Study on the market for decommissioning nuclear facilities in the European Union

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Aknowledgments
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Table of contents

Abstract

The European decommissioning and dismantling (D&D) market of nuclear facilities is featured by a significant long-term growth, hence representing an important opportunity of businesses and employment creation in the continent. In the next 20 years, the market size of the D&D market for nuclear power plants may reach EUR 2.2 billion per year, with an expected decline of the D&D expenses in the United Kingdom balanced by the progressive growth of the German programme (following the decision to phase-out from nuclear). The completion of this latter will then be balanced by the consolidation of the French programme, which may drive the market to a peak of about EUR 3.0 billion per year in 2045 (but depending on decisions on long term operations of existing nuclear power plants). Despite the positive outlook, a number of challenges exist to enable an open, safe and fast growing D&D market in the EU. First, specific issues linked to key schedule and cost drivers of the D&D projects (e.g. national waste strategies, national regulations, social impact of installations shutdowns) may induce potential investors to perceive the market still as uncertain and highly complex and hence discourage investments. Second, the D&D industrial landscape remains largely domestic in several Member States and with a predominant role and budget share for the utilities/operators/owners' own personnel, resulting in somewhat reduced competition. Third, unlike D&D of nuclear power plants (which relies upon proven processes and technologies), D&D for fuel cycle and research installations still requires a certain degree of industrial development before being considered as a completely mastered activity.

Executive Summary

I. Scope of the study and definitions used

The nuclear decommissioning market in the EU is still in a relatively early stage. Nevertheless, many nuclear installations will be decommissioned in the coming decades. Understanding the main drivers and the expected evolution of this market will ensure that the maximum impact can be brought to the European economy, deploying the highest standards for safety and cost-competitiveness.

This study aims to provide a general understanding about how the market for decommissioning nuclear facilities in Europe works. To do that, it analyses the key determinants of the market, in particular as concerns main actors, key segments, growth potential, existing barriers to competition and impact of technology.

This study refers to *decommissioning and dismantling* (*D&D*) as the full extent of the nuclear facilities decommissioning and dismantling tasks plus the *onsite* waste management activities (e.g. characterisation, packaging, handling, onsite interim storage or clearance until waste is ready to be shipped offsite). Typically, this is the central concern of decommissioning projects. The study refers to *waste management (WM)* as the overall activities concerning the offsite waste treatment, storage and disposal. D&D and WM activities as a whole are referred to as *decommissioning and waste management (D&WM)*.

II. Market estimation and evolution over time

Overall decommissioning and waste management market estimation

The quantification of the D&WM European market is summarised below (aggregated values up to the end of the programmes)[1].

EU market estimation (EUR_{2016} billion) up to around 2130	United Kingdom	France	Germany	Other Member States	Total
Decommissioning and waste management of all nuclear installations	155.0	114.0	>49.0	87.0	**<u>>405.0</u>**
Country weight in the EU overall market	*38%*	*28%*	*12%*	*21%*	*100%*
D&D of NPPs only	30.0	26.6	20.2	33.2	110.0
Country weight in the EU NPPs D&D market	*27%*	*24%*	*18%*	*31%*	*100%*
Decommissioning and waste management of the main single largest programme: Sellafield in the UK	99.0	-	-	-	-
Weight in the EU overall market	*24%*				
Decommissioning and waste management budgets by major actors: NDA in the UK and EDF in France	132.0	79.0	-	-	-
Weight in the EU overall market	*33%*	*20%*			

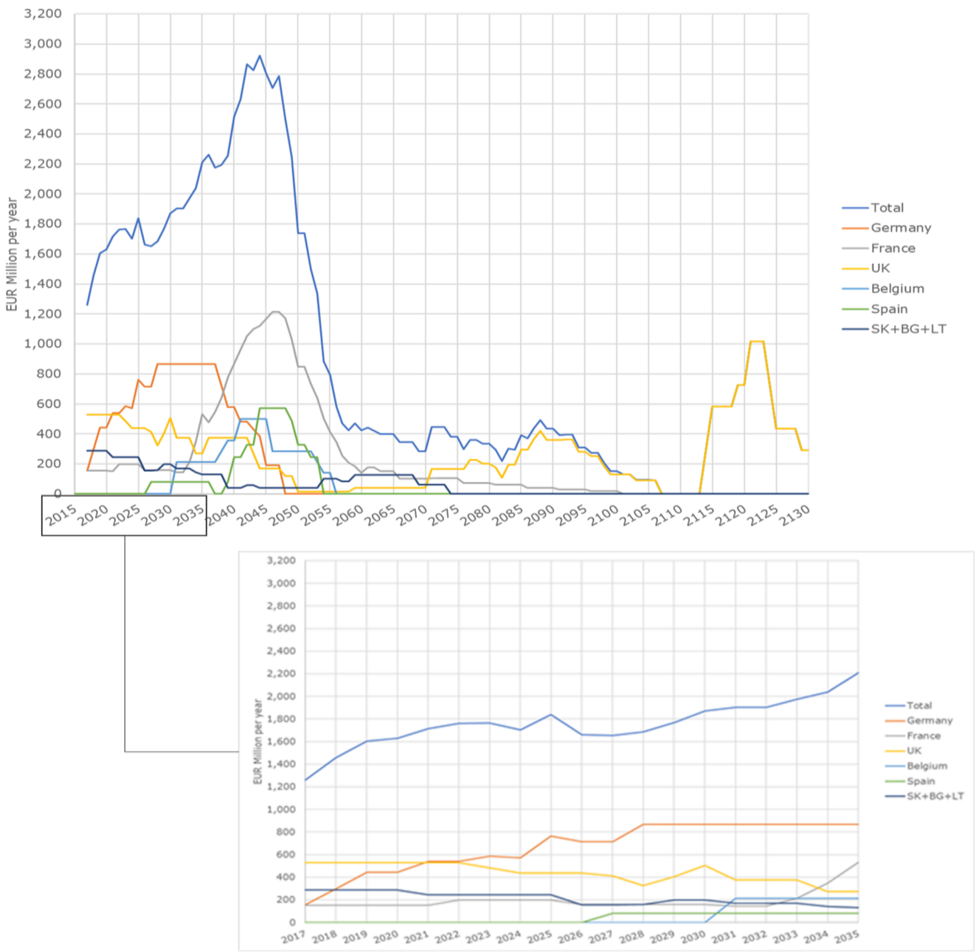
[1] These figures represent the aggregate European decommissioning and waste management budgets. They have been calculated by adding the EUR_{2016} 320 billion budgets for Germany, France and UK (based on accounting data) to the expenditure estimations for the other European countries as contained in the European Commission's *SWD (2017) 158 final*.

