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1. 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 may be its biggest obstacle. The nuclear sector relies heavily on a specialized and highly trained workforce for its safety and sustainability.

The work of the task force has demonstrated that it is very difficult to get precise data on the nuclear workforce through European wide surveys. A national Nuclear Workforce Assessment (NWA) can be an important tool for establishing comprehensive understanding of current and future human resources demands, understanding the supply of skills and competences, identifying possible gaps between supply and demand, and establishing an action plan with remediate measures. According to our research the direct workforce for the EU27 + UK in nuclear Research and Development, Regulation and Decommission and Waste Management are estimated around 52,500 jobs, with the following distribution:

- Nuclear R&D (incl. TSO's and research reactors): 22,500 jobs
- Nuclear Decommissioning and Waste Management: 25,000 jobs
- Nuclear Regulators (safety and security): 5,000 jobs

Indirect jobs supported through the supply chains are assumed to be similar in number, bringing the total to over 100,000 jobs. To sustain current operations, these sectors will require over 30,000 additional jobs by 2036 just to compensate for retirements. Results from the survey indicated diverse opinions regarding the most in-demand nuclear jobs in the next ten years. However, the top five disciplines reported were:

- decommission and waste management,
- radiological protection,
- nuclear engineering,
- (nuclear) physics,
- medical application.

Demand for specific nuclear jobs may vary across European countries due to variations in energy policies, public health policies, and nuclear capacities. Nevertheless, the afore mentioned disciplines are generally expected to be high in demand as Europe continues to tackle its energy needs, public health policies, nuclear safety, and waste management challenges.

The demand for clean energy, the increased range of non-power applications, as well as long term perspectives related to nuclear fusion and the ITER project, are likely to ensure that the nuclear sector as a whole will continue to evolve and expand over the next ten years and beyond. However, such increase is likely to vary in the different nuclear subsectors, depending on national policies and programmes. It should be stated that this report does not cover human resources needs necessary for the development of the European nuclear fusion activities.

A full understanding of the workforce size, its needs in terms of competences and possible mitigating measures can only be established through involvement of all relevant stakeholders (ministries responsible for nuclear programmes, industry organizations, regulatory authorities, technical safety organizations, research and training infrastructures and academia).

Nuclear energy will continue being a backbone of the electric generation in Europe. Despite the phasing out policy followed by some EU countries, nuclear energy is considered in many countries as quite important and a clear asset to achieve the goal of net zero carbon emissions beyond 2050. Therefore, strong commitments have been undertaken by 11 countries to accelerate the development and construction of new nuclear power plants. These new reactors are designed with extremely high safety features and an expected lifetime exceeding 60 years. In those countries, R&D centres and institutional as well as industrial support have indicated their intention to increase their human resources and skills in nuclear. Countries that have decided to phase-out nuclear energy will have nonetheless to deal with decommissioning, dismantling and waste management issues with the appropriate human resources.

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2. Introduction

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 networks on public information,
- energy context including, as we experienced it painfully recently, high intensity 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.

Factors which should be considered when looking at the consequences in terms of human resources needs in each specific country include:

- background regarding nuclear science and technology: is there already a nuclear history in the country (research reactor operated locally, use of nuclear applications in medicine or in any other non-energetic nuclear application, etc.)? Are there E&T structured opportunities for students who wish to embark on a career 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, consideration of SMR option, wish to develop a local nuclear value chain or rely on international cooperation up to 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) and 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.

The scope of organizations and stakeholders that are involved in the analysis of HR needs is large:

- government related organizations (ministries, governmental agencies including those in charge of environmental issues, etc.),
- safety regulators that require specific attention as an anticipated deployment of critical competences is compulsory (e.g., for licensing processes),
- owner / operator (that could be separate organizations) for the operation and maintenance of the NPP,
- industrial in the local supply chain for manufacturing products, nuclear components, or providing services, etc.

Moreover, the scope of competences will change over the life cycle of the nuclear facilities, clearly inducing a strong impact on the anticipation of the number and types of competences needed overtime. Some milestones will introduce changes in the number and type of competences needed such as:

- regulatory framework set up, investment decision,
- owner/operator set up,
- first concrete, first fuel loading, first connection to the grid,
- start of decommissioning, dismantling phase, etc.

The case of the plant owner and/or operator is a typical and critical example because it must:

- manage construction phase, engineering, on site works control, civil works competences will be critical and will induce peaks in terms of number of workers,
- ensure availability of staff for safe and secure operation and maintenance of the nuclear plant during its whole lifetime (60 years or more), shift managers need a very specific and long-lasting training before being certified. Job mobility, retirements, and eventually new builds to come simultaneously must be considered in HR long-term planning,
- acquire in-depth knowledge of the plant to conduct decommissioning and dismantling phases, therefore relying mainly on owner/operator staff in charge of the plant during its operation. For dismantling, specialized companies might bring their own know-how, therefore introducing new needs in competences.

Whereas the trained workforce should be available at the right time, it is also essential that the trained workforce is not ready too early. Experience has demonstrated that many trained people, when they have had no opportunity to work for the nuclear sector because of delays, moved to other activities and were then “lost” for the nuclear value chain.

It is therefore essential to keep as a main goal the achievement of a highly resilient organization of the HR capabilities assessment and preparation for the nuclear sector in the 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 attractively and sustainable career solutions to the workforce embarked, especially young talents. Excellent workforce should remain the basic enabler of safe long-term operation of existing facilities and development of future advanced ones.

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. Building such an analysis at the EU level, rather than at a country-by-country level, 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. It should be strongly emphasized that, while the focus is usually placed on engineers and experts, the nuclear sector does not require only nuclear specialists to be maintained and developed. Nuclear facilities operation as well as nuclear new builds need multidisciplinary, multicultural competencies. Moreover, experience has shown that the technicians and semi-skilled workers form a very large portion of the needed workforce. The former needs a much longer period for initial education and must be considered adequately, whereas the latter, technicians and semi-skilled must be addressed cautiously.

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 recycling frequency. The level of detail can vary from one job to another depending on its sensitivity. ISCO (International Standard Classification of Occupations) is one possible way to work on shared definitions of “skills”, “competencies”, “jobs”, “occupations”. The skills assessment system must also define skill levels, in the field know-how needed for the various jobs, and determine the assessment criteria to measure the skills of staff members. Rules need also 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.

To address these challenging issues, Work Package WP1 (Leader NCBJ, contributions from GIFEN-I2EN, ENEN, CEA, JRC, SCK CEN, ENS, UNIVLEEDS, ENEA, IST, RATEN) of ENEN2+ project aims to explore human resources analysis in the nuclear sector. The overall objective is to evaluate the workforce required by the nuclear sector in Europe and to identify any gaps in terms of nuclear education & training to match the needs.

Nuclear research centres, regulatory bodies and technical safety organizations (TSO) and waste management agencies or companies rely on high skills in many domains and contribute to training of nuclear engineers even in countries that don’t have nuclear power. Research reactors are facilities readily available for students, PhDs, postdocs, and teachers. Even though the number of professionals needed for research, waste management or TSOs is much lower than the workforce in the nuclear industry, the level of knowledge and expertise from those individuals is high, often at the level of PhDs or postdocs.

Other research organizations and universities, even if not equipped with a research reactor, play a role in E&T for building nuclear competences (training the trainers for example). However, due to time constraints in the scope of the project, only rough estimations of the needs will be available.

3. Methodology

In terms of methodology, data was collected through a survey. The survey was prepared in full coordination with TF1.1 as detailed below. Data analysis of the responses has been complemented with a literature review. Benchmarking / extrapolation from one country to another, as much as possible within the EU perimeter, washas been used for waste management organizations/companies and safety organizations in case of a low response rate from the survey.

Safety and sustainability of the nuclear sector heavily relies on specialized and highly trained employees. Therefore, monitoring, and continuous improving of human performance has become one of the key challenges in the human resources management in the nuclear sector. Effective human resource management ranges from education over training to continuous monitoring of the human resources needs to improve the workforce's performance. The objective of this study is to analyse the present and future human resources (HR) needs in the EU27 + UK perimeter in institutions operating research reactors, nuclear waste organizations, regulatory authorities, and technical safety organizations.

The analysis performed in this report is expected to contribute to the identification of professions which will be most in demand and identify skill gaps in the afore mentioned organizations.

As a result, this will allow for the preparation of a future that should support international efforts to implement effective training programmes and develop different strategies to cope with the lack of experts.

This study is based on two approaches:

3.1 Secondary data sources

This approach gathers data from secondary sources including survey reports, websites of professional bodies, official documents, and statistical information as well as the Research Reactor Database (RRDB) of the IAEA.

During the study, an analysis of the literature and a selection of relevant information washas been carried out. The results of the literature study can be found in Chapters 4.1.1 - 4.1.3.

It should be emphasized that there are some methodological limitations to such an approach. Mostly, the literature review is limited to online information and available databases.

3.2 Target group survey

To gather information about employment in EU countries and the UK, a structured questionnaire was developed. The questionnaire template can be found in Appendix 7.1. Survey results could supplement collected information about current employment and foresee future requirements in the nuclear sector across EU countries and the UK.

In December 2022, an e-mail with a link to the HR survey and a pdf version was sent to 132 selected organizations that conduct research or operate nuclear facilities (within the scope of WP1 Task 1.2: waste management and decommissioning, research and development (R&D) organizations, technical safety organization (TSO) and some universities). From these 132 e-mails, 30 responses were received, yielding a response rate of 22.7%.

To improve the survey response rate, personalized emails with surveys were sent outwere implemented. Each task partner was responsible for sending the survey to organizations from respective partner's countries, for details see Appendix 7.2. The survey was open for a period of ten weeks, until 19 February 2023. During that time, two emails reminders were sent to all selected organizations in an effort to increase the response rate.

All survey responses are held in strict confidence. In Chapter 4.2 we publish only collective results. In order to have a better understanding of the results and their implications, the analysis uses both the data received and the data from the literature survey.

4. Results

4.1 Current situation – Literature studies

4.1.1 Current status of the European waste management and decommissioning facilities

The most recent data reporting the total amount of nuclear waste worldwide, are provided by the IAEA [01] and refer to the end of December 2016. Based on this information, the total global inventory of solid radioactive waste was approximately 38 million m^3, of which 81% is permanently disposed of, and a further 19% is stored in temporary facilities awaiting final disposal. More than 98% of the volume of solid waste is classified as very low-level waste (VLLW) or low-level waste (LLW), and most of the remaining is intermediate level waste (ILW). 98% of the total radioactivity is from ILW and high-level waste (HLW). With reference to the same period, in Europe, the total amount of spent fuel discharged from nuclear power plants (NPPs) was 201,500 t HM (tons of heavy metal), and the spent fuel stored from research and other reactors 1,061 t HM. For the solid radioactive waste, there were, in storage: 245,000 m^3 of VLLW, 890,000 m^3 of LLW, 2,583 million m^3 of ILW, and 22,000 m^3 of HLW, and in disposal: 369,000 m^3 of VLLW, 3 million m^3 of LLW, 43,000 m^3 of ILW, and no HLW. With respect to liquid radioactive waste, there was about 156,500 m^3 of all categories stored in Bulgaria, Hungary, Lithuania, and Slovakia.

Radioactive or nuclear waste is one of the products from nuclear reactors, fuel processing plants, hospitals, and research facilities. Radioactive waste is also generated by the decommissioning of NNPs which is the main sources of nuclear waste. Worldwide there are 422 NPPs in operation, 17 in suspended operation, 57 under construction, 67 planned for construction, 192 permanently shut down, and of these 158 under decommissioning [02-03].

This situation reflects that of the European Union (EU) and United Kingdom (UK), where currently all the NPPs life cycle phases are present scattered between sixteen Member States (MS). More specifically, as reported in Table 4.1.1.1, there are 109 NPPs in operation and 87 under decommissioning. These two phases require the implementation of a suitable nuclear waste management process.

Table 4.1.1.1 State of the art of European Union and United Kingdom NPPs as of April 2023 ([02-04]).

Country	NPPs Operational	NPPs under Construction	NPPs permanently shut down	NPPs in decommissioning
Belgium	5	-	3	1
Bulgaria	2	-	4	4
Czech Republic	6	-	-	-
Finland	5	-	-	-
France	56	1	14	10
Germany	0	-	33	28
Hungary	4	-	-	-
Italy	-	-	4	4
Lithuania	-	-	2	2
Netherlands	1	-	1	1
Romania	2	-	-	-
Slovenia	1	0	-	-
Slovakia	5	1	3	3
Spain	7	-	3	3
Sweden	6	-	7	5
United Kingdom	9	2	36	26
Total UE +UK	**109**	**4**	**113**	**87**

Following the EU's Radioactive Waste and Spent Fuel Management Directive 2011/70/Euratom ([02]), all the EU member states (MS) generating spent fuel and radioactive waste, have developed their own laws and political practices to implement a national programme for the management of these materials.

The practice, according to Euratom guidelines and to the national policies on spent fuel management and radioactive waste management, is that final waste is to be disposed of in the country where it is generated. Although spent fuel may be transferred for reprocessing in another country, the HLW or ILW from reprocessing is generally returned to the originating country for long-term management. This does not prohibit collaboration between countries, and some countries are seeking joint (or multilateral) solutions for the management of spent fuel and radioactive waste, including disposal in facilities that are operated jointly by, or on behalf of, several countries ([01]).

