA). The SUP included safety improvements such as the installation of alternate bunkered systems for cooling water injection, an alternate system for cooling the spent fuel pool, a filtered venting system, passive hydrogen recombiners, an emergency control room, and enhanced flood protection measures, among others. These improvements were completed by the end of 2021.

The Krško reactor is located in a seismically active area, and on 29 December 2020, it was temporarily shut down due to a 6.3 magnitude seismic event near the town of Petrinja, approximately 30 km from the plant.

In January 2010, GEN Energija submitted an application to the Ministry of Economy for a second reactor, known as the JEK 2 project, with a capacity ranging from 1100 to 1600 MWe at the Krško NPP site. The decision regarding the construction of a new NPP will be made by 2027, based on the national energy and climate programme. The energy permit for JEK 2, issued by the Ministry of Infrastructure in July 2021, represents an important step in the planning procedures for the investment¹⁷⁰.

¹⁶⁸ 'Nuclear Power in Slovenia | Slovenia Nuclear Energy - World Nuclear Association', accessed 19 May 2023, <https://world-nuclear.org/information-library/country-profiles/countries-o-s/slovenia.aspx>.

¹⁶⁹ 'Life Extension for Slovenia's Krško NPP - Nuclear Engineering International', accessed 19 May 2023, <https://www.neimagazine.com/news/newslife-extension-for-slovenias-krsko-npp-4885976/>.

¹⁷⁰ Nucnet, 'Krško / Slovenia To Take Investment Decision On New Unit By 2027, Say Reports'.

17. Spain

Number of operation reactors: 7

Nuclear capacity: 7,123 MWe

The Spanish government's energy and climate plan specifies that installed nuclear capacity will remain at current levels of about 7,100 MW until at least 2025 but will be reduced to just over 3,000 MW from 2030 onwards¹⁷¹.

At present, Spain has seven power reactors in operation on five sites: Almaraz I and II, Ascó I and II, Cofrentes, Trillo and Vandellós II. Three other power reactors have already been shut down: José Cabrera, Vandellós I and Santa María de Garoña¹⁷².

Decommissioning of nuclear facilities is the responsibility of the Spanish radioactive waste management agency Empresa Nacional de Residuos Radiactivos S.A. (Enresa)¹⁷³.

18. Sweden

Number of operation reactors: 6

Nuclear capacity: 6,937 MWe

Sweden is preparing for a potential expansion of its nuclear power sector in the coming years. The Swedish government has announced that it is working on legislation to allow for the construction of new nuclear power plants, removing some of the obstacles to the deployment of small modular reactors (SMRs) in the country¹⁷⁴.

The decision to explore nuclear expansion is in line with Sweden's draft National Energy and Climate Plan (NECP), which includes a target of net-zero greenhouse gas emissions by 2045. The NECP recognizes nuclear power as an important low-carbon energy source and states that Sweden will continue to rely on nuclear power for the foreseeable future.

The government's plans for new nuclear construction and SMRs could potentially lead to the installation of additional nuclear capacity beyond the current level of approximately 7 GWe.

The development of SMRs has become an important topic in Sweden, with energy companies exploring the potential for these smaller reactors to be deployed in the country¹⁷⁵. SMRs offer the potential for more flexible and localized energy production, which could be useful in Sweden's remote areas.

¹⁷¹ Spasić, 'Spain on Track to Phase out Nuclear Power, Coal by 2035'.

¹⁷² 'Spain 2019', accessed 19 May 2023, <https://cnpp.iaea.org/countryprofiles/Spain/Spain.htm>.

¹⁷³ 'Nuclear Power in Spain | Spanish Nuclear Energy - World Nuclear Association', accessed 19 May 2023, <https://world-nuclear.org/information-library/country-profiles/countries-o-s/spain.aspx>.

¹⁷⁴ Nucnet, 'Sweden / Government Preparing Legislation For Construction Of New Nuclear Power Plants :: NucNet | The Independent Nuclear News Agency', The Independent Global Nuclear News Agency, 28 June 2022, <https://www.nucnet.org/news/government-preparing-legislation-for-construction-of-new-nuclear-power-plants-1-3-2023>.

¹⁷⁵ 'Swedish Government Frees up Legislation on Nuclear Expansion'.

19. United Kingdom

Number of operation reactors: 9

Nuclear capacity: 5,883 MWe

The British Energy Security Strategy is centred on a significant expansion of nuclear energy, with an ambition of up to 24 GWe of capacity by 2050 to provide about 25% of electricity¹⁷⁶. To achieve this the UK government plans are to deploy both large scale NPPs and develop small modular reactors.

The United Kingdom currently has nine operating nuclear reactors (8AGRs and 1PWR) at 6 generating stations across England and Scotland. Two new EPR reactors are currently under construction at Hinkley Point¹⁷⁷ and there are two in the pipeline at Sizewell. Overall, 8 new reactors could be built in the United Kingdom during the coming years¹⁷⁸.

All eleven of the Magnox NPPs have ceased operating and are in varied states of defueling and decommissioning. Responsibility for decommissioning of the Magnox nuclear power reactors in the UK lies with the Nuclear Decommissioning Authority (NDA), which will also decommission the AGRs once the de-fuelling stage has been undertaken¹⁷⁹.

A recent survey showed an increase in support for nuclear as a result of the global energy crisis and the war in Ukraine¹⁸⁰.

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¹⁷⁶ 'British Energy Security Strategy', GOV.UK, accessed 19 May 2023, <https://www.gov.uk/government/publications/british-energy-security-strategy/british-energy-security-strategy>.

¹⁷⁷ 'Nuclear Power in the United Kingdom |UK Nuclear Energy - World Nuclear Association', accessed 19 May 2023, <https://world-nuclear.org/information-library/country-profiles/countries-t-z/united-kingdom.aspx>.

¹⁷⁸ 'Energy Strategy'.

¹⁷⁹ 'United Kingdom 2022', accessed 19 May 2023, <https://cnpp.iaea.org/countryprofiles/UnitedKingdom/UnitedKingdom.htm>.

¹⁸⁰ 'Polls Find Strong Support for Nuclear in UK and Switzerland : Nuclear Policies - World Nuclear News', accessed 19 May 2023, <https://www.world-nuclear-news.org/Articles/Polls-find-strong-support-for-nuclear-in-UK-and-Sw>.

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Final Audit Report

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