The table shows:

- the European *decommissioning and waste management* market can be estimated as more than EUR_{2016} 405 billion over the coming century;
- the three main *decommissioning and waste management* markets in Europe are France, Germany and United Kingdom, totalling about EUR_{2016} 320 billion over the coming century and representing about 80% of the market in the EU;
- the budgets for *decommissioning and dismantling* activities of nuclear power plants (NPPs) total about EUR_{2016} 110 billion over the coming century.

Expected market evolution over time for D&D activities related to existing nuclear power plants (NPPs)

The figures below detail the expected evolution of the D&D market for *existing* NPPs in Europe[2,3] over the coming century and up to 2035.



The figures show:

[2] The estimation is based on a market model including 219 European NPPs. For each NPP, the shutdown date and the D&D start date as well as corresponding D&D budgets have been retrieved or assumed according to the latest and most reliable information available (accounting documents stemming from the utilities have been used when possible). On average, a lifetime of 50 years is used for existing NPPs (this is for example the EDF accounting assumption "*without prejudging the outcomes of the coming 40-years reviews related decisions of the French authorities*").
[3] NPPs that are not yet built are not considered in the Figure.

- the total yearly expense for D&D activities for existing NPPs should report a growth up to 2035 and can be estimated between EUR 1.4 billion and 2.2 billion per year;
- this expense should increase even more emphatically after 2035 and reach a peak of about EUR 3.0 billion per year in 2045;
- in particular until 2050, the market will be strongly characterised by country-wide decisions concerning D&D programmes in France, Germany and the United Kingdom:
  - in France, an important increase in D&D activities is to be expected after 2030, but subject to policy decisions concerning the reduction of nuclear in the energy mix and long-term operations (LTOs) of existing NPPs;
  - the D&D activities in Germany are expected to increase in the mid-term (with a peak between 2025 and 2040), following the decision to phase-out from nuclear energy;
  - in the United Kingdom, a progressive decline from current levels is expected following the completion of the D&D activities for the nuclear reactors at Sellafield[4].

Segmentation of the D&D market for nuclear power plants

The following table reports an estimation of the D&D market for nuclear power plants by segment and gives an overview of the type of competitors involved. It directly refers to the International Structure for Decommissioning Costing (ISDC) – Level 1[5].

ISDC	ISDC Activity	Weight in D&D Budget	EU market estimation EUR billion per year up to 2045		Typically open to competition?	Type of competitors
			Minimum	Maximum		
8	PROJECT MANAGEMENT, ENGINEERING AND SITE SUPPORT	33% to 75% - average **50%**	0.9	1.5	No	Mainly decommissioning programme owner. Contractors for specific tasks and/or in case of shortage of internal resources.
1	PRE-DECOMMISSIONING ACTIONS					
2	FACILITY SHUTDOWN ACTIVITIES					
6	SITE SECURITY, SURVEILLANCE AND MAINTENANCE					
11	MISCELLANEOUS EXPENDITURE					
4	DISMANTLING ACTIVITIES WITHIN THE CONTROLLED AREA	15% to 56% - average **35%**	0.6	1.1	Yes	Large, highly specialised companies.
7	CONVENTIONAL DISMANTLING, DEMOLITION AND SITE RESTORATION					Small, local and/or civil engineering companies.
5	WASTE PROCESSING, STORAGE AND DISPOSAL	10% to 27% - average **15%**	0.3	0.5	Yes	Depending on the activity, both specialised and barely specialised small companies
10	FUEL & NUCLEAR MATERIAL					

[4] Activity sub-peaks may appear around 2090 and the 2120 due to the current D&D strategy for the Magnox (NDA estate) and AGR (EDF Energy). A type of "safe enclosure" (called "care & maintenance") of the plants is implemented, allowing for radioactivity decay and an easier D&D 50 years later. If the Magnox D&D strategy is changed for an immediate D&D instead of the current strategy, expenses would appear earlier.

[5] ISDC is a standardised cost structure for decommissioning costs of nuclear installation defined as following a joint initiative of the OECD Nuclear Energy Agency (NEA), the International Atomic Energy Agency (IAEA) and the European Commission (EC). ISDC items 3 and 9 are not used in this study (see chapter 2.3.2 for details).

As concerns "extended" project management activities (ISDC items 1, 2, 6, 8 and 11):

- on average, they typically represent 50% of the project budgets;
- these activities are usually kept internal by the operators, which set up dedicated D&D divisions (e.g. SOGIN in Italy, JAVYS in Slovakia, the four utilities in Germany, EDF, AREVA and CEA in France);
- when internal resources are insufficient, operators rely on contractors to ensure specific support tasks (e.g. engineering, licensing, planning, procurement):
    - these contractors are generally domestic, with some exceptions (e.g. in Slovakia).

As concerns other D&D activities:

- dismantling activities (ISDC items 4 and 7) represent on average 35% of the project budgets, while on-site waste management activities (ISDC items 5 and 10) represent on average 15% of the project budgets;
- they are usually open to competition (not kept internal). Nevertheless, the level and type of competition depends on the specific nature of the activity. In this respect, two main sub-segments can be observed:
    - activities requiring high level of skills, technologies and know-how (e.g. activities in the Controlled Area such as decontamination, reactor vessel and internals cutting or onsite waste treatment and activities linked to spent fuel management such as interim storage cask supply):
        - the market for these activities is dominated by a few large, highly specialised, international companies (e.g. Areva, Westinghouse, Siempelkamp, EWN, GRS) even though a number of niche domestic players are also involved;
        - the required high level of skills, technologies and know-how form a substantial barrier to entry for new players;
        - the market is fragmented and the awarded contract value is relatively low (average value around EUR 5.0 million[6]), potentially discouraging new players from making the necessary commercial investments to enter the segment.
    - activities requiring low levels of skills, technology and know-how (e.g. conventional dismantling, building demolition and basic low-level waste processing):
        - these activities are usually handled by local companies and local manpower;
        - competition is normally keen and margins are low, with new entrants (small domestic companies) trying to join the market on an opportunity base;
        - many companies entering these activities had usually worked with the utility since the operation phase of the power plant.

[6] See Italian and Slovakian examples further in the text. A typical primary circuit decontamination costs far less than EUR 5 million. Only some specifically large and delicate segmentation operations (e.g. pressure vessel, reactor internals) on turnkey basis can reach EUR 30-50 million values, but they are indeed numerically rare.