Even though the primary responsibility for managing spent fuel and radioactive waste stays with the owner or license holder of the facility from which the spent fuel and radioactive waste originates, many States have created national radioactive waste management organizations (WMOs) that are responsible for developing arrangements for the disposal of spent fuel and radioactive waste, others have opted for an industry approach (e.g., Finland, Sweden). In some countries, for example France, spent fuel is not considered as waste since a reprocessing industrial step allows to recover remaining usable radioactive materials they contain as well as to reduce the volume of final waste. To avoid double-counting of HR needed, companies in charge of these processes and their HR needs for spent fuel management (namely Orano in France) will be analysed in Task Force 1.1 of the Work Package. >Therefore, the perimeter of Task Force 1.2 is dealing with waste management strictly speaking. The WMO have the responsibility to implement the national policy, and to develop and implement a safe and socially acceptable plan for the decommissioning of NPPs, and the long-term containment and isolation of nuclear waste from people and the environment.

Currently in the EU there are twenty-three public and/or private WMOs operating in 23 EU countries and in the UK, as reported in the Table 4.1.1.2 performed according to the data published in the European Commission Staff Working Document 2017 ([05]).

Table 4.1.1.2 EU Waste Management Organizations.

Country	Waste management Organization	Public or Private
Austria	Nuclear Engineering Seibersdorf GmbH (NES)	Public/Private
Belgium	Belgium’s Agency for Radioactive Waste and Enriched Fissile Materials (ONDRAF/NIRAS)	Public
Bulgaria	State Enterprise Radioactive Wastes (SERAW)	Public
Croatia	Radioactive Waste Management Centre	Public
Czech Republic	Radioactive Waste Repository Authority (SÚRAO)	Public
Denmark	Danish Decommissioning (DD)	Public
Estonia	A.L.A.R.A. AS	Public
Finland	Posiva OY	Private

France	National agency for management of radioactive waste (ANDRA)	Public
Germany	German Service Company for the Construction and Operation of Waste Repositories (BDE)	Public
Greece	National Center for Scientific Research (NCSR) "Demokritos"	Public
Hungary	Public Limited Company for Radioactive Waste Management (PURAM)	Public
Italy	Company for management of nuclear power plants (SOGIN)	Public
Latvia	Latvian Environment, Geology and Meteorology Centre (LVGMC)	Public
Lithuania	State Enterprise Radioactive Waste Management Agency (RATA)	Public
Netherlands	The Central Organization for Radioactive Waste (COVRA)	Public
Poland	Radioactive Waste Management Plant (RWMP)	Public
Portugal	Instituto Superior Técnico (IST)	Public
Romania	Nuclear Agency for Radioactive Waste (ANDR)	Public
Slovakia	Slovak Nuclear and Decommissioning Company (JAVIS)	Public
Slovenia	Agency for Radwaste Management (ARAO)	Public
Spain	National radioactive waste company (ENRESA)	Public
Sweden	Swedish Nuclear Fuel and Waste Management (SKB)	Private
United Kingdom	The Nuclear Decommissioning Authority (NDA)	Public

The structure and role of WMOs in countries with a nuclear power programme varies. In some countries, the generators of spent fuel and radioactive waste are responsible for all activities for its safe management, encompassing the disposal of radioactive waste (including HLW from reprocessed spent fuel) and spent fuel classified as radioactive waste. In such cases (e.g., Finland and Sweden) the waste generators have formed WMOs that are owned and operated by them. In other countries (e.g., France and Germany) the State has created a separate State-owned organization responsible for waste disposal of all applicable radioactive waste classes, while the responsibility for the interim management of spent fuel and radioactive waste remains with the spent fuel or waste producer. Other countries may have a mixed approach whereby, for example, private companies are responsible for the short-term management of spent fuel, whereas a State-owned or State-controlled body is responsible for the long-term management of spent fuel and/or HLW. The private companies might also be responsible in such cases for the management of radioactive waste (with exception of HLW) and/or decommissioning [01].

For countries without nuclear power programmes, the quantity of waste concerned might not justify the existence of a dedicated WMO. In these cases, responsibility for such matters is taken by a national research centre, a ministerial department or other body [01].

The nuclear national programmes must include technical solutions for spent fuel and radioactive waste management (from generation to disposal), and for the institutional control and preservation of knowledge in the post-closure phase (European Commission Staff Working Document Progress of implementation of Council Directive 2011/70/EURATOM). For the spent fuel, there are two different management strategies: 'open cycle' and 'closed cycle'. The former considers the spent fuel as waste and consists of direct disposal, whereas the latter considers spent fuel as a potential energy resource using reprocessing to recover valuable fissile materials (uranium and plutonium) ([01]).

Although the choice depends on the country's waste inventory and on the national strategic programme on radwaste and spent fuel management. The three most effective options for the permanent disposal of nuclear waste are: the Deep Geological Disposal Facility (GDF) (typically 200–1000 m deep in a stable geologic environment, with in some cases addition of a "reversibility" consideration in order to take into account possible future improvement of knowledge on the processes according to future results of research on these issues) for the storage of spent fuel and HLW, Near Surface Disposal Facility (NSDF) (sub-surface infrastructure, few meters deep), and Surface Disposal Facility (SDF) (above the surface) for the storage of LLW/ILW (Figure 4.1.1.1). Currently in Europe, France and UK operate respectively two reprocessing facilities. This reprocessing step aims inter alia to reduce the volume of waste, as previously mentioned. Other countries in the EU, including Belgium, Bulgaria, Hungary, the Czech Republic, Germany, Italy, the Netherlands, Slovakia, Spain, and Sweden, have used services provided by foreign facilities for the reprocessing of their spent fuel.

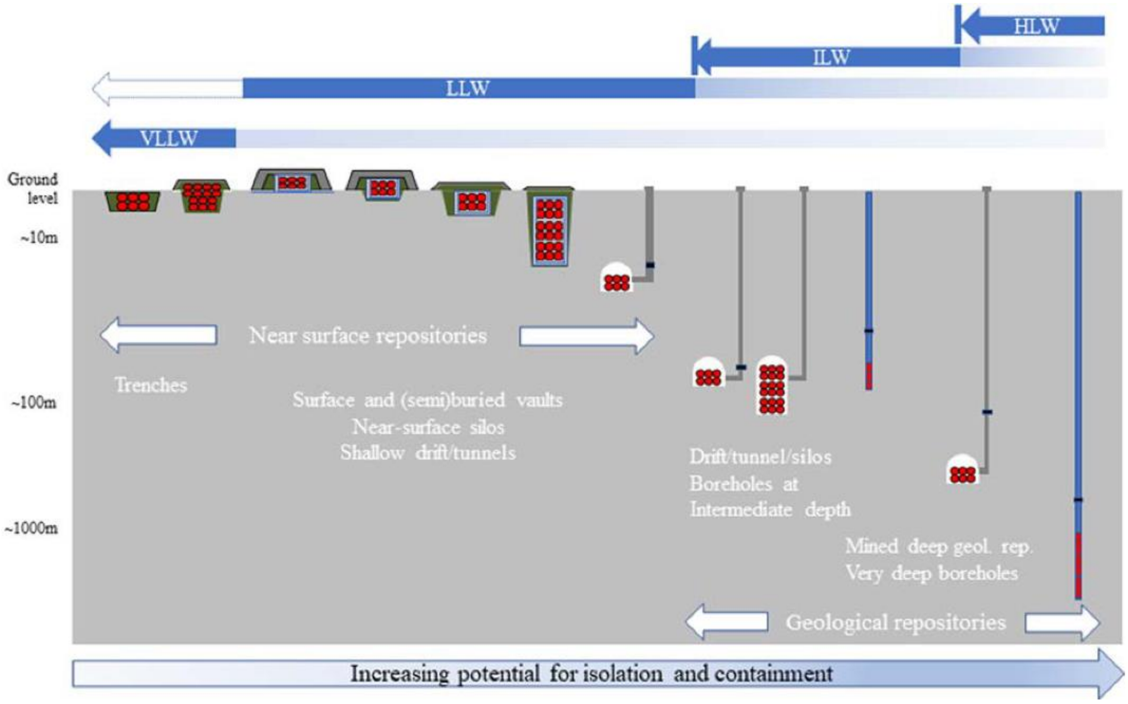

Figure 4.1.1.1 Conceptual illustration of disposal concepts
for different classes of radioactive waste ([01]).

Any design solution which entails the construction of such a facility implies the implementation of a high engineering infrastructure for which different times and costs are required depending on the amount of waste to be disposed of, and on the characteristics of the site (ONDRAF/NIRAS, 2010. International Benchmarking of Community Benefits Related to Facilities for Radioactive Waste Management). More specifically, the life cycle of these infrastructures is divided in seven main phases: siting, design, licensing, construction, operational, closure, and institutional control. Generally, the siting phase requires a very long time to be implemented.

In the EU all the life cycle phases of the three permanent repository types are present in different stages of implementation. In many cases the temporal horizon for their implementation is not well defined, and waiting for the later final disposal, interim storage facilities (ISF) hosting conditioned waste of all categories are present. On one hand, this is the case for Italy (whose both HLW and LLW/ILW is currently stored in about 20 temporary sites) [06], Belgium (in which all waste categories are centralized on the interim storage facility in Dessel) [07], and Germany (whose HLW and LLW/ILW are currently stored in more than thirty temporary sites) [08].

On the other hand, over 30 permanent disposal facilities for Very Low-Level Waste (VLLW) and LLW are in place in 12 MS. Fifteen MS have a plan for the GDF, of these Finland is the first country where the construction of a GDF has begun and is expected to be in operation by 2024. It is followed by Sweden and France where the facilities are in the licensing phase and are planned to be operational by 2032 and 2035 respectively. In Italy the National SDF for LLW/ILW is in the siting phase, and no long-term options are still planned for HLW, while in Belgium and the Netherlands the solution is under discussion. The remaining MS are in the siting phase for a GDF (Table 4.1.1.3). These time schedules are beyond the timeframe of the present ENEN2+ study. Consequently, HR needs analysed here will have to be updated in order to take into account progress in implementing these future facilities.

Table 4.1.1.3 State of the art of SDF, NSDF, and GDF in EU.

Country	Type	Site	State of the art
Belgium	GDF	Dessel	No date defined pending national policy [09]
	SDF	Dessel	Planned, pending authorization for the construction [10]
Bulgaria	GDF		Siting phase [11].
	SDF	Novi Han	In operation [12].
	SDF	Radiana	Under construction, it is expected to be complete at the end of 2030 and to operate for about 60 years after commissioning [13].
Czech Republic	GDF	Unknow	Siting phase, timetable for choosing a final location for the repository by the end of the 2030 [14]
	SDF	Hostim	Closed, under institutional control [15]
	SDF	Dukovany	In operation [15]
	SDF	Richard	In operation [15]
	SDF	Bratrstvi	In operation [15]

Finland	GDF	Olkiluoto	In operation, LLW/ILW disposal. New tunnel under construction to dispose of HLW [16]
	GDF	Loviisa	In operation, LLW/ILW disposal [16]
France	GDF	Bure	License applied and under examination [17]
	SDF	L'Aube	In operation [18]
	SDF	La Manche	Closed, under institutional control [19]
Germany	GDF	Unknown	Siting phase [20]
	NSDF	Asse	Closed [21]
	NSDF	Morsleben	Closed [21]
	SDF	Konrad	Licencing [21]
Hungary	GDF	Bátaapáti	In operation [22]
	SDF	Püsköpszilágy	Closed, under institutional control [23]
Italy	SDF	Unknown	Siting phase [24]
	GDF	Unknown	Evaluation pending
Lithuania	GDF	Unknown	GDF site under selection [25]
	SDF	Maišiagala	Closed, under institutional control [26]
	SDF	Ignalina	Licensing [27]
Netherlands	GDF		Option under evaluation [05]
Romania	GDF	Unknown	It is assumed that the site will be chosen around 2055, becomes operational in 2065 and storage is completed around 2085.[28]
	NSDF	Baita Bihor	In operation [29]
	SDF	Saligni	Under construction [30]
Slovakia	GDF	Unknown	Siting phase [31]

	SDF	Mochovce	In operation [32]
Slovenia	GDF	Unknown	Option under evaluation [33].
	SDF	Vrbinia	Under construction, it is planned to be operational by 2024[29]
Spain	GDF	Unknown	Siting phase [34]
	SDF	El Cabril	In operation [35]
Sweden	GDF	Östhammar	Licensing [36]
	SDF	Forsmark	In operation [37]

Figure 4.1.1.2 shows the reported nuclear workforce in decommissioning in the 2018 survey. The survey indicates that the number will remain stable until 2025 but will increase by 30% by 2030. The reported workforce for decommissioning in the survey is very low (about 7,000). Recent published data indicates a current decommissioning workforce of 10.000 for UK alone. In-depth knowledge of the plant is compulsory to conduct decommissioning and dismantling phases. Part of the owner/operator’s staff previously in charge of operating the plant will therefore remain on site and be involved in these phases.

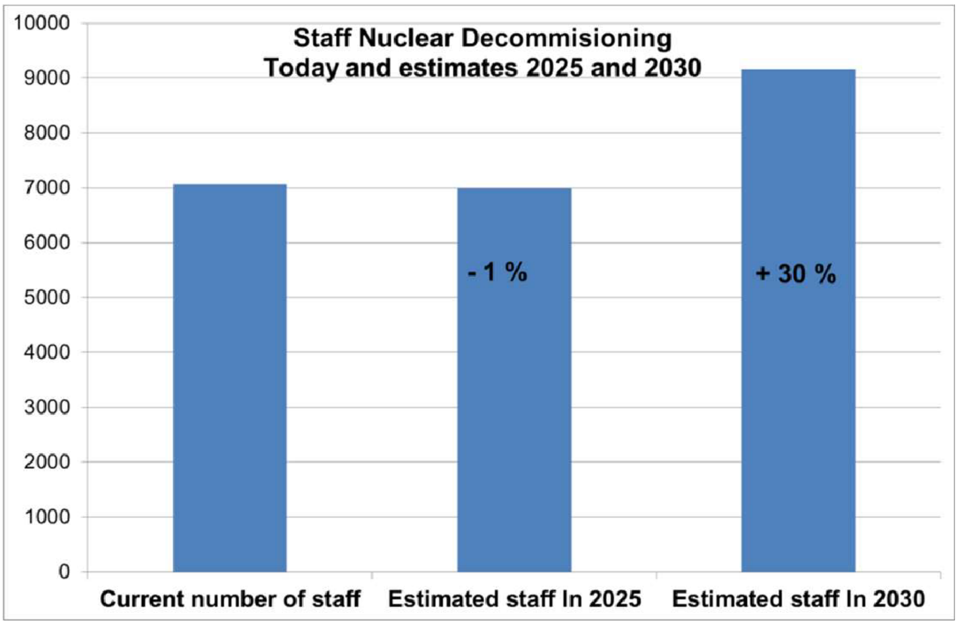

Figure 4.1.1.2 Nuclear workforce in nuclear decommissioning projects
and estimated needs in 2025 and 2030. [38]

4.1.2 Current status of the European research reactors

Data from the IAEA's Research Reactor Database (RRDB) [39] available online provides information with respect to the status of the world's research reactors (RRs).

Research reactors are facilities used by various research communities, open, as any research activity is by nature, to wide international cooperation. This is the reason why neighbouring countries have been mentioned in the Figures 4.1.2.1 and 4.1.2.2.

Regional distribution of the operational RRs in Europe EU27 and UK, is shown in Figure 4.1.2.1. Figure 4.1.2.2 shows the regional distribution of the RRs under construction and planned in Europe and UK. Current situation in Europe collected from the IAEA RDDB database, as of May 2023, shows 32 operational research reactors, 14 permanent shutdown, 4 shutdown reactors, 155 under decommissioning or decommissioned, and 4 under construction or planned (Belgium, Netherland, France and Czech Republic). These reactors are located in 13 countries.

Figure 4.1.2.1 Regional distribution of the operational RRs in EU27 + UK.

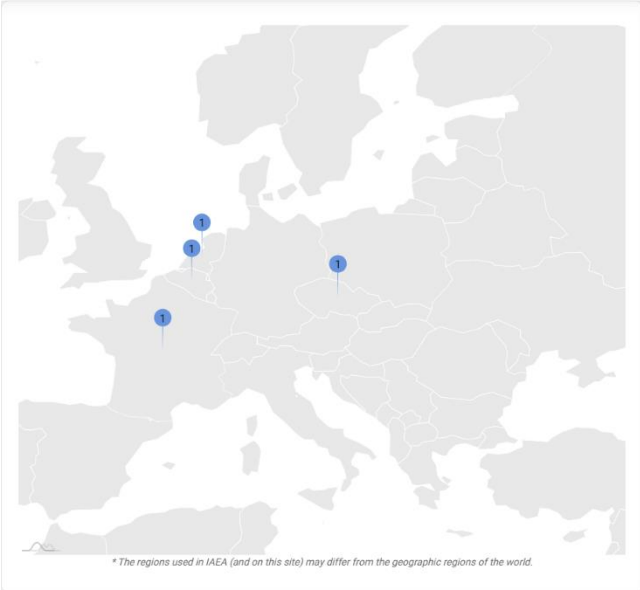

Figure 4.1.2.2 Regional distribution of the RRs under construction and planned in EU27 + UK.

It is worth noticing that more than 80 percent of the RRs are over 20 years old, or older. On the other hand, more new RRs are planned or under construction now than in the previous years.

The primary use of RRs is to provide a neutron source for research, e.g., material studies and non-destructive examination, neutron activation analysis, radioisotope production for medical and industrial use, neutron irradiation for materials testing for fission and fusion reactors.

Another important area where RRs make a large contribution is education and training in all nuclear technology areas for operators, maintenance and operational staff of nuclear facilities, radiation protection personnel, regulatory personnel, students, and researchers [40]. This is the reason why in some cases number of people involved in RRs operation might be different considering the organization responsible for it, and the research teams invited, which might come from other organizations, including universities, for specific research programmes. Members of such collaborating teams should also be trained, even with shorter programmes before their intervention in the RRs' locations.

Although RRs are small compared to power reactors whose primary function is to produce electricity, the building regulation and procedures of safety operations are almost the same as in the case of NPP. That is why, the human resources management is the pillar of a safety operation, decommissioning and development of the new facilities. The evaluation of both present and expected individual competences of the employees is necessary to ensure safe operation of these facilities.

Table 4.1.2.1 presents the current employment in EU RRs, Switzerland and the United Kingdom based on the IAEA data available online.

Table 4.1.2.1 Current employment in European research reactors.

Country	Research Reactor	STAFF		
		Operators	Other e.g., technicians	Total
Austria	TRIGA II VIENNA	3	10	24
Belgium	BR-1	6	3	9
	BR-2	31	-	80
	VENUS-F	5	-	8
Czech Republic	LR-0	5	-	8
	LVR-15 Rež	15	-	40
	VR-1	13	-	19
France	Cabri	25	-	25
	ILL High Flux Reactor	30	-	105
	Isis	2	-	3
Germany	AKR-2	3	-	3
	FRMZ	5	-	7
	SUR Furtwangen	1	-	2
	SUR Stuttgart	1	-	2
	SUR Ulm	2	-	3
Greece	GR-B Subcritical Assembly	-	-	-

Hungary	Budapest Research Reactor	11	-	45
	Nuclear Training Reactor	5	-	~65
Italy	AGN-201 Costanza	1	-	8
	LENA, TRIGA II PAVIA	10	-	12
	RSV TAPIRO	5	-	7
	SM-1 Subcritical Assembly	2	-	5
	TRIGA RC-1	6	-	13
Netherlands	Delphi	-	-	-
	HFR	36	-	85
	HOR	12	12	24
Poland	MARIA	35	-	70
Romania	TRIGA II Pitesti - Pulsed	12	-	-
	TRIGA II Pitesti - SS Core	12	-	80 (for both cores)
Slovenia	TRIGA- MARK II LJUBLJANA	4	1	5
United Kingdom	Neptune	1	-	1

*”-” stands for lack of data

The data presented in Table 4.1.2.1 was collected over the years 2018-2022. The data shows that currently more than seven hundred people are employed in research reactors, of which about 40 percent work as a reactor operator. The remaining part is made up of technical personnel, e.g., mechanics, dosimetrists, etc.

4.1.3 Status of the technical safety organizations (TSO) and regulatory authorities

The organizations represented in Table 4.1.3.1 are the European national regulatory authorities regarding nuclear topics such as nuclear safety, security, radiation protection and others. [41-44] 44.

Table 4.1.3.1 Overview of National Regulatory Authorities [41-44].

Country	Abbreviation	Full name
Austria	BMK BMSGPK	Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology Federal Ministry of Social Affairs, Health, Care and Consumer Protection
Belgium	FANC	Federal Agency for Nuclear Control
Bulgaria	BNRA	Bulgarian Nuclear Regulatory Agency
Croatia	SORNS	The State Office for Radiological and Nuclear Safety
Cyprus	DLI	Department of Labour Inspection, Radiation Inspection and Control Service
Czech Republic	SUJB	State Office for Nuclear Safety
Denmark	DEMA DHARP (SIS)	Danish Emergency Management Agency Danish Health Authority, Radiation Protection
Estonia		Environmental Board - Radiation Safety Department
Finland	STUK	Radiation and Nuclear Safety Authority
France	ASN	Nuclear Safety Authority
Germany	BfS BMUV BASE	Federal Office for Radiation Protection Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection Federal Office for the Safety of Nuclear Waste Management
Greece	EEAE	Greek Atomic Energy Commission

Hungary	HAEA NPHC	Hungarian Atomic Energy Authority National Public Health Centre
Ireland	EPA	Environmental Protection Agency
Italy	ISIN	National Inspectorate for Nuclear Safety and Radiation Protection
Latvia	RSC	Radiation Safety Centre
Lithuania	VATESI RPC	State Nuclear Power Safety Inspectorate Radiation Protection Centre
Luxembourg	DRP	Ministry of Health, Department of Radiation Protection
Malta	OHSA / RPC	Occupational Health & Safety Authority / Commission for the Protection from Ionizing and non-Ionizing radiation.
Poland	PAA	National Atomic Energy Agency
Portugal	APA	Portuguese Environment Agency
Romania	CNCAN	National Commission for Nuclear Activities Control
Slovakia	NRA UVZSR	Nuclear Regulatory Authority of the Slovak Republic Public Health Authority of the Slovak Republic
Slovenia	SNSA SRPA	Slovenian Nuclear Safety Administration Slovenian Radiation Protection Administration
Spain	CSN	Nuclear Safety Council
Sweden	SSM	Swedish Radiation Safety Authority
The Netherlands	ANVS	Authority for Nuclear Safety and Radiation Protection
United Kingdom	ONR CQC UKHSA	Office for Nuclear Regulation Care Quality Commission UK Health Security Agency

The performed survey provides limited information on staffing for some of the authorities. These results are presented in Table 4.1.3.2. The information is supplemented with staffing info received from annual reports of the respective organizations.

Table 4.1.3.2 Overview of staffing for regulatory authorities [45-49].

Country	Abbreviation	Number of staff category according to survey or based on number of staff in literature	Number of staff (year)
Belgium	FANC	100-499	154 (2020) [46]
Bulgaria	BNRA	100-499	
Cyprus	DLI	1-9	5 (2021) [50]
Czech Republic	SUJB	100-499	218 (2021) [51]
Denmark	DEMA	100-499	
Finland	STUK	100-499	303 (2022) [52]
France	ASN	500-999	519 (2021) [53]
Germany	BfS	500-999	511 (2018) [54]
Ireland	EPA	100-499	448 (2021) [55]
Italy	ISIN	10-99	66 (2019) [56]
Lithuania	VATESI	10-99	58 (2021) [57]
Poland	PAA	100-499	102 (2022) [59]
Romania	CNCAN	10-99	107 (2021) [60]
Slovakia	NRA	100-499	118 (2021) [47]
Slovenia	SNSA	10-99	
Spain	CSN	100-499	421 (2021) [48]

Sweden	SSM	100-499	300 (2022) [45]
United Kingdom	ONR	500-999	671 (2021) [49]

Based on the available data presented in the table above the Figure 4.1.3.1 represents the number of regulatory authorities per category. Most organizations are in the '100-499' category. The total number of employees for the 16 organizations for which recent staffing information is available is just above 4,000.

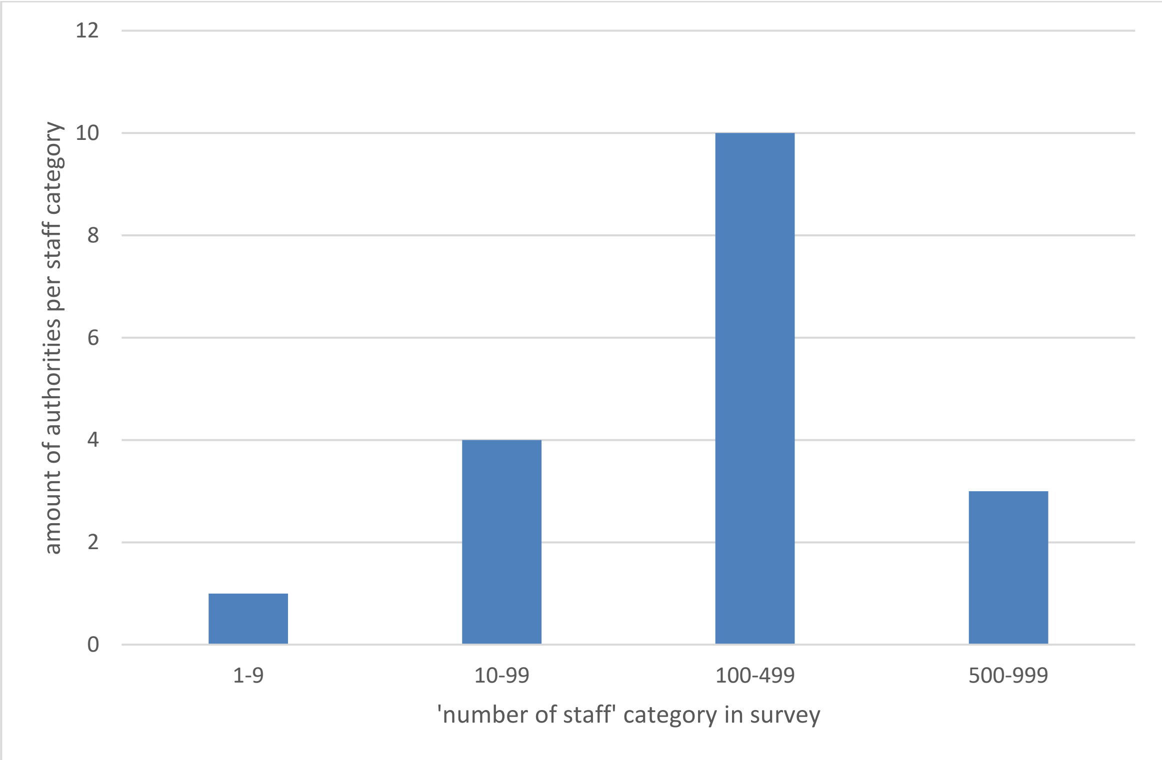

Figure 4.1.3.1 Overview of staffing for regulatory authorities per category.