III. Main cost drivers in D&D projects for nuclear power plants

The following elements have a significant impact on NPPs D&D project costing:

- *Availability of waste management routes and the possibility to implement a full "waste driven decommissioning" approach*. The most cost-efficient way to conduct D&D projects is typically to send spent fuel and radioactive waste away from the site for disposal as soon as it is generated, to avoid supplementary onsite logistics and storage costs[7]. Nevertheless, this option is not always possible:
    - for spent fuel (to be reprocessed or not) and high-level waste, pending the availability of final deep geological disposal sites, interim centralised or decentralised storages may be built in the operation phase, representing both a cost and a constraint in many D&D projects;
    - as concerns low-level waste categories, depending on the waste routes available, operators may tend to decontaminate the dismantled plant equipment and structures more or less extensively to adjust the volume of waste[8].
- *Project duration*. In Europe, D&D projects generally take around 20 years to complete, a substantially higher duration than in other international contexts (e.g. in the US the average duration of D&D projects is about 10 years). Generally, the greater the duration, the higher the total project cost, in particular due to fixed and personnel costs. The main determinants of the long duration of the projects are the regulatory regimes in place and, to a lesser extent, the specificities linked to the management of human resources.
    - *Regulatory regimes.* D&D project scheduling is often defined by the need to meet country-specific requirements and by the time-consuming authorisation processes[9]. Indeed, these requirements are critical in order to assure a safe decommissioning. Nevertheless, under the regulatory aspect D&D projects are often "one-of-a-kind", requiring substantial resources to be deployed for project management, risk-management and control activities, making it difficult to unlock learning effects.
    - *Management of human resources.* Pre-decommissioning and post-shutdown phases in particular (which can last up to five years) typically represent a significant challenge for operators in terms of adaptation of the human resources needs in terms of quantity and skills. In this respect:
        - operator's personnel may be trained on D&D tasks, but in many cases training is not sufficient as specific D&D competences are necessary and need to be acquired on the market;
        - social plans and pre-retirement schemes are sometimes necessary but their feasibility and effectiveness depend on national legislations and political contexts.

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[7] The need to have well defined waste routes has recently fostered in the USA a new approach to D&D projects, in which operators "temporarily sell" the plant to a waste specialist which is in charge of the overall D&D project, until the nuclear license can be terminated.

[8] Many Member States have chosen to permanently store the low-level waste in surface disposals. Some are considering the option to to store it in deep geological disposal facilities when available.

[9] In the USA, the D&D licensing process is a two-step process within a stable national regulatory frame. In Germany the process comprises four or five steps and is highly influenced by regional authorities (Länder). Despite federal regulations, each region presents specific aspects making each project unique. Risks in project duration linked to regulatory specificities also impede the participation of foreign industry in national projects.

IV. Main barriers to competition

For the segments of D&D that typically are not managed internally, the following elements represent substantial barriers to competition and to the entry of new players in the market:

- *Technology levels* and *technology readiness*. For companies that want to compete in segments of the D&D markets such as decontamination, reactor vessel and internals cutting, onsite waste treatment and activities linked to spent fuel management, the availability of a high level of technology is a prerequisite. In addition, further technology advancements are indeed expected in the D&D processes in next years along with the consolidation of the market. Potential new entrants would hence need to invest massively in order to fill the technology gap with incumbents and to accept a high level of risk on the investment.
- *Member States' regulatory regimes*. Specific codes and standards are generally in force in each Member State and specific qualifications and accreditations are often required. These acts include nuclear safety, site works (e.g. health, safety and environment, radioprotection) and decommissioning waste transport. The national language is generally used for both the preparation of the documents and for correspondence with the authorities. The need of a specific expertise and a structure able to cope effectively with the national regulatory regimes may hence represent a hurdle for potential new foreign entrants.
- *Contractors proximity and "owner bias".* On the owner's side, a preference may arise for contractors with extensive experience in the country and/or already carrying over operations in the nuclear power plant. Relying on these contractors is sometimes considered as a way to reduce project risks. As a consequence of this type of "owner bias", non-incumbents may find more difficult to enter a new market[10].
- *Contracts value and structure*. Many of the contracts in key D&D segments are of a relatively limited value (below EUR 5.0 million) and still have reduced perspectives of recurrence. Potential new entrants with no previous experience in D&D projects may be discouraged to do the necessary investments to be able to deliver an effective value proposition. Such a problem increases with the increase in the sophistication of the specific D&D activity covered by the contract.
- *Cost of relocating manpower abroad*. Many low-skills D&D activities are manpower intensive. Generally, this makes it difficult for foreign companies to be competitive when people have to be posted abroad. In addition, competition between national companies is already fierce in non-specialised segments and margins are often thin, further discouraging international competition.

V. The D&D market for other nuclear installations

The market value for D&D of *research reactors* is far smaller than the one for nuclear power plants. It can be evaluated at a total of around EUR 2.0 billion up to 2050 (but depending upon the lifetime of the existing reactors), excluding France and UK[11].

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[10] In many cases, having a domestic subsidiary or partnering with a domestic company is often a forced option for potential new entrants.

[11] For these two countries, corresponding budgets are often mixed with the other cycle installations budgets and hence a detailed estimation is not possible.

In addition to NPPs and research reactors, a third market involves *other research installations and nuclear fuel cycle facilities.* This market covers a variety of installations encompassing various technologies and issues. This market is significant and, in terms of budgets, is concentrated essentially in UK and France. Such a market:

- is the most complex, ranging from smaller laboratories to large programmes (like Sellafield, Marcoule or Eurodif) which may include D&D, waste management and new builds and in which the D&D share is difficult to isolate;
- is characterised by the wide diversity of the installations, making each project "one-of-a-kind" with a reduced learning effects and specific R&D needs for adapted processes and equipment;
- even though available information does not allow for an analytical, installation-by-installation market evaluation, it shows the following characteristics:
    - NDA in UK and CEA and Orano in France are the main players;
    - its growth is going to be somewhat limited for the next 20 years (NDA expenses are slowly declining over the years, CEA spends a constant EUR 0.6-0.8 billion per year, two-thirds of the Orano decommissioning expenses in market are reported to occur after 2036).