Technical safety organizations (TSO's) are responsible for independent scientific and technical support to the local regulatory body regarding nuclear safety and, in some cases, also nuclear security and safeguards [61],[62]. A TSO can be an external organization recognized by the regulator or an internal organizational unit of the regulatory body. In the latter, support from other external partners is often necessary. [61], [63], [62].

Most of the European TSO's are members of the European Technical Safety Organizations Network (ETSON) [61], [63]. This network reported 16 partners in 2020 [63]. The current ETSON members are presented in Table 4.1.3.3. The Nuclear Regulation Authority (NRA, Japan), State Scientific and Technical Center (SSTC, Ukraine) and Scientific and Engineering Center for Nuclear and Radiation Safety (SEI NRS, Russia) are associate partners. [61], [63]. International relations, networking among experts, especially sharing best practices, is a key factor of efficiency in this field and should be promoted in a first step among EU27 MS + UK, but also more globally.

Table 4.1.3.3 Overview of ETSON member [61], [63].

Country	Abbreviation	Full name
Belgium	BelV	BelV
Czech Republic	SÚRO	National Radiation Protection Institute
Finland	VTT	Technical Research Centre of Finland
France	IRSN	Institut de radioprotection et de sûreté nucléaire
Germany	GRS	Gesellschaft für Anlagen – und Reaktorsicherheit
Hungary	EK-CER	Centre for Energy Research
Italy	ENEA	Italian National Agency for New Technologies, Energy and Sustainable Economic Development
Lithuania	LEI	Lithuanian Energy Institute
Romania	RATEN ICN	Institutul de Cercetari Nucleare Pitesti
Slovakia	VUJE	VUJE
Slovenia	JSI	Institut Jožef Stefan
Switzerland	PSI	Paul Scherrer Institut
United Kingdom	Jacobs	Jacobs

In its annual report 2021 ETSON mentions "… discussions with several European TSO's and safety authorities with embedded TSO …" and a report on a previous survey done by EHRON in 2019 lists several organizations in the category 'regulatory authorities, TSO, reactor safety' [63], [41]. This indicates other existing TSO organizations but no direct information on their organization and staffing information is available except for Poland and Sweden. Both regulatory authorities have an internal TSO. [64], [41].

Most recent (2015) data on staffing obtained by the IAEA is presented in Table 4.1.3.4 [62]. The data is supplemented with information of the performed survey within the ENEN2+ project.

Table 4.1.3.4 Overview of number of staff for TSO's according to IAEA data (2015) [62].

Country	TSO	Number of staff in 2015 (2022)
Belgium	BelV	80 (120*)
Finland	VTT	200
France	IRSN	1624
Germany	GRS	350
Italy	ITER	22
Italy	ENEA	NA
Lithuania	LEI	50

*Only staff with EQF level 7-8

Some organizations not presented in the table above reported in their ENEN2plus surveys TSO activities. These organizations are Nuclear Research and consultancy Group (NRG, The Netherlands), Institut Jožef Stefan (JSI, Slovenia), Nuclear Safety Research Institute (NUBIKI, Hungary) and VEIKI Energia+ Kft (Hungary). There is no data available on the staffing regarding the TSO part as all institutes also reported 'research institute' activities and only the total workforce is indicated.

4.2 Data analysis of surveys

The objective of this study is to estimate the number of jobs in the field of the nuclear sector and identify skills gaps. A survey was conducted in order to collect data regarding present and future employment needs and job qualifications, to identify the difficulties in the recruitment processes and to identify the projections of the workforce needs for the RRs, waste management and decommissioning facilities and technical safety organizations as well as the regulatory authorities. The results of the latest EHRO-N Job Taxonomy [65] were used to prepare the structured survey, to identify the projections of the workforce's needs for the research and development institution, waste management and decommissioning facilities and technical safety organizations.

In order to conduct the survey, a questionnaire entitled: "ENEN2+ on HR and skills needs in the nuclear sector" was created. The part of the questionnaire which refers to Task 1.2 was divided into three sections:

- Company/organization information,
- Employment in company/organization and projections,
- Workforce needs.

To prevent overlapping or duplication of work within WP1, the survey for T1.2 was merged with the survey from T1.1 of the WP1 and extended to cover data on workforce needs. The full questionnaire can be found in Appendix 7.1.

The survey was sent to 132 nuclear stakeholders from all European countries and the United Kingdom. Out of 132 organizations the survey was sent to, 30 responded, which correspond to response rate 22,7%. The countries in which the contacted stakeholders are located, and their answering rate per country are listed in Table 4.2.1.

Table 4.2.1 Country distribution of stakeholders contacted with the response rate.

Country	Number of contacted organizations	Number of positive responses	% rate of response
Austria	14	2	14
Belgium	6	5	83
Bulgaria	2	2	100
Croatia	1	0	0
Cyprus	2	0	0

Czech Republic	2	1	50
Denmark	8	1	13
Estonia	3	0	0
Finland	11	0	0
France	3	2	67
Germany	5	1	20
Greece	2	0	0
Hungary	18	2	11
Ireland	1	0	0
Italy	3	1	33
Latvia	1	0	0
Lithuania	6	1	17
Luxembourg	1	0	0
Malta	1	0	0
Netherlands	4	2	50
Poland	9	4	44
Portugal	2	0	0
Romania	4	3	75
Slovakia	2	0	0
Slovenia	4	2	50
Spain	6	1	17
Sweden	5	0	0

United Kingdom	6	0	0
Total	**132**	**30**	**22,7**

For the purpose of this report, professions requiring formal nuclear education background (bachelor, master, PhD) were divided into three subcategories:

- Chemistry and environment and decommissioning (nuclear waste management, decommissioning and dismantling [including R&D and planning), radiochemistry, water chemistry (incl. corrosion)],
- Nuclear technology, construction, and operation (construction engineering, electrical engineering, instrumental and control, mechanics/mechanical engineering, nuclear fuel cycle (R&D, front-end, reprocessing and back-end), process engineering, project management, reactor and "hot" lab operation, radiation protection, quality management and inspections),
- Reactor physics, safety, and security (organizational and human factors, materials science and engineering (nuclear facility materials, failures, component engineering, inspections and lifetime management), nuclear and particle physics, reactor physics and dynamics, thermal hydraulics and coolants, risk analysis (incl. probabilistic risk assessments), safeguards, safety and security (business security and fire safety), severe accidents).

The results of the data collected through the survey from December 2022 until March 2023 are presented below.

When asked about the total number of employees in their companies/organizations, 30 of the participants answered. Six surveys came from research and development institutions, 3 institutions declared that they are the R&D Institutions but at the same time play a role of TSO, 7 responses came from waste management and decommissioning organizations and 2 additional which are at the same time waste management and technical safety organizations, 7 surveys were sent from regulatory authorities, and 5 from other stakeholders (e.g., universities).

The number of employees in research and development institutions among the 6 organizations is in the range 500-999. The number of employees working in the regulatory authorities' sector is in the range of 100-499 employees. The number of employees working in the waste management and decommissioning sector activities is in the range of 100-499. It should be emphasized that the number of people employed in the organizations strictly depends on the volume of radioactive waste.

The number of employees working in the organizations which play only the role of TSO is in the range of 100-499 employees. Those which perform a dual function employ 1000-9999 persons or even more.

Figures 4.2.1 show the survey result in relation to the sectors in which professions are employed.

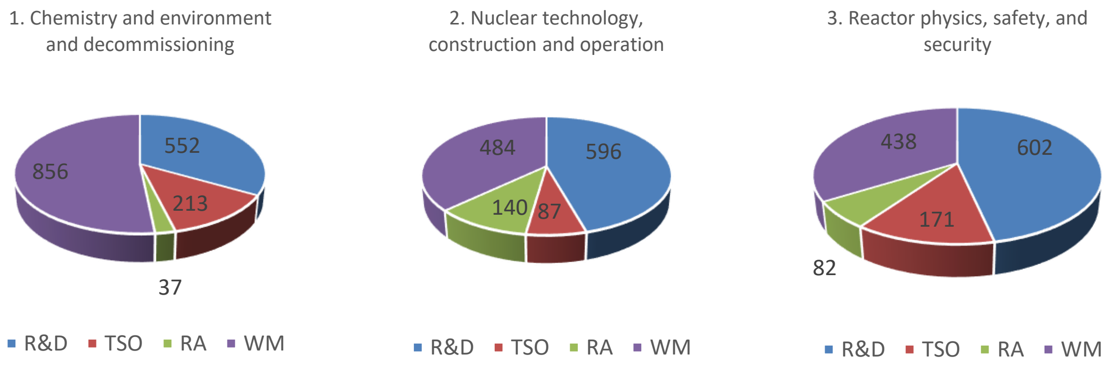

Figure 4.2.1 Number distribution of the reported professions by type of nuclear sector.

This data can be interpreted in reference to EHRO-N report from 2018 [38], see Figure 4.2.2.

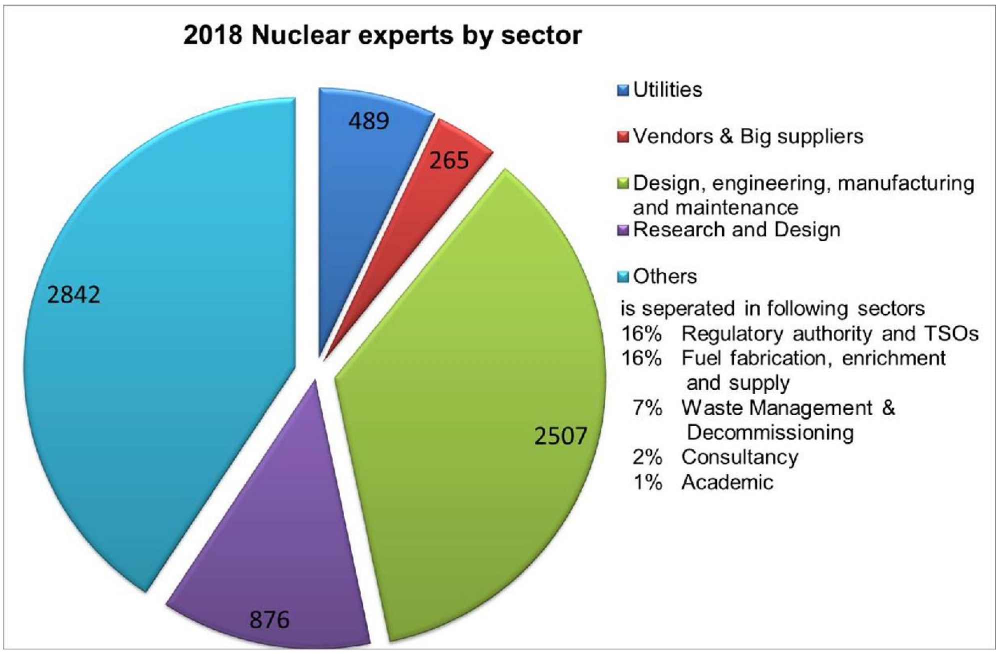

Figure 4.2.2 Source Ref. [41] shows the survey result in relation to the sectors where nuclear experts are employed.

EHRO-N survey data Ref. [38], show research and design institutions operating research reactors represent 12% of the nuclear experts. Only 7 percent of the nuclear experts reported to work for the Utility sector and 16 percent in regulatory authority (RA) and technical safety organization (TSO).

It seems important when looking at these data, limited to nuclear experts, to remind that experience has shown that the technicians and semi-skilled workers form a very large portion of the needed workforce, for which E&T must also be addressed cautiously. The survey did not include information about technicians; therefore, the recommendations cannot address any gaps in this area and would need to be further investigated.

The organizations were questioned about current employment (Figure 4.2.3.a-4.2.3.d). Figures 4.2.3a-d present a diagrammatic representation of employment structure in research and development institutions (Fig 4.2.3.a), waste management and decommissioning (Fig. 4.2.3.b), regulatory authorities (Fig. 4.2.3.c) and technical safety organizations (see Fig. 4.2.3.d).