VI. Conclusions on the key characteristics of the D&D market

- D&D for nuclear power plants in Europe is a mastered activity. Companies with the necessary expertise, competences and technology exist. Processes, even though they can be streamlined and, to a lesser extent, standardised, have been developed.
- The industrial D&D landscape extends from large international companies to local domestic small and medium enterprises and from high-level technicians to low-skill, manpower-intensive contractors. Various industrial organizations can be observed but a predominant role (and corresponding budget) is often kept for the personnel of the utilities/operators/owners in charge of the programme.
- The D&D market for NPPs is expected to grow significantly in the long term. The total yearly expenditure for D&D activities for existing NPPs may still remain somewhat contained up to 2035 (up to EUR 2.2 billion per year), but this expenditure should increase more emphatically afterwards to peak at about EUR 3.0 billion per year in 2045.
- D&D market characteristics lead to a handful of large companies (and their often specialized nuclear-market subsidiaries) capturing a dominant market share of the tier-one contracts across Europe characterised by highly technical activities. These companies are progressively building on the experience and references acquired in their original domestic markets.
- The major cost drivers of D&D projects (project duration, regulations, availability of waste routes and management of human resources) often make the market country-specific and exposed to a certain level of uncertainty.
- Small and medium enterprises face fierce competition in the segments in which they operate (in particular activities requiring low-level skills, technology and expertise) and are confronted with high barriers to entry in the other market segments and in foreign markets. In this scenario, a significant exception is given by providers specialised in delivering engineering, licensing, planning and procurement services.

VII. Strengthening the market of D&D in Europe

Heterogeneous regulations and waste routes (particularly for the low-level waste) over Europe are among the most decisive impediments to an open D&D market in Europe. Long-term commitment and international cooperation would be needed to tackle these issues.

Nevertheless, a series of actions can be foreseen already in the short-term to enhance competition, with potential benefits in terms of cross-fertilisation of good practices, paving the way towards European synchronisation and operation cost-effectiveness.

- *White Papers*. Each Member State could be encouraged to prepare a White Paper relative to the D&D programmes in the country. The main items covered by such a document should be the applicable regulations, the waste management system in place and information on the forthcoming D&D projects. White Papers would allow to spread operational knowledge of each national landscape and would allow potential investors to better understand the opportunities given by the market.
- *Centres of Excellence.* Nuclear industry associations where companies and other stakeholders in the nuclear supply chain can develop common and complementary approaches as well as address common issues are being developed across the EU. Similar organisations can be encouraged as concerns D&D, by means of "Centres of Excellence". In these organisations, several D&D companies (eventually also involving IT partners) would group together to implement specific innovative projects with the aim to foster product or process innovation. Such organisation may also support actively and participate in the European Learning Initiatives for Nuclear Decommissioning and Environmental Remediation (ELINDER).
- *Increasing transparent and converging procurement processes*. Competition would be fostered through a higher level of transparency as concerns future accessible open procurement procedures (e.g. in the case of owners announcing intended future procedures to be launched over the next 12 to 18 months). Similarly, higher harmonisation of the bidding criteria for similar projects would make it easier for companies to enter a specific market (by avoiding the need to deal with Member State or project specific bidding criteria, sometimes requiring particular supplier qualifications).
- *Framework contracts*. Interesting initiatives backed by the use of framework contracts are taken in some procurement approaches, such as the DDP ("Decommissioning Delivery Partnership") in the UK for the Sellafield project. A key feature of the DDP programme is that it allows work to be started rather quickly, with projects of up to GBP 5.0 million being directly allocated to any one of the framework partners. This could shorten the time of the procurement procedure and its administrative burden, including for the bidding companies (once having successfully passed the less stringent selection for being included in the framework contract). This kind of contracts could be further analysed to test their possible advantages if used on a wider scale and scope.

List of figures

List of tables

List of abbreviations

A&G	Administrative & General expenses
ASA	Asset Sale Agreement
BWR	Boiling Water Reactor
BME	German Ministry of Environment
CAGR	Compound Annual Growth Rate
D&D	Decommissioning & Dismantling
D&WM	Decommissioning & Waste Management
DOC	Decommissioning Operations Contractor
E&T	Engineering & Technology
EBRD	European Bank for Reconstruction and Development
EC	European Commission
EU	European Union
ECVET	European Credit System for Vocational Education and Training
ENSI	Swiss Federal Nuclear Inspectorate
G&A	General and Administrative expenses
GTCC	Greater than Class C Radioactive Waste
HLW	High Level Waste
HSE	Health, Safety & Environment
ILW	Intermediate Level Waste
INB	Installation nucléaire de base (Basic Nuclear Installation)
ISDC	International Structure for Decommissioning Costing of Nuclear Installations
ISF	Onsite (waste) storage installation
ISFSI	Independent Spent Fuel Storage Installation
KS	Kosten Studie (cost evaluation)
LLC	Limited Liability Company
LLW	Low Level waste
Magnox	Magnesium Non-Oxidizing (gas cooled reactors in the UK)
MS	Member State of the European Union
NPP	Nuclear Power Plant
O&M	Operations & Maintenance
PINC	Nuclear Illustrative Programme
PM	Project Management
PWR	Pressurized Water Reactor
RCA	Reactor Controlled Area
SLC	Site Licence Company (UK)
SKA	Swedish Nuclear Fuel and Waste Management Co
SME	Small & Medium Size Enterprises
TEDE	Total Effective Dose Equivalent
VLLW	Very Low-level waste
WBS	Work Breakdown Structure
ZS	ZionSolutions

1. Background

The average operating age of nuclear power plants in the EU is about 30 years and the approved operating life of individual reactors varies from 40 to 60 years. This means that the decommissioning of nuclear power plants will become an increasingly important activity for European industry in the coming decades. In parallel, other types of nuclear installations are, or soon will be, in the process of being decommissioned. This is the case in particular of research reactors and fuel cycle facilities.

There are currently 94 nuclear power plants on permanent shutdown in the EU but only a few EU nuclear power plants have been decommissioned. The international perspective puts this in a clearer light: out of the 166 reactors in permanent shutdown mode worldwide, only about a dozen have been completely decommissioned, mostly in the United States (three in Europe, all in Germany). The Nuclear Illustrative Program (PINC)[12] estimates that more than 50 of the 126 reactors currently in operation in the EU will be shut down by 2025. In this respect, it is estimated[13] that EUR 263 bn will be needed for nuclear decommissioning and radioactive waste management from now to 2050, with EUR 123 bn for decommissioning and EUR 140 bn for spent fuel and radioactive waste management, as well as deep geological disposal. Consequently, even if only a few facilities have been decommissioned in the EU, the decommissioning of nuclear power plants and other types of nuclear installations will become a crucial activity for the nuclear EU industry in for the coming years.