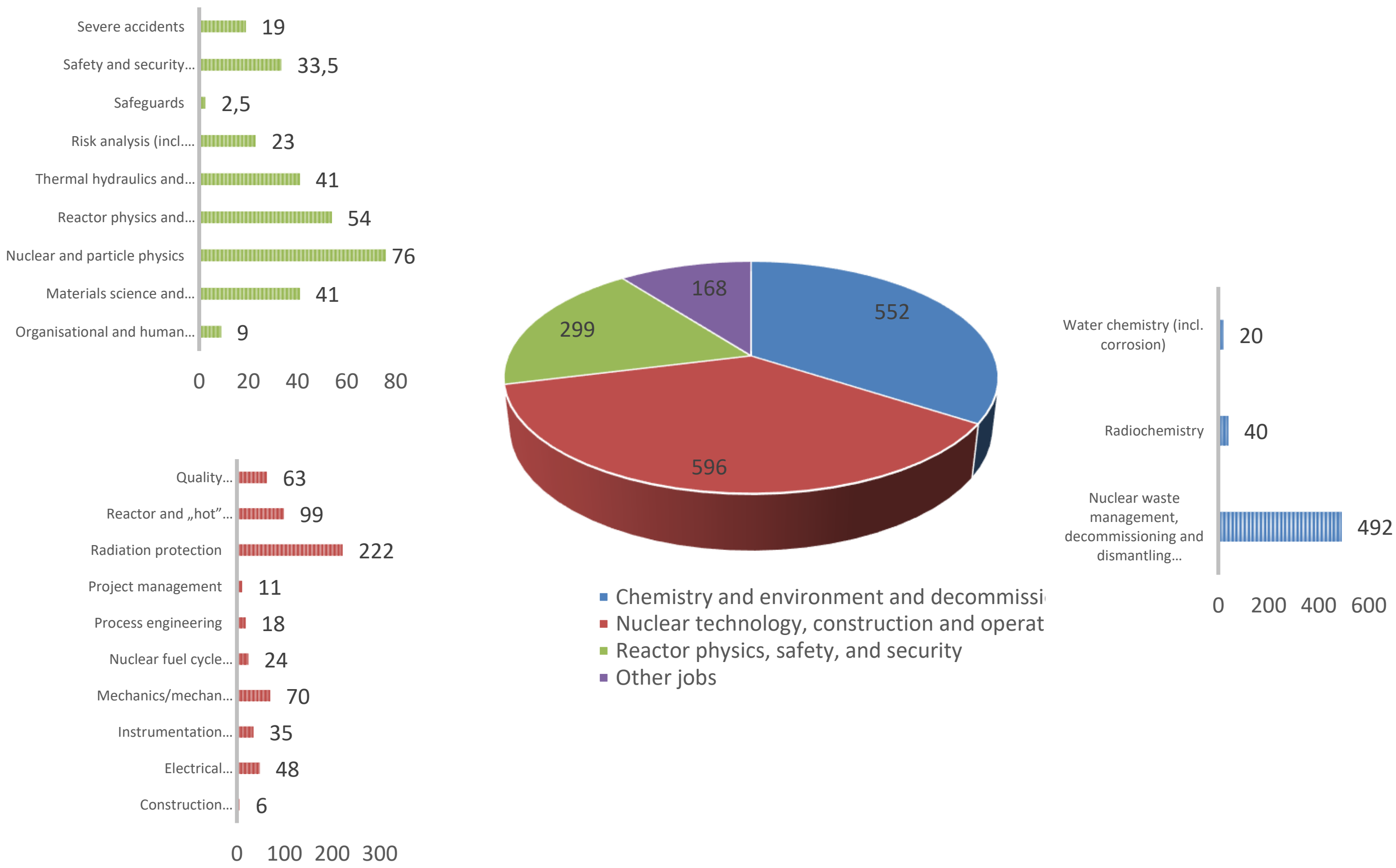

Figure 4.2.3.a Diagrammatic representation of employment structure in Research and Development Institutions

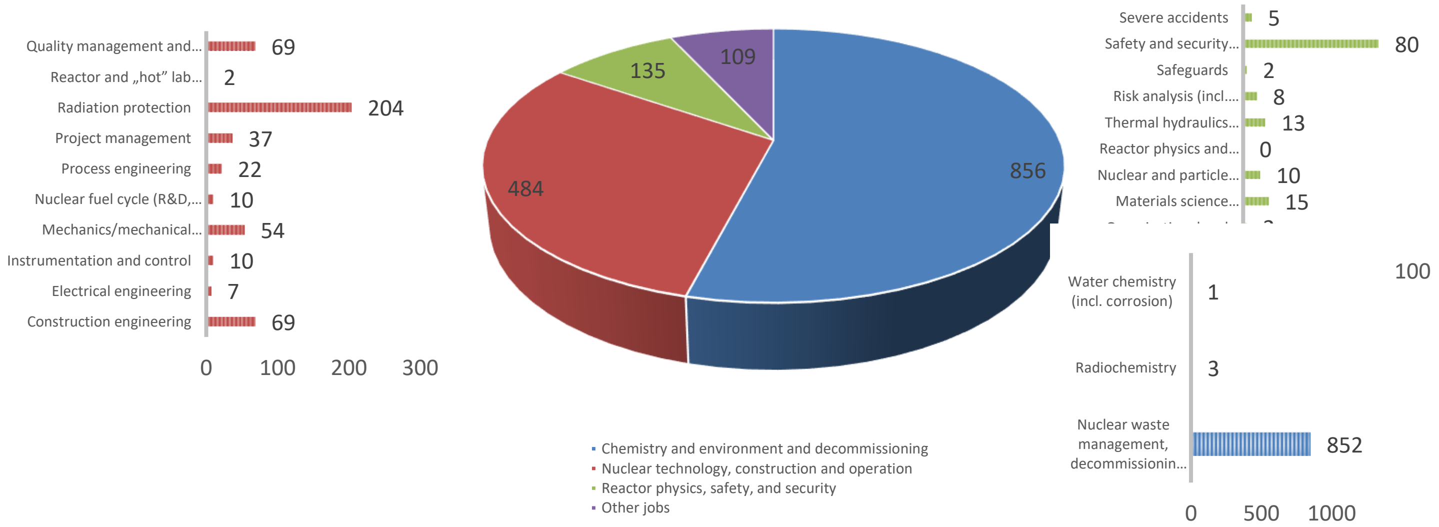

Figure 4.2.3.b Diagrammatic representation of employment structure in Waste Management and Decommissioning Organizations.

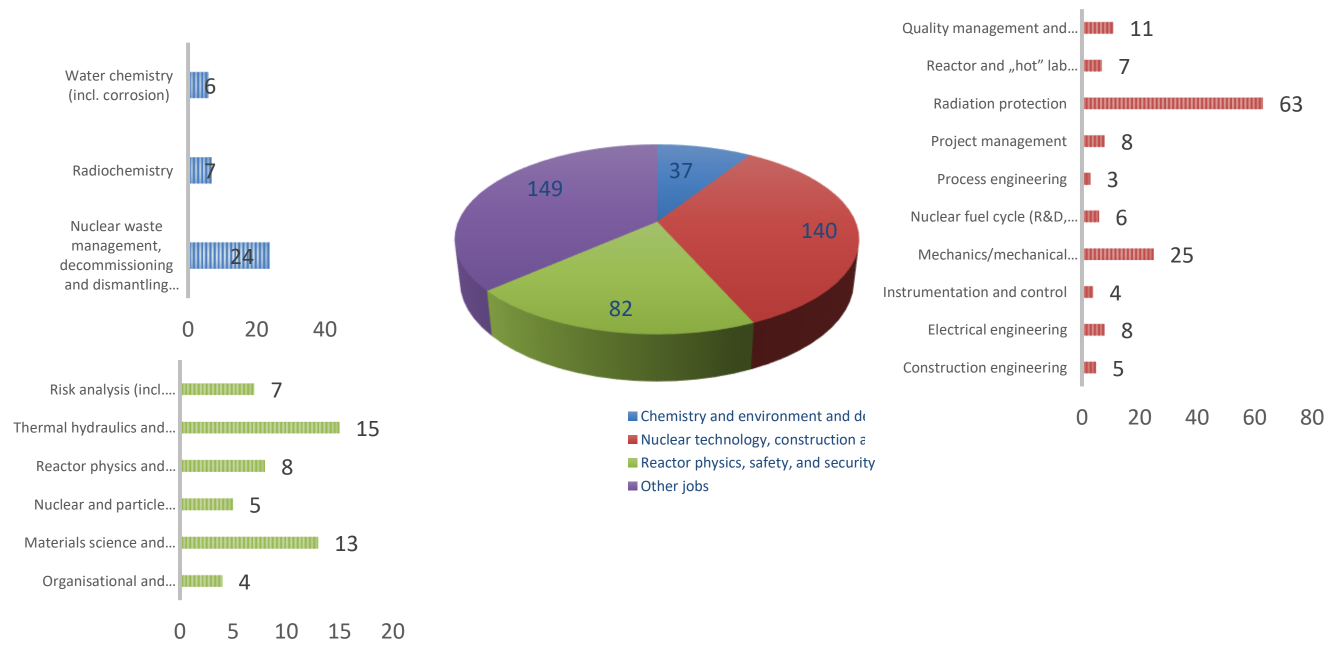

Figure 4.2.3.c Diagrammatic representation of employment structure in Regulatory Authorities.

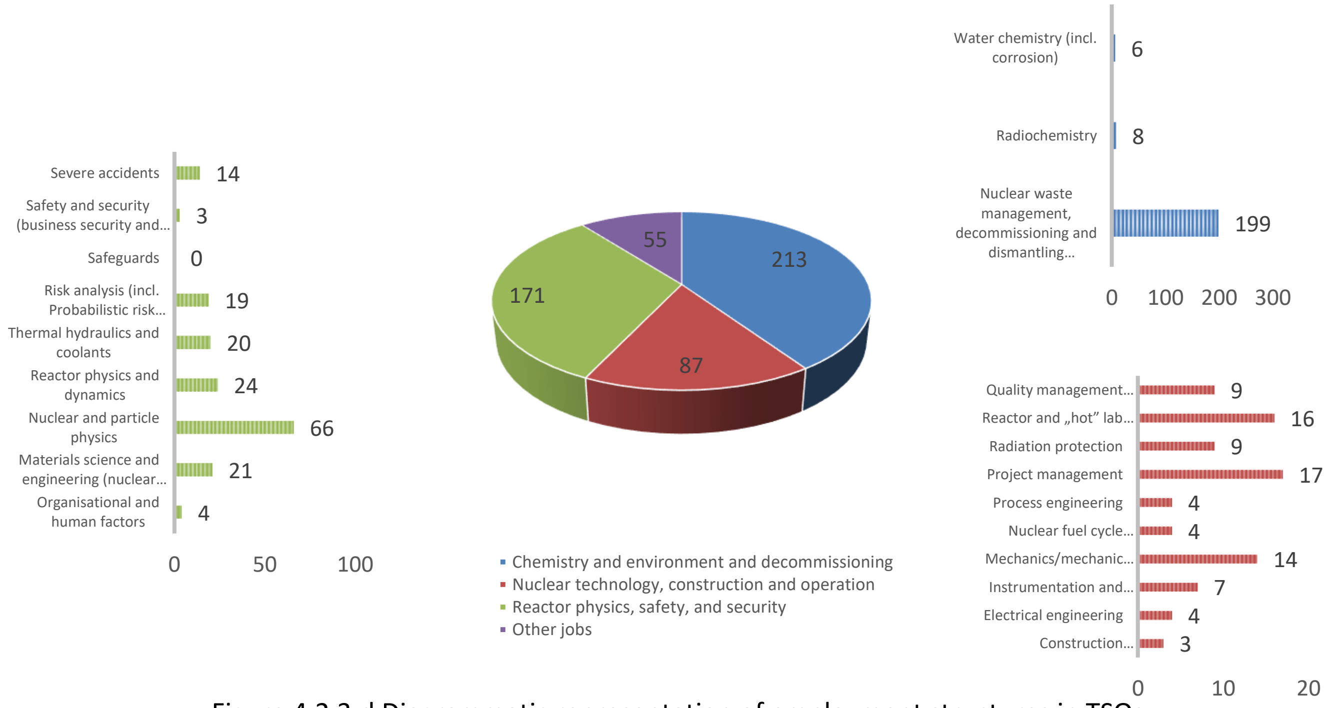

Figure 4.2.3.d Diagrammatic representation of employment structures in TSOs.

Professions that are not directly related to nuclear technical jobs were not listed directly in the survey table and were classified as 'Other' (Section 3, Table 4 of Survey). Total number of experts in those fields of activity is 1,591. Most frequently mentioned professions are: personnel who are responsible for training, management, document management, finance, emergency preparedness response, human resources, legal duties/regulations, cybersecurity and administration and medical (see Figure 4.2.5). 43.81% are hired in research and development institutions, 13.64% in technical safety organizations, 10.18% in regulatory authorities, and 32.37% in waste management and decommissioning organizations; see Fig. 4.2.4.

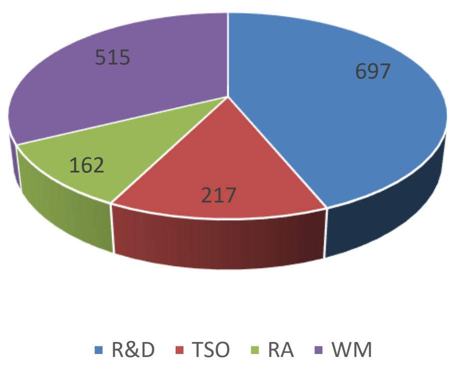

Figure 4.2.4 Numbers of professionals working in different Institutions.

Figure 4.2.5 presents the most frequently mentioned other nuclear jobs which were not listed directly in the survey table and were classified as ’Other’.

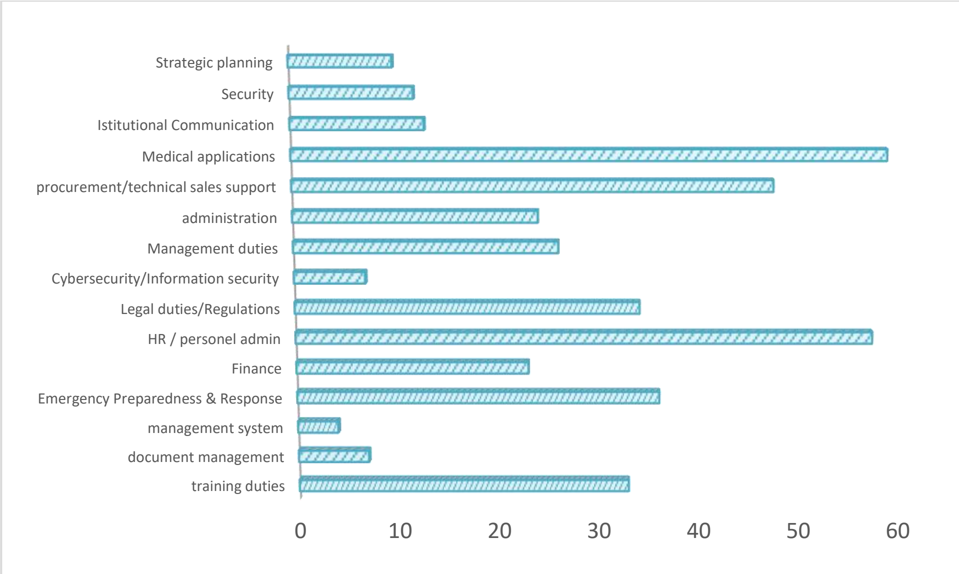

Figure 4.2.5 Number of most frequently mentioned ‘other’ nuclear jobs.