The nuclear decommissioning market is at a relatively early stage and has considerable potential for growth. Companies in the EU have the opportunity of developing a highly specialised expertise and favourably position themselves in the international market. The PINC stresses that the nuclear industry in the EU has developed into a global technology leader in all nuclear segments. It directly employs between 400,000 and 500,000 individuals, while indirectly creating about 400,000 additional jobs[14]. Such leadership can be an important asset worldwide, considering the fast development of the use of nuclear energy outside the EU (e.g. China and India). The EU must maintain its technological leadership in the nuclear domain, including in decommissioning, through further research and development and industrial activities so as not to increase energy and technology dependence, and to give business opportunities for European companies. This will in turn support EU growth, jobs and competitiveness.

Several EU companies have already started up in the nuclear decommissioning industry and are developing extensive expertise, especially in the most technically critical aspects. These companies have an opportunity of becoming global players if they develop the required skills in the domestic market (including measures to encourage an increased participation of SMEs). A global and competitive European decommissioning industry must be developed to face adequately the foreseeable industrial challenges, ensuring maximum impact on

[12] (EC 2017a).
[13] Based on information provided by the Member States in December 2014.
[14] Nuclear Illustrative Programme. COM(2017) 237 final, page 4.

the EU economy and jobs while maintaining the highest standards for safety and cost-competitiveness.

In such a context, the Commission has launched this study to aims to provide a general understanding about how the market for decommissioning nuclear facilities in Europe works. To do that, it analyses the key determinants of the market, in particular as concerns main actors, key segments, growth potential, existing barriers to competition and impact of technology.

To do that, the present report is structured as follows. Chapter 2 describes the analytical framework. Chapter 3 evaluates the existing data concerning the decommissioning market and gives an analytically updated on market data through a segmentation by Member States and type of nuclear installation. Chapter 4 presents an analytical model of the decommissioning market for nuclear power plants in Europe and explains the export perspectives for European companies as well as the consequences on employment. Chapter 5 highlights the D&D industry and the major companies working on each segment according to the ISDC in five EU Member States (France, Germany, Italy, Slovakia and United Kingdom). Chapter 6 quantifies the D&D market for each ISDC item. Chapter 7 outlines the main drivers and barriers to competition obstructing the development of the D&D market. Chapter 8 provides a series of proposed measures to strengthen the market of the D&D in Europe while keeping safety at the highest level.

2. Analytical framework

This section presents the overall approach to the study, including an overview of the methodology and the key issues linked to the analyses to be undertaken.

2.1 Methodology and approach for the study

The first step of the study is to evaluate the overall decommissioning market in the European Union (EU). This is done by segmenting the market according to:

- different types of nuclear installations to be decommissioned;
- geography (in particular in order to identify the money value of the largest national markets).

Going deeper into the characteristics of the market for different nuclear installations and analysing the dimension of the largest national markets offers useful insights as concerns the main drivers of the overall market in the EU.

The second step is to produce an analytical model for each type of nuclear installation to estimate the evaluation of *annual* value of the decommissioning market in the EU. This allows assessing some of the key determinants of the market, such as attractiveness for new entrants and effects on employment.

The third step is to analyse the level of competition of the market by identifying the key industrial players in each segment. To do that, the International Structure for Decommissioning Costing (ISDC) – Level 1 is taken as a reference. Five different markets are analysed in detail (France, Germany, Italy, Slovakia and United Kingdom)[15]. In this respect, current projects and the main players involved are observed.

Finally, in the final step each ISDC segment is quantified using different cost estimation approaches for the decommissioning of nuclear facilities. By linking the nuclear decommissioning budgets' share to each ISDC segment with the industrial players active in the market, challenges and opportunities for the companies currently not present or having a reduced role in the decommissioning supply chain can be studied.

2.2 Data collection

Due to the lack of extensive experience in the field of decommissioning in the EU, it is often difficult to gather reliable and precise data concerning past projects. For this reason, part of the data used in this study consists of estimations.

The most recent accounting documents such as annual reports published by nuclear installation operators or the bodies in charge of the decommissioning programmes have been retrieved and privileged when publicly available. These reports include:

- annual reports and strategy documents published by Nuclear Decommissioning Authority (NDA) for the United Kingdom;
- annual reports published by EDF, CEA and Areva for France;

[15] Most of the reactors in shutdown in the EU are located in these Member States.

- annual reports published by the four German nuclear utilities including RWE, E.ON, Vattenfall and EnBW;
- an audit in 2014 for the German Ministry of Environment and Energy;
- JAVYS's annual reports for Slovakia;
- annual reports published by SOGIN and its subsidiary Nucleco for Italy;
- a series of other reports published by nuclear operators and regulatory authorities in the EU.

These data have been completed with various other publically available documents issued by international organisations, such as:

- IAEA;
- European Commission;
- World Nuclear Association;
- US Nuclear Regulatory Commission;
- OECD/NEA.

For a detailed analysis of decommissioning project costs, some site-specific cost studies have been also used, such as the KS11 for Switzerland[16] and TLG Services Inc. cost studies for the USA[17].

Finally, other documents used to retrieve supplementary data are:

- NucAdvisor database and expert networks in France, Germany and the United Kingdom;
- European Bank for Reconstruction and Development (EBRD) procurement database[18] on the Bohunice International Decommissioning Support Fund for Slovakia;
- SOGIN's procurement website[19] for Italy.

A reference list is given at the end of this report.

2.3 Decommissioning definition

The term "decommissioning" may cover different activities. Thus, the definition should be clarified to avoid misunderstandings.

Decommissioning budgets are generally split between "decommissioning and dismantling" and "waste management". However, their relative boundary is often ambiguous. For instance, in France, decommissioning budgets for nuclear power plants cover their activities until the waste is packaged on-site whereas decommissioning budgets in the US also cover all the waste management activities, onsite and offsite, until waste is delivered to the disposal site. In the US, disposal costs are included in the budgets, even if spent fuel management costs are isolated, allowing for discussions with the US DOE[20], legally responsible for spent fuel disposal. Site remediation costs are also included but specifically identified as not being part of the "license termination" costs.

With regard to fuel cycle facilities, "decommissioning" is even more ambiguous. For instance, the Nuclear Decommissioning Authority (NDA) in the United Kingdom does not cover only decommissioning and waste management but

[16] (Kostenstudie 2011).
[17] (TLG 2013).
[18] (EBRD 2016).
[19] (SOGIN 2017).
[20] Department of Energy.

also legacy and defence waste management including disposal and new build installations.

Even the terms decontamination and restoration can be understood in different ways, sometimes having substantial consequences on costs. Some authorities associate this word with a non-conditional subsequent civil use of the decommissioning site (another word for "greenfield"), while operators implement more and more an "As Low As Reasonably Achievable" (ALARA) -type approach that is a "technical and economical optimisation of environment protection and waste production[21]". Even the concept of non-conditional civil use of decommissioned sites raises questions because the corresponding regulatory clearance limits are largely country-dependent[22]. All these parameters need to be considered carefully when assessing budgets.

This study refers to *decommissioning and dismantling* (*D&D*) as the full extent of the nuclear facilities decommissioning and dismantling tasks plus the *onsite* waste management activities (e.g. characterisation, packaging, handling, onsite interim storage or clearance until waste is ready to be shipped offsite). Typically, this is the central concern of decommissioning projects. The study refers to *waste management (WM)* as the overall activities concerning the offsite waste treatment, storage and disposal. D&D and WM activities as a whole are referred to as *decommissioning and waste management (D&WM)*.

2.3.1 International Structure for Decommissioning Costing (ISDC)

The presentation of the D&D task-type typology is the way that operators of installations around the world organise their projects and set up their D&D budgets. However, industrial organisations and programme Work Breakdown Structures (WBS) are often country-specific, when not site-specific resulting in the budget codes of account also being very specific, impeding any easy comparison between the various projects. This prompted OECD/NEA to set up an International Structure for Decommissioning Costing (ISDC)[23].

While the value of having a common reference to facilitate catalogue and interchanges has to be recognised, the ISDC is not (yet) used widely for cost estimations *per se*[24]. Cost estimations are often made using *ad hoc* (national or site-specific) methods. Hence, the comparison between the various data involves conversion activities, which can be difficult to perform because of the large differences between costing structures and project scopes as well as limited granularity of available information.

In this study, the ISDC has been chosen as reference to set up project tasks and market segmentation. The first level of the ISDC structure is given here below.

1st Level of the ISDC:

1. Pre-decommissioning actions

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[21] To the knowledge of the authors, none of the reactor buildings of the four large NPPs decommissioned in Germany has yet been demolished after decontamination.
[22] See Appendix 6.
[23] (NEA 2012).
[24] (NEA 2016).

2. Facility shutdown activities
3. Additional activities for safe enclosure or entombment
4. Dismantling activities within the controlled area
5. Waste processing, storage and disposal
6. Site infrastructure and operation
7. Conventional (non-radiological) dismantling, demolition and site restoration
8. Project Management, engineering and support
9. Research and Development
10. Fuel and Nuclear Material
11. Miscellaneous expenditures

Due to the fact the ISDC is not being used widely for cost estimations or costs recording *per se*, only the Level 1 of the ISDC will be used in the attempt to compare the estimations made with other costs structures and to segment the market. ISDC sub-levels are used only for double-checking the specific contents of the relevant Level 1 items. For illustrative reasons, an extract of the Level 2 of the ISDC is shown here below.

2nd Level of the ISDC Cost Structure *(for Items 1-4)*:

1. Pre-decommissioning actions
    - 01.0100 Decommissioning planning
    - 01.0200 Facility characterisation
    - 01.0300 Safety, security and environmental studies
    - 01.0400 Waste management planning
    - 01.0500 Authorisation
    - 01.0600 Preparing management group and contracting
2. Facility shutdown activities
    - 02.0100 Plant shutdown and inspection
    - 02.0200 Drainage and drying of systems
    - 02.0300 Decontamination of closed systems for dose reduction
    - 02.0400 Radiological inventory characterisation to support detailed planning
    - 02.0500 Removal of system fluids, operational waste and redundant material
3. Additional activities for safe enclosure or entombment
    - 03.0100 Preparation for safe enclosure
    - 03.0200 Site boundary reconfiguration, isolating and securing structures
    - 03.0300 Facility entombment
4. Dismantling activities within the controlled area
    - 04.0100 Procurement of equipment for decontamination and dismantling
    - 04.0200 Preparations and support for dismantling
    - 04.0300 Pre-dismantling decontamination
    - 04.0400 Removal of materials requiring specific procedures
    - 04.0500 Dismantling of main process systems, structures and components
    - 04.0600 Dismantling of other systems and components
    - 04.0700 Removal of contamination from building structures
    - 04.0800 Removal of contamination from areas outside buildings
    - 04.0900 Final radioactivity survey for release of buildings

2.3.2 D&D project task characterisation

To characterise the industrial players of the D&D market, quantify their relative market share and better understand the market drivers, it is useful to consolidate ISDC tasks. This consolidation is used in the rest of the report to analyse main players' activities and evaluate the global budget shares for the various project tasks, respectively. In this respect, ISDC tasks[25] can be grouped as follows:

- ISDC items 1, 6, 8 and 11: "extended" project management tasks;
- ISDC item 2: post-shutdown preparatory works;
- ISDC item 4: critical and complex activities;
- ISDC item 5: decontamination operations and waste management;
- ISDC item 7: conventional dismantling of the buildings and site restoration/remediation.

These five groups of tasks require very different skills, meaning the involvement of various industrial organisations, often country-dependent, and different Tier 1, 2 and 3 companies working on these projects.

The first group of tasks (ISDC items 1 and 8 with their supporting ISDC items 6 and 11) are sometimes referred to as "project management and engineering" or, in some countries such as France or the US, as "owner costs". They require highly skilled resources who are not necessarily fully available within each nuclear operator organisation (which are generally more operation than project management oriented).

The second set of tasks (ISDC item 2) calls for close collaboration between plant operation staff, which must be adequately retained and incentivised, and decommissioning project staff. In this field, wide reaching experience has been developed in particular in the US (e.g. "cold and dark" actions[26], plant tagging, temporary systems implementation, specific decontamination technologies).

The third group of tasks comprises the most critical tasks (ISDC item 4). They also require highly skilled resources and specific technologies, generally not available inside the utility. In the past, numerous problems arose during these operations both in the US and Europe. Since then however, a handful of world-class companies (e.g. Siempelkamp, Areva, EWN, Westinghouse) have developed extensive experience and are able to handle these tasks while mastering the associated risks. This segment is hardly accessible to small and medium enterprise or companies that are not already familiar with the nuclear domain.