The participating organizations were asked to estimate the percentage of the change in their organization's staff number in ten years, regarding today's numbers. Table 4.2.2 presents organizations’ estimate of the staff number in ten years from now. Through 30 responses (not all of them hire personnel listed on the survey), it is reported that most of the participants believe that in ten years their staff will either increase or the staff number will remain the same. Only in one case, the predicted growth in employment will be higher than 10%, the organization indicated that ten years from now they increase the employment of people educated in risk analysis.

Table 4.2.2 Organizations’ perceptions regarding staff number in ten years from now.

1. Chemistry and environment and decommissioning	Nuclear waste management, decommissioning and dismantling (including R&D and planning)	# RESPONS	Perception
	Radiochemistry	17	increase less than 10%
	Water chemistry (incl. corrosion)	10	no changes or slight increase less than 10%
2. Nuclear technology, construction, and operation	Construction engineering	10	no changes
	Electrical engineering	8	no changes or slight increase less than 10%
	Instrumentation and control	9	no changes
	Mechanics/mechanical engineering	7	increase less than 10%

	Nuclear fuel cycle (R&D, frontend, reprocessing and back-end)	12	increase less than 10%
	Process engineering	10	no changes
	Project management	8	increase less than 10%
	Radiation protection	11	no changes
	Reactor and „hot" lab operation	13	no changes
	Quality management and inspections	11	no changes
3. Reactor physics, safety, and security	Organizational and human factors	14	no changes
	Materials science and engineering (nuclear facility materials, failures, component engineering, inspections and lifetime management)	9	no changes
	Nuclear and particle physics	6	increase less than 10%
	Reactor physics and dynamics	9	no changes
	Thermal hydraulics and coolants	11	increase less than 10%
	Risk analysis (incl. Probabilistic risk assessments)	12	increase more than 10%
	Safeguards	11	increase less than 10%
	Safety and security (business security and fire safety)	6	no changes
	Severe accidents	11	increase less than 10%

For preparing education and training programmes and formulating recommendations, the most relevant part of the survey is the answer to the open questions. Participants were asked about the professions directly related to their sector activities in which they encounter difficulties in finding highly skilled personnel.

25 out of the 30 institutions answered open-end-questions. Survey results show that those organizations mostly have problems finding skilled workers in the following fields:

- ➢ nuclear engineering,
- ➢ radiation protection (all levels from operational radiation protection personnel to R&D, safety cases etc.),
- ➢ nuclear physics,
- ➢ electrical and system engineering.

Also, it is difficult to find skilled personnel specialized in waste management, decommissioning and radiochemistry. Some organizations pointed out that today it is very difficult to recruit specialists/experts in different nuclear fields like thermal-hydraulics, severe accidents, reactor physics, I&C, electrical systems, etc.

As the process of recruiting employees in the nuclear sector becomes more difficult, it is important to understand why this is happening. The organizations were questioned why it is so difficult nowadays to recruit well-skilled nuclear experts. There are several factors that are contributing to this problem, however, among the respondents, the most frequently emphasized reasons were:

- transfer to private sector with better salaries;
- reduced attractiveness of R&D salaries in comparison with industry (NPP);
- limited possibility to recruit foreign experts due to the language barrier;
- some organizations indicated the decrease of the number of students at universities in comparison with the market needs;
- nuclear specializations involve high efforts and longer time to be ready to work.

4.3 Forecast

This report reflects, as requested, HR needs over the next ten years. However, first, taking into account the number of new nuclear facilities to be built soon after the ten-year mark, and second, that a lot of the data is old (2015), the report is therefore probably underestimating the actual human resources that will be needed. At the same time, there is a level of uncertainty because the new build projections are based on a very unstable geopolitical situation and a war at Europe's doorstep, with more than significant consequences on the energy resilience of the EU member states + UK.

There are currently (as of April 2023) 109 nuclear reactors in operation in (EU27+UK) with a cumulative power of 102.5 GW. In addition, there are 110 reactors that are in permanent shutdown mode.

Although some EU countries have decided to phase out nuclear energy, it is foreseen that a number of new nuclear power plants will be constructed in Europe in the next 20 years (see the list in Table 4.3.1). In addition to one PWR (in Slovakia) and 3 EPR units under construction today (1 in France and 2 in UK), 44 new build reactors are planned or proposed in 12 countries (Bulgaria, Czech Republic, Finland, France, Hungary, Netherlands, Lithuania, Poland, Romania, Slovakia, Slovenia, and the United Kingdom).

Therefore, there is a need to enhance human capacity to support these new units for construction, operation, and maintenance. There is also a need for nuclear expertise in dismantling and waste management to properly decommission the 110 shutdown reactors. All these activities rely also on regulatory expertise, efficient licencing processes, on-site inspections, etc. which will mean responding to HR needs in regulatory bodies and TSO.

Updated table 4.3.1. Number of new reactors planned or proposed in European Union and United Kingdom (data from World Nuclear Organization webpage [66]):

Country	Number of reactors in construction	Number of planned reactors	Number of proposed reactors	Total additional future reactors
Bulgaria	0	1	3	4
Czech Republic	0	1	3	4
Finland	0	1	0	1
France	1	0	6	8
Hungary	0	2	0	2
Lithuania	0	0	2	2
Netherlands	0	0	2	2
Poland	0	0	6	6
Romania	0	2	1	3
Slovakia	1	0	1	2
Slovenia	0	0	1	1
United Kingdom	2	2	10	14
TOTAL: EU + UK	4	9	35	49

In **Bulgaria**, the government decided to build new nuclear power plants at Kozloduy and Belene. However, both NRA[1] and INRNE[2] point out a shortage of students entering nuclear programmes due to the long-lasting stop-and-go decisions in new build, as demonstrated by the unsuccessful restart of the construction project at Belene since 2002.

The **Czech Republic** is a strong advocate of nuclear energy use having a large support from its public opinion. The development of nuclear is expected to increase in all domains: new build at Dukovany and Temelín, lifetime extension of existing operating reactors, design of innovative SMR, R&D at Řež and technical universities (ČVUT[3], UWB[4]), waste management (SÚRAO), safety (SÚJB) and support from the government and Recovery & Resilience call (CANUT[5]). All skills and competencies are expected to increase in the coming years, strengthening the overall workforce in the country.

In **Finland**, the EPR reactor at Olkiluoto started commercial operation in 2023. It should significantly increase the nuclear share of electricity generation in the country. Finland will also be one of the first countries in the world to open a deep geological repository for nuclear waste (Onkalo), constructed and operated by Posiva.

France is the country having the largest nuclear share in the electric mix (70%) and accordingly the largest nuclear workforce in Europe (220,000 direct and indirect jobs). In President Macron’s speech in Belfort on 10 February 2022, in a major policy change, he announces the reversal of the 2015 law that aimed to reduce the nuclear share below 50%. He also announced the construction of 6 new nuclear power plants – and the consideration of 8 additional reactors – as well as €1 billion programme dedicated to SMR/AMR future technologies. Nuclear new build projects are currently under consideration in the French Parliament for approval. If the Parliament signs off the new build plan, R&D (CEA[6]), the waste management agency (Andra[7]) and safety organizations (ASN[8], IRSN[9]) will not only have to maintain their skills but will need to hire significant number of human resources in particular during the construction phase of all these new units.

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[1] Bulgarian Nuclear Regulatory Agency

[2] Institute for Nuclear Research and Nuclear Energy

[3] Czech Technical University in Prague

[4] University of West Bohemia

[5] Center of Advanced Nuclear Technology

[6] Commissariat à l’énergie atomique et aux énergies alternatives

[7] Agence nationale pour la gestion des déchets radioactifs

[8] Autorité de sûreté nucléaire

[9] Institut de radioprotection et de sûreté nucléaire

In addition to the life extension of the operating reactors in **Hungary**, the government decided the construction of two new nuclear units at Paks. An intergovernmental agreement has been signed with the Russian Federation to build 2 new VVER-1200 units.

In 2021, a prior decision to phase out nuclear in the **Netherlands** has been reversed and two new nuclear power units are now proposed in accordance with EU climate objectives of CO_2 reduction. NRG[10] is also operating the high-flux reactor in Petten delivering medical isotopes and preparing for its replacement by Pallas.

Although **Poland** has no nuclear operating power plants today, the country would like to diversify its electricity generation and reduce carbon emissions by developing nuclear power. The plan is to build 6 nuclear power units. An intergovernmental nuclear agreement has been signed with the US to prepare for the country's first nuclear reactor. NCBJ[11] is operating the MARIA research reactor at Świerk. PAA[12] is the nuclear authority and ZUOP[13] operates the National Radioactive Waste Repository (KSOP) in Różan. It is expected that all nuclear skills shall be enhanced in the country in support of the national programme development and the new build construction.

In **Romania**, the government confirmed the construction of new CANDU units at Cernavoda together with the refurbishment of the existing ones. RATEN ICN[14] at Pitesti would like to increase nuclear skills and develop generation IV reactors. CNCAN[15] is the safety authority and ANDR[16] the waste management agency of the ministry of energy. Romanian nuclear utility Nuclearelectrica (SNN) signed an agreement with U.S. small modular reactor (SMR) vendor NuScale to build a 462MW NuScale SMR plant at a former coal plant in Romania [67].

In **Slovakia**, a new reactor (Mochovce-3) has been recently connected to the grid in 2023, and another reactor is being built on the same site. Some R&D and engineering is conducted at VUJE[17] with E&T at STU[18].

[10] Nuclear Research and Consultancy Group

[11] National Center for Nuclear Research

[12] National Atomic Energy Agency

[13] Radioactive Waste Disposal Entreprise

[14] Institute for Nuclear Research

[15] Romanian National Commission for Nuclear Activities

[16] Nuclear and Radioactive Waste Agency

[17] Nuclear Power Plant Research Institute

[18] Slovak University of Technology in Bratislava

Slovenia is sharing the Krško nuclear power plant with **Croatia**. Besides life extension, an application for the construction of a new unit has been submitted to the ministry of Infrastructure. Therefore, both the SNSA[19] and the JSI[20] are foreseeing a significant increase in terms of human resources.

Although the **United Kingdom** left the EU, it is one of the most active countries in new nuclear development. Nuclear is one pillar of the decarbonation strategy of the UK government. EDF Energy is constructing 2 EPR reactors at Hinkley Point C and is preparing for the construction of 2 additional ones at Sizewell C. Other sites have also been identified to implement power reactors including SMRs. The NDA[21] is the nuclear waste management agency overseeing the decommissioning of all nuclear sites.

In **Belgium**, although nuclear phase-out has been postponed because of the gas shortage caused by the war in Ukraine, there is still some uncertainty about future nuclear policy. That clearly weakens the attractiveness of the nuclear sector in the country. R&D will continue at SCK-CEN with the proposed accelerator-driven system Myrrha while industry will focus on dismantling and waste management.

In **Germany**, the last reactors have stopped all operation in 2023. The focus of work by institutional bodies and industrials will be from now on dedicated to dismantling and waste management. Nevertheless, R&D and innovation are continuing on fusion reactors.

In **Spain**, nuclear power is expected to continue operation at current level, postponing the shutdown of reactors, with no replacement envisioned at this point.

In **Lithuania**, the dismantling of the RBMK reactors in Ignalina will proceed as planned.

Sweden reversed the former phase-out policy by deciding the replacement of existing reactors. Recently, the government announced reconsidering nuclear energy to fight global warming eventually introducing innovative SMRs. SKB[22] operates a repository for low-level and intermediate waste and proposed a geological repository for high-level waste in granite rock.

In summary, nuclear energy will continue being a backbone of the electric generation in Europe. Despite the phasing out policy followed by some EU countries, nuclear energy is considered in many countries as quite important and a clear asset to achieve the goal of net zero carbon emissions beyond 2050. Therefore, strong commitments have been undertaken by 11 countries to accelerate the development and construction of new nuclear power plants. These new reactors are designed with extremely high safety features and a lifetime exceeding 60 years. In those countries, R&D centres and institutional as well as industrial support have indicated increasing their human resources and skills in nuclear. While in

[19] Slovenian Nuclear Safety Administration

[20] Jožef Stefan Institute

[21] Nuclear Decommissioning Authority

[22] Swedish Nuclear Fuel and Waste Management Company

countries phasing out nuclear, competences shall be mainly oriented towards dismantling and waste management.

4.3.1 Workforce

The direct workforce for the EU27 + UK in nuclear R&D, regulation, and decommission and waste management are estimated around 52,500 jobs, with the following distribution:

- Nuclear R&D (incl. TSO's and research reactors): 22,500 jobs
- Nuclear decommissioning and waste management: 25,000 jobs
- Nuclear regulations (safety and security): 5,000 jobs

Indirect jobs supported through the supply chains are assumed to be similar in number, bringing the total to over 100,000 jobs. To sustain current operations, these sectors will require over 30,000 additional jobs by 2036 just to compensate for retirements.

The demand for clean energy and the increased range of non-power applications is likely to ensure that the nuclear sector as whole will continue to evolve and expand the next ten years. However, such increase is likely to vary in the different nuclear subsectors, depending on national policies and programmes.

4.3.2 Nuclear research and development

Continued research and development in the nuclear area is important for addressing challenges like the demand for clean energy, advancements in non-power applications in emerging fields like medicine, industry, and space exploration.

Thirteen new power reactors are either under construction or in planning in the EU27 + UK translating into an increase of about 12% in nuclear power if no existing reactors are closed down. It is likely that the R&D sector would experience at least a similar growth, especially with the appearance of new reactor concepts like e.g., small modular reactors (SMR's). Further, the advancements in nuclear technology offer supports applications in various fields, including medicine, industry, agriculture, research, and space exploration.

Given the technical complexity and critical nature of nuclear R&D, it requires a highly educated staff in a wide range of disciplines, e.g., nuclear engineering, materials science, (nuclear) physics, (nuclear) chemistry, advanced reactor technologies, health physics and radiation protection, environmental science, computer science and engineering, mathematics and statistics.

The high level of education, experience and skills in nuclear R&D contribute to the advancement of nuclear science, the development of innovative technologies, and the safe operation and use of nuclear power and non-power applications. Nuclear R&D is constantly evolving, and new skills and technologies may emerge, and continuous learning and professional development is crucial for the sector.

4.3.3 Nuclear decommissioning and waste management

Nuclear decommissioning and waste management is expected to increase due to aging nuclear infrastructure and the retirement of some nuclear power plants. Stricter safety and environmental regulations, along with public concerns and expectations, further drive towards an increase of D&WM activities. A survey report made by EHRO-N suggest that the sector could see an increase up to 30% in the next decade.

Some of the main discipline required in nuclear decommissioning and waste management are nuclear engineering, radiation protection, environmental science, and materials science. Besides these scientific disciplines, the D&WM sector will also need project managers with experience in large projects and logistics, transport, handling and lifting.

4.3.4 Nuclear regulations

There is likely to be some increase in nuclear regulation and oversight in the next decade with the aim of continued enhancement of safety, security, and radiological and environmental protection. However, it is important to note that the specific direction and extent of regulatory changes vary among different countries and regions. While some countries are considering strengthening their regulatory frameworks, others may maintain their current levels or focus on streamlining regulatory processes.

Nuclear regulation encompasses a variety of disciplines to ensure the safe and responsible operation of nuclear facilities. Some of the main disciplines required by Nuclear Regulation are Nuclear Engineering, Radiological Protection, Health Physics, Environmental Science, Nuclear Safety, Legal and Regulatory Compliance, Risk Assessment and Management.

4.3.5 Results from the survey

Results from the survey indicated diverse opinions regarding the most in-demand nuclear jobs in the next ten years. However, the top five disciplines reported were:

- Decommissioning and waste management
- Radiological protection
- Nuclear engineering
- (Nuclear) physics
- Medical application

Demand for specific nuclear jobs may vary across European countries due to variations in energy policies, health policies, and nuclear capacities. Nevertheless, the mentioned disciplines are generally expected to be high in demand as Europe continues to tackle its energy needs, health policies, nuclear safety, and waste management challenges.

5. RECOMMENDATIONS

The work of the task force has demonstrated that it is very difficult to get precise data on the nuclear workforce through European wide surveys. A national Nuclear Workforce Assessment (NWA) can be an important tool for establishing comprehensive understanding of current and future human resources demands, understanding the supply of skills and competences, identifying possible gaps between demand and supply, and establishing an action plan with remediate measures. The main steps of such assessment process are:

1. mapping of current nuclear workforce (can include demographic information such age, years of experience, competences, gender, and education level);
2. predicting future nuclear workforce needs (can be scenario based and supported with workforce modelling tools);
3. mapping of supply of workforce to the nuclear sectors (consider that one academic discipline can supply workforce to different economic sectors and that supply can also be through mobility, reskilling and upskilling);
4. gap analysis;
5. develop a nuclear skills strategy addressing possible gaps;
6. implementation of skills strategy;
7. review of the nuclear NWA process (e.g., every ten years or significant changes in national situation).

A full understanding of the workforce size, its competence needs, and possible mitigating measures can only be established through involvement of all relevant stakeholders (ministries responsible for nuclear programmes, industry organizations, regulatory authorities, technical safety organizations, research and training infrastructures and academia).

EU mobility: As a general recommendation, in order to address the issue of HR supply and demand, it is necessary for the EU institutions to 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. This means, in order to attract the young generation to the nuclear sector, it will be necessary to reinforce flexibility in career development, either within a company or institution, from one country to another, and from one nuclear activity to another (e.g., safety to dismantling).

5.1 Recommendations for Industry

The Work Package 1 consists of surveys conducted among industry (Task Force 1.1), research (including research reactors), safety authorities and technical safety organizations, waste management and decommissioning activities (Task Force 1.2), and medical and non-power applications (Task Force 1.3). In both TF 1.1 and 1.2 cases, even if analysis not yet completed for TF1. 1, the data collection brought answers in max 30% of expected rate, which is rather low and leads to uncertainties in data interpretation.

The future of the European nuclear industry strongly depends on highly skilled and well-trained employees. Considering the number of nuclear new build projects in the EU and at the same time the number of decommissioning of nuclear and research reactors, it is clear the sector is in high need of new staff. The estimations vary depending on the country therefore a pan-European overview of HR situation, periodically updated, is strongly recommended. The successful HR planning of the European nuclear workforce, which will continue a safe operation of the existing nuclear fleet and conduct research, should be based on reliable numbers of staff in all organizations mentioned. The efforts in these data collection should be seen as a regular and necessary exercise supported by all stakeholders involved. Only with a clear overview of nuclear employees' numbers will we be able to attract new talents, passing the right message about many opportunities. Industry should be a main driving force in attracting the next generation to the nuclear sector.

Furthermore, industry should be encouraged to increase its investment in R&D which is linked to industry performance and safety improvements.

On-the-job training is also a critical aspect to be taken into account by industry, as it complements initial academic training whatever the level of study.

In summary, it is recommended to:

1. **Support national nuclear workforce assessment:** It is recommended that the nuclear industry supports the process of performing a comprehensive national nuclear workforce assessment. This includes contributing comprehensive workforce data, including demographic information (age, years of experience, gender, education level), competences, and establishing future needs in terms of workforce size and competences.
2. **Increase R&D investment:** The nuclear industry should increase investment in research and development by allocating dedicated resources to initiatives focused on nuclear technology, safety, waste management, and other relevant areas. This increased investment will enable the industry to drive innovation, enhance safety measures, improve operational efficiency, and develop advanced nuclear technologies.
3. **Strengthen education and training support:** The industry should increase support to education and training in the sector. This can be done by providing support for scholarships, and grants to students pursuing nuclear-related degrees. Embracing the concept of lifelong learning and offering additional industry-specific training programmes, workshops, and seminars could enhance the knowledge and skills of the sector.

5.2 Recommendations for Education

Universities in countries that have already an established nuclear civil programme with a possible large inventory of radwaste (LIMS) [68] are more in tune with the skills to be need in the future of the radwaste management than the ones that have research reactors phasing out with/without no spent fuel or very small radwaste inventories. The last 30 years have shown important changes in the curricula of the university's studies where fundamental curricular units such as radiochemistry, have been wiped out from the curricula studies all over the world. Traditional schools such as French, Russian, British, and American ones, just to mention the oldest and large ones resulting from the XIX century developments, from the WWII and from the development of the first NPPs, have lost importance since the research drive of the companies switch to the overall world of engineering. The last 35 to 40 years of R&D have been more directed to nuclear designs, fuel assemblies, nuclear physics and safety and security. At that time, studying nuclear was considered very prestigious. Only recently with the impact of accidents/incidents with sealed sources in the industry and medical applications and nuclear accidents such as Three Mile Island, Chernobyl and Fukushima have had an impact on the rise of studies, such as safety of nuclear reactors, increasing robustness of containment designs, but also strengthening areas such as intervention in nuclear/radiological emergencies and decontamination techniques like the example of Goiânia in Brazil or the ongoing clean-up of the Fukushima accident. It is not clear if the follow-up of these situations had any impact on the curricula of the universities, besides the normal flow of masters and PhD students. However, segments of society such as the media, the general public, and politicians, have been some of the most important stakeholders have impacted public acceptance on one hand, and on the other hand security of energy supply was not the sensitive subject as it is today to warrant a strong new build programme. The change of paradigm, namely the war at Europe's doorstep is having a significant impact including in the number of students applying for degree programmes in countries that are now pushing forward to develop or expand their nuclear energy programmes. That being said, the management radioactive waste remains sensitive (political and public acceptance), and it will be necessary to be attentive to ensure that students are attracted to this track as well.

Regulators, TSO and WMO are the ones that are directly affected by the consequences of these areas not being addressed but it is the research institutes traditionally linked to the nuclear field that do the major developments in research once they have been the pool of skills to which the others go for experts with the needed skills. State labs from the past that modernized themselves are able to respond to the needs of demand of TSO and WMO. Research institutions, TSO, WMO, regulators and operators are indeed the ones that have a clear idea about the developments going on as well as the needs and skills needed for the future. Even though universities have been developing masters, PhD, and post-graduate studies, it is fundamental to increase links with the industry and health sectors to complete the full panorama. Only in one area, the radioactive waste management, it has been clear that what started by being only a technical, scientific, and political problem, is today, a social concern as well for two types of reasons. First, the evolution of the knowledge that started more than 40 years ago with the study of treatment techniques for spent fuel, the resulting HLW, the transports of these wastes to sites where they could be interim storage and/or disposed of in different repositories designs including the GD option. The radwaste solutions have been since ever the culprit of the nuclear field and still are despite the years of R&D and the many millions already spent. Only in the last years, it was possible to establish a platform, IGD-TP and now, the EJP EURAD, to take on board not only the knowledge of the LIMS (large inventory member states) and SIMS (small inventory member states) in an effort to harmonize procedures, techniques and strategies for common waste streams. The rise of the role of the civil society among the other stakeholders traditionally involved in the same platforms and EU R&D projects is evident. The interaction with the civil society as well as the need to increase exchange in a language that could be understood not only by the social scientists and communication schools. Problems that can arise are the strict curricula the universities have and the difficulties that somehow experienced when trying to implement new programmes of studies, or the fact that communication between the universities and the working job world is sometimes upside down. The universities need to develop the fundamental aspects of solving the real technical problems faced by the other institutions, therefore a change in curricula from traditionally to disciplinary is essential and ensure better preparedness for new challenges. This is only effective if a chain of demand globally includes all interested parties and a dialogue that provides students with fundamental know-how and target research interests, vocational trained new employees in the research institutes and, finally, skilled workers in the needed jobs [69]. Different organizations have been studying and providing information about the decline in certain curricular units and the toll over the human resources that will be needed in the future as well as the need to include new subjects as radiological protection and communication and digital skills [70]. The operators, WMO, TSO and regulators have been finding their human resources, in a large extent, in professional courses including the vocational education and training referring to instructional programmes or courses that focus on the skills required for a particular job function or trade [71]. ECVET was a European credit system for vocational education and training. Its aim is to help individuals on their way to achieving a qualification with the transfer, recognition, and accumulation of learning outcomes [72],[73]. This system had the objectives to increase transparency of qualifications, support mobility and provide a systematic and transparent approach to present, document and validate the professional's knowledge, skills, and competence. The term competence is in this case limited to meaning autonomy and responsibility. ECVET was replaced by a Council Recommendation of November of 2020, on vocational education and training (VET), for sustainable competitiveness, social fairness and resilience. The new recommendation also supports the learning outcomes approach. In vocational training, education prepares students for specific careers, disregarding traditional, unrelated academic subjects. Regarding the nuclear sector, projects of the Euratom Fission Training Schemes (such as ENENIII, ENETRAP II, PETRUS II, PETRUS III, etc.), were and are designed such that training is structured to establish a common certificate for professionals throughout the EU. The learning outcomes approach has been adopted by numerous projects, but still must evolve towards qualification and education standards, assessment and recognition. It must consider all stakeholders. Benefits of collaboration is clear with increased transparency, quality assured learning processes and transferable competences. It will be important that the universities continue to be part of the overall efforts, meaning, looking attentively to the problems that the world outside academia face and establish the fundamental and practical curricula needed to contribute to future solutions in the areas mentioned [74-77].

In a summary it is recommended to:

1. **Creation of transdisciplinary programmes** which will also address communications skills.

2. **Promotion of nuclear awareness modules** in education curriculum including in vocational training (technicians, computer technology, health professionals, etc.). This awareness should begin as early as possible in the young people's education and might help make the nuclear sector more attractive as a whole.

3. **Harmonization of VET**: Education and training institutions should continue to work towards harmonization. For Vocational Education and Training (VET), it is recommended to follow the seven recommendations put forward by Cedefop to improve the quality, relevance, and effectiveness of VET trainings. A first step would be to establish learning outcomes for VET courses.

5.3 Recommendation for Policymakers

Currently about half of the low-carbon electricity in the EU is generated by the nuclear sector. In the context of climate policies, nuclear power may increase its contribution for a clean, safe, reliable, dispatch able, and stable supply with affordable prices and more independence in the geopolitical crisis. Strategic planning both at MSs and EU levels is crucial to ensure the conditions to keep enough workforce 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 MSs 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 a performant 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 attractivity 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 the rapid actions at national level, especially for the countries implementing a nuclear programme are necessary, an 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.

A 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 MSs where the phase-out was already declared and the need to prepare the workforce by vocational education should be considered as well.

Taking into consideration the important role of the regulators both in the operational and new nuclear developments, an important focus should be devoted to the preparation of their competences, especially for the innovative technologies, where the efforts might be more extensive and require a longer period of time.

In a summary it is recommended to:

1. **Facilitate national nuclear workforce assessment:** Policymakers should 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.

2. **Increase R&D investment:** Policymakers should increase investment programmes in research and development by allocating dedicated resources to initiatives focused on nuclear technology, safety, waste management, and other relevant areas. This investment will drive technological advancements and support the growth and innovation of the nuclear industry.