The fourth set of tasks (ISDC item 5) also requires suppliers who have developed wide experience, generally country-specific given the diversity of waste and decontamination strategies (and associated regulations) across the different countries. Among the companies working in this segment, some require highly specific knowledge of waste characterisation, decontamination techniques or offsite waste processing (e.g. melting and casks design) while

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[25] ISDC items 3 and 9 cover respectively "Additional activities for safe enclosure or entombment" and "Research and development" (equipment, techniques and procedures, and simulation of complicated works). A distinction is generally made between three D&D strategies: i) immediate decommissioning, ii) deferred decommissioning and iii) entombment. The first strategy is generally preferred in Europe, except for the Magnox and AGR fleet in the UK. For these reactors, the second strategy has been chosen, called "Care and Maintenance", but is also currently being challenged as it may lead to higher costs. Hence, ISDC item 3 has not been retained in the above table and corresponding UK budgets split over the other ISDC items. ISDC item 9 has not been individualised either because NPP D&D now relies on proven technologies and contractors, reducing the need for R&D. When applicable, mock-ups and simulation activities are included in ISDC item 4.

[26] "Cold and dark" means de-energizing the plant and draining the plant systems to facilitate D&D work and increase worker security.

much of the work to be performed is craft-intensive, devoted to onsite decontamination operations, waste handling, packaging and offsite transportation and disposal.

All the four first groups of tasks, which represents a large share of the D&D costs, require the preparation and management of a considerable amount of documentation. Such documentation is under the direct responsibility of the owner and it is often subject to approval by the nuclear safety authorities and other regulatory bodies prior to works implementation.

The fifth group of tasks (ISDC item 7) requires lower nuclear-specific skills, given that these operations are usually performed once the plant is free of radioactive waste. This is a typical job for civil works companies, which master dismantling techniques and conventional waste disposal routes.

3. European decommissioning market evaluation

Decommissioning programmes in the EU concern three main types of nuclear installations: nuclear power plants, nuclear fuel cycle facilities and nuclear research reactors. While nuclear power plants are the most numerous type of nuclear installations in the EU, fuel cycle facilities and research reactors are characterised by their wide diversity[27].

The number of these nuclear installations according to their status (operation or decommissioning) can be found in the IAEA portals[28,29]. The budget for D&D programme is sometimes published by the organisation responsible for decommissioning in its annual accounting reports. In some cases, the most up-to-date data can be also found in the Commission's reports[30,31].

Although the documentation data for the decommissioning of nuclear power plants is relatively abundant, it is less so in the case of fuel cycle facilities and nuclear research installations. The published budgets of this latter can even be misleading since there is usually no obvious separation between D&D tasks and waste management, including storage and/or disposal. In addition, the distinction between civil and defence budgets is not always clear. For instance, this is the case of the highly complex Sellafield programme where the “decommissioning” budget covers waste management, site remediation and new build projects and hence raises several evaluation issues (see Figure 2).

In consideration of the above, the next paragraphs clarify the available data and the assumptions considered in this report.

3.1 Nuclear power reactors

There are 219 nuclear power reactors either in operation or in a state of shutdown or decommissioning in the EU. A complete list of these plants is given in Appendix 1. As shown in Figure 1, France, Germany and United Kingdom account for the majority of these plants and represent the largest decommissioning markets in the EU country-wise.

The D&D of nuclear power plants is generally well documented in all Member States. Since these installations are not as diverse as the fuel cycle facilities and research installations, decommissioning and dismantling of power reactors becomes more and more proficiently mastered. In addition, operators of nuclear power plants (usually private companies) often publish a certain level of relevant information along with their balance sheets and annexed documents[32].

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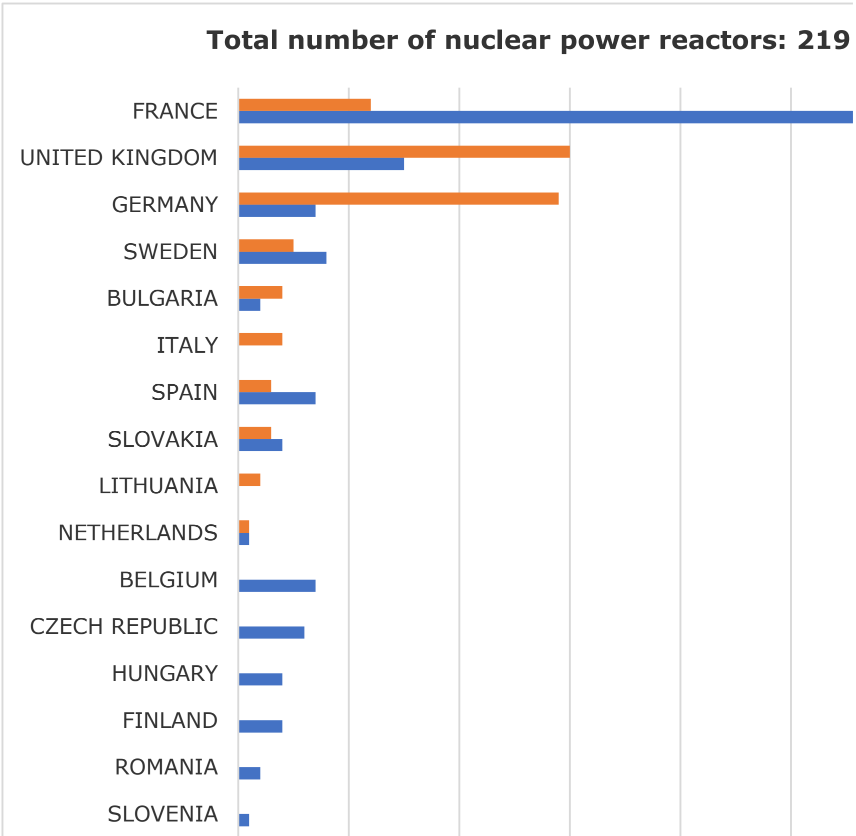
[27] A wide range of different fuel cycle facilities and research reactor types can be found in Appendix 2 and Appendix 3.
[28] (IAEA 2017a).
[29] (IAEA 2017b).
[30] (EC 2017a).
[31] (EC 2017b).
[32] However, the decommissioning budget may not be explicit as to whether it includes waste management cost or not. This means scrutinising the accounting reports of the main owners.

Figure 1: Total number of all nuclear power reactors in operation and permanent shutdown status (including those undergoing decommissioning) in the EU[33]



3.1.1 United Kingdom

The budget for the decommissioning programme in the UK was retrieved from the annual reports published by the NDA[34] and EDF Energy[35]. The detailed analysis of the provisions is given in Table 1.

The UK civil[36] decommissioning and waste management market can be evaluated at about EUR_{2016} 155 bn (undiscounted) over the next century. It is in the charge of two main responsible organisations: NDA and EDF Energy. This programme comprises the decommissioning and dismantling of nuclear power plants (Magnox Limited with a budget of EUR_{2016} 16.98 bn, Dounreay Site Restoration Ltd with a budget of EUR_{2016} 2.78 bn, EDF Energy with a budget of EUR_{2016} 15.2 bn) but also the decommissioning and waste management activities related to fuel cycle facilities and research installations. The Sellafield programme represents more than the two-thirds of the budget in the UK, nearly EUR_{2016} 99.2 bn.

[33] Long-term shutdown, also called suspended operation, is the reactor unit status used in the IAEA/PRIS database. If an intention not to restart the shutdown unit has been officially announced by the owner, the unit is considered "permanently shut-down". Nevertheless, there is no reactor in Europe with long-term shutdown status. Source: authors' elaboration on data IAEA (IAEA 2017a).A detailed list of NPPs by country is given in Appendix 1.
[34] (NDA 2016a).
[35] (EDF 2016a).
[36] Defence activities (e.g. atomic weapons establishment, submarine dismantling) are excluded from the scope of this study.

Table 1: Decommissioning and waste Management budget in the UK[37,38]

Owner	Site Licence Companies	Liability	*2015/2016 discounted (EUR million)*	2015/2016 undiscounted (EUR million)
NDA	Magnox Limited	Magnox reactors	*26,223*	16,984
	Dounreay Site restoration Ltd	Dounreay reactors	*3,049*	2,788
	Sellafield Ltd	Sellafield site	*131,982*	99,204
	LLWR Ltd	LLWR	*849*	650
	INS Contracts		*22*	20
	Springfields		*1,013*	699
	Capenhurst		*1,338*	1,093
	Geological Disposal Facility		*16,034*	10,522
	Authority Total		*164,476*	**131,959**
	NDA Group companies		*94*	**89**
	Total budget for NDA Group		*164,580*	**132,048**
EDF Energy	EDF Energy	Spent fuel management	*1,849*	2,984
		Radioactive waste management	*904*	5,125
		D&D	*5,831*	15,208
	Total budget for EDF Energy		*8,584*	**23,317**
Total budget for the UK (NDA and EDF Energy)			*173,164*	**155,365**

As illustrated in Figure 3, NDA's resources profile[39] shows that the NDA programme extends over more than a century. The works peak out in 2020s and the effort declines overall until 2120. Small peaks follow between 2070 and 2090 as a consequence of the Magnox decommissioning strategy. In this kind of "deferred decommissioning" strategy, the plants are first put in "care and maintenance" status, protected by a containment, while awaiting radioactive decay. Full decommissioning takes place 50 years later. From the resources profile, it is clear that, whereas new build activities are dominant in the 2020s, waste and decommissioning activities tend to balance each other out later on, until after 2070 when waste management activities become the major part of the programme.

[37] The discounted value of the UK NDA's decommissioning programme jumped from GBP 70 bn in the 2014/2015 report to GBP 161 bn in the 2015/2016 report. Indeed, to reflect the fact that the cost of government borrowing was lower than inflation, from 2012-13 the Treasury introduced negative discount rates for short- and medium-term cash flows which were applied from 2015-2016. An original approach like this illustrates the importance of the discount rates and the necessity to compare only undiscounted values.
[38] GBP/EUR is assumed as 1.124.
[39] (NDA 2016b).

Figure 2: Sellafield plan (NDA/Sellafield Ltd/NMP) in 2011[40]

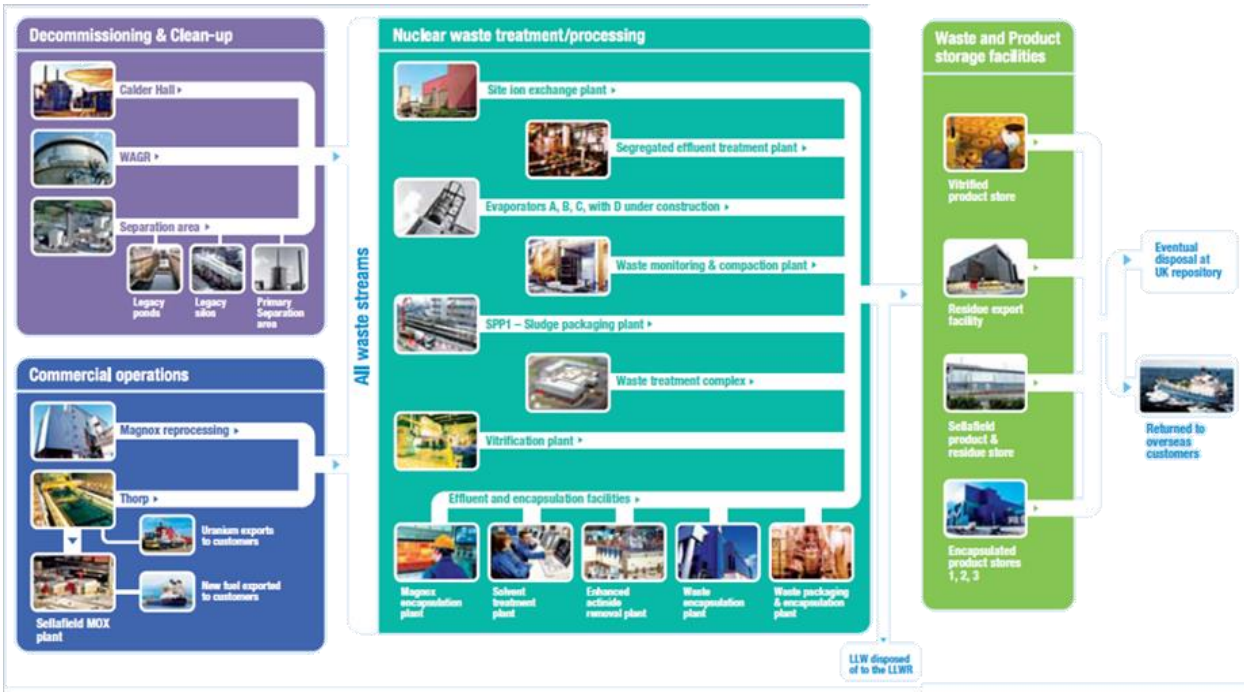