3. **Support education and training infrastructure:** Policymakers should allocate the necessary resources and support to enhance education and training infrastructure that is needed to support nuclear programmes. This includes providing the required facilities, equipment, and expertise to ensure high-quality education and training in the nuclear sector.

4. **Funding and financing**: Further explore possibilities and good practices under existing initiatives and funding programmes and funding instruments, such as Euratom R&T Programme, Horizon Europe Framework Programme, Erasmus+ Programme, the European Social Fund Plus and the Recovery and Resilience Facility etc.; Strengthen further collaborations, mobility and exchanges among students, doctoral candidates, and post-docs, building on the existing initiatives.

5. **Harmonize safety authority training:** Establish harmonized training opportunities, possibly at the European level, for safety authorities. This will enhance their competence and, over time, lead to streamlined licensing procedures. By aligning training programmes and competences, safety authorities can improve consistency, share best practices, and ensure the highest safety standards.

6. LIST

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Appendix

7.1 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?

Select Country

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

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

(*) Please Specifiy

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									
☐	Nuclear waste management, de-commissioning and dismantling (including R&D and planning)				○	○	○	○	○
☐	Radiochemistry				○	○	○	○	○
☐	Water chemistry (incl. corrosion)				○	○	○	○	○

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								
☐	Construction engineering				○	○	○	○	○
☐	Electrical engineering				○	○	○	○	○
☐	Instrumentation and control				○	○	○	○	○
☐	Mechanics/mechanical engineering				○	○	○	○	○
☐	Nuclear fuel cycle (R&D, front-end, reprocessing and back-end)				○	○	○	○	○
☐	Process engineering				○	○	○	○	○
☐	Project management				○	○	○	○	○
☐	Radiation protection				○	○	○	○	○
☐	Reactor and „hot" lab operation				○	○	○	○	○
☐	Quality management and inspections				○	○	○	○	○
	3. Reactor physics, safety, and security								
☐	Organisational and human factors				○	○	○	○	○
☐	Materials science and engineering (nuclear facility materials, failures, component engineering, inspections and lifetime management)				○	○	○	○	○
☐	Nuclear and particle physics				○	○	○	○	○
☐	Reactor physics and dynamics				○	○	○	○	○
☐	Thermal hydraulics and coolants				○	○	○	○	○
☐	Risk analysis (incl. probabilistic risk assessments)				○	○	○	○	○
☐	Safeguards				○	○	○	○	○
☐	Safety and security (business security and fire safety)				○	○	○	○	○
☐	Severe accidents				○	○	○	○	○

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 (*)					
☐					○	○	○	○	○
☐					○	○	○	○	○
☐					○	○	○	○	○
☐					○	○	○	○	○
☐					○	○	○	○	○
☐					○	○	○	○	○
☐					○	○	○	○	○
☐					○	○	○	○	○
☐					○	○	○	○	○
☐					○	○	○	○	○
☐					○	○	○	○	○
☐					○	○	○	○	○
☐					○	○	○	○	○

(*) 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	☐	☐	☐	☐	☐		
Radioprotection	☐	☐	☐	☐	☐		
Nuclear chemistry	☐	☐	☐	☐	☐		
Decommissioning	☐	☐	☐	☐	☐		
Other...							
	☐	☐	☐	☐	☐		
	☐	☐	☐	☐	☐		
	☐	☐	☐	☐	☐		
	☐	☐	☐	☐	☐		
	☐	☐	☐	☐	☐		
	☐	☐	☐	☐	☐		
	☐	☐	☐	☐	☐		
	☐	☐	☐	☐	☐		

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

2 Mooc (Massive Open Online Course)

Section 7: Contact information

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

○ Yes ○ No

Name:

Surname:

Phone:

e-mail:

7.2 Database of organizations

Country	Abbreviation	Name of Institution	Type of organization
Austria		Nuclear Engineering Seibersdorf	Waste Management and Decommissioning
		ANDRITZ	Design, Engineering, Manufacturing and Maintenance
	AIT	Austrian Institute of Technology GmbH	Research Design and Development
		Federal Ministry of Climate Action, Environment, Energy, Mobility, Innovation and Technology	Regulatory Authority
		Atominstitut der Österreichischen Universitäten	University
		Erich-Schmid Institute for Materials Science	University
		Graz University of Technology	University
	HEPHY	Institute for High Energy Physics	University
		Technische Universität Wien	University
	SMI	The Stefan Meyer Institute	University

Country	Abbreviation	Name of Institution	Type of organization
		University of Innsbruck	University
		University of Natural Resources and Applied Life Sciences	University
	VERA	Vienna Environmental Research Accelerator	University
		Med Austron	Cancer Treatment and Research Centre
Belgium	ONDRAF/NIRAS	Belgium's Agency for Radioactive Waste and Enriched Fissile Materials	Waste Management and Decommissioning
Belgium		Westinghouse Electric Belgium	Design, Engineering, Manufacturing and Maintenance
	JRC	Joint Research Centre	Research Design and Development
	SCK CEN	Belgian Nuclear Research Centre	Research Design and Development
		BelV	Technical Safety Organization
	FANC	Federal Agency for Nuclear Control	Regulatory Authority
Bulgaria	INRNE	Institute for Nuclear Research and Nuclear Energy	Research Design and Development
	BNRA	Bulgarian Nuclear Regulatory Agency	Regulatory Authority

Country	Abbreviation	Name of Institution	Type of organization
Croatia		University of Zagreb, Faculty of Electrical Engineering and Computing	University
Cyprus		The Radiation Inspection and Control Service Department of Labour Inspection	Regulatory Authority
		University of Cypress Department of Physics	University
Czech Republic	CTU ČVUT	Czech Technical University in Prague (České vysoké učení technické v Praze)	University
	UWB	University of West Bohemia	University
Denmark	DD	Danish Decommissioning	Waste Management and Decommissioning
		Copenhagen Atomics	Research Design and Development
		Seaborg Technologies	Research Design and Development
	DEMA	Danish Emergency Management Agency	Regulatory Authority
	DHARP	Danish Health Authority, Radiation Protection	Regulatory Authority

Country	Abbreviation	Name of Institution	Type of organization
		Aarhus University Department of Physics and Astronomy	University
		Technical University of Denmark Plasma Physics and Fusion Energy	University
		University of Copenhagen Niels Bohr Institute	University
Estonia		Estonian Academy of Sciences	University
		Tallinn University of Technology	University
		University of Tartu	University
Finland		Fortum	Utilities
	TVO	🇫🇮 Teollisuuden Voima Oyj	Utilities
Finland		Posiva	Waste Management and Decommissioning
		VTT Technical Research Centre of Finland	Research Design and Development
	STUK	Radiation and Nuclear Safety Authority (🇫🇮 Säteilyturvakeskus)	Regulatory Authority

Country	Abbreviation	Name of Institution	Type of organization
		Aalto University	University
		Academy of Finland	University
		Helsinki Institute of Physics	University
		Lappeenranta University of Technology	University
		University of Helsinki	University
		University of Jyväskylä	University
France	ANDRA	Agence nationale pour la gestion des déchets radioactifs	Waste Management and Decommissioning
	CEA	Commissariat à l'énergie atomique et aux énergies alternatives	Research Design and Development
France	IRSN	Institut de radioprotection et de sûreté nucléaire	Technical Safety Organization
Germany		VKTA	Waste Management and Decommissioning
		Framatome GmbH	Research Design and Development
		ENGIE Deutschland Gmbh (industrial company)	Building services for nuclear power plants

Country	Abbreviation	Name of Institution	Type of organization
		IAF-Radioökologie GmbH	Radionuclide laboratory- Radiation safety- radiological consultant
		Wälischmiller Engineering GmbH (industrial company)	Industry - safe manipulators for the nuclear sector
Greece		National Centre of Scientific Research	Research Design and Development
		Greek Atomic Energy Commission	Regulatory Authority
Hungary		MVM Paks Nuclear Power Plant Ltd	Utilities
		Bátaapáti	Waste Management and Decommissioning
Hungary	PURAM	Public Limited Company for radioactive Waste Management	Waste Management and Decommissioning
		Püspökszilágy-Kisnémedi	Waste Management and Decommissioning
		Bay Zoltán Non-profit Ltd. for Applied Research	Research Design and Development
	BNC	Budapest Neutron Centre	Research Design and Development
		Centre for Energy Research	Research Design and Development

Country	Abbreviation	Name of Institution	Type of organization
		MTA ATOMKI	Research Design and Development
	NRIRR	"Frédéric Joliot-Curie" National Research Institute for Radiobiology and Radiohygiene	Research Design and Development
		VEIKI Energia+ Kft	Research Design and Development
	HAEA	Hungarian Atomic Energy Authority	Regulatory Authority
		MTA EK	Technical Safety Organization
	NUBIKI	Nuclear Safety Research Institute	Technical Safety Organization
Hungary	BME-NTI	Budapest University of Technology and Economics The Institute of Nuclear Techniques (Techniques Nukleáris Technikai Intézet)	University
		Eötvös Loránd University	University
		University of Debrecen	University
		ISOTOP	Institute of isotopes
	NyMTIT	West Mecsek Public Information Association	Association of Local Governments

Country	Abbreviation	Name of Institution	Type of organization
Ireland		Environmental Protection Agency	Regulatory Authority
Italy		SOGIN	Waste Management and Decommissioning
		Newcleo	Research Design and Development
		SIET S.p.A.	Research Design and Development
Latvia		State Environmental Service	Regulatory Authority
Lithuania		Ignalina Nuclear Power Plant	Waste Management and Decommissioning
		Lithuanian Energy Institute	Research Design and Development
	VATESI	State Nuclear Power Safety Inspectorate	Regulatory Authority
		Kaunas University of Technology	University
		Vilnus University	University
		Vytautas Magnus University	University
Luxembourg		Ministry of Health	Regulatory Authority

Country	Abbreviation	Name of Institution	Type of organization
Malta		Commission for the Protection from Ionising and Non-Ionizing Radiation	Regulatory Authority
Netherlands	COVRA	Centrale Organisatie Voor Radioactief Afval	Waste Management and Decommissioning
	NRG	Nuclear Research and Consultancy Group	Research Design and Development
		PALLAS	Research Design and Development
	ANVS	Authority for Nuclear Safety and Radiation Protection	Regulatory Authority
Poland	ZUOP	Radioactive Waste Management Plant	Waste Management and Decommissioning
	IChTJ	Institute for Nuclear Chemistry and Technology	Research Design and Development
	NCBJ	National Centre for Nuclear Research	Research Design and Development
		Department of Nuclear Energy	Regulatory Authority
	PAA	National Atomic Energy Agency	Regulatory Authority
		Cyclotron Center Bronowice	Nuclear Facility Vendor another big supplier
	AGH	AGH University of Science and Technology	University

Country	Abbreviation	Name of Institution	Type of organization
		Warsaw University of Technology	University
		Wroclaw University of Technology	University
Portugal	APA	Portugese Environment Agency	Regulatory Authority
	IST	Instituto Superior Técnico	University
Romania		National Society "NUCLEARELECTRICA" SA	Utilities
Romania	ANDR	Nuclear and Radioactive Waste Agency	Waste Management and Decommissioning
		Nuclear Technology and Engineering Center (Centrul de Inginerie Tehnologică Obiective Nucleare)	Design, Engineering, Manufacturing and Maintenance
		Horia Hulubei National Institute of Physics and Nuclear Engineering (Institutul Național de Cercetare-Dezvoltare pentru Fizică și Inginerie Nucleară „Horia Hulubei”)	Research Design and Development
	RATEN ICN	Institute for Nuclear Research Pitesti	Research Design and Development
	CNCAN	National Commission for Nuclear Activities Control	Regulatory Authority

Country	Abbreviation	Name of Institution	Type of organization
Slovakia	JAVIS	Slovak Nuclear and Decommissioning Company	Waste Management and Decommissioning
	ÚJD SR	Nuclear Regulatory Authority of the Slovak Republic (Úrad jadrového dozoru Slovenskej republiky)	Regulatory Authority
Slovenia	ARAO	Slovenian Radioactive Waste Agency (Agencija za radioaktivne odpadke, Ljubljana)	Waste Management and Decommissioning
Slovenia	JSI	Jožef Stefan Institute	Technical Safety Organization
	SNSA	Slovenian Nuclear Safety Administration	Regulatory Authority
		University of Ljubljana	University
Spain		CN Almaraz	Utilities
	ENRESA	Empresa Nacional de Residuos Radiactivos, S.A.	Waste Management and Decommissioning
		Enusa Industrias Avanzadas, S.A.	Design, Engineering, Manufacturing and Maintenance
		IBERDROLA Spain	Design, Engineering, Manufacturing and Maintenance

Country	Abbreviation	Name of Institution	Type of organization
Sweden	CIEMAT	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas	Research Design and Development
	CSN	Spanish Nuclear Safety Council	Regulatory Authority
	SKB	Swedish Nuclear Fuel and Waste Management Company	Waste Management and Decommissioning
Sweden		SVAFO	Waste Management and Decommissioning
		Studsvik	Research Design and Development
	SQC	Swedish Qualification Centre	Research Design and Development
	KSU	Nuclear Training and Safety Centre (Kärnkraftsäkerhet och Utbildning)	Training provider
United Kingdom		Cyclife	Waste Management and Decommissioning
	NDA	Nuclear Decommissioning Authority	Waste Management and Decommissioning
		Nuclear Waste Services	Waste Management and Decommissioning

Country	Abbreviation	Name of Institution	Type of organization
United Kingdom		Sellafield	Waste Management and Decommissioning
		VEOLIA Nuclear Solutions	Waste Management and Decommissioning
		Office for Nuclear Regulation	Regulatory Authority

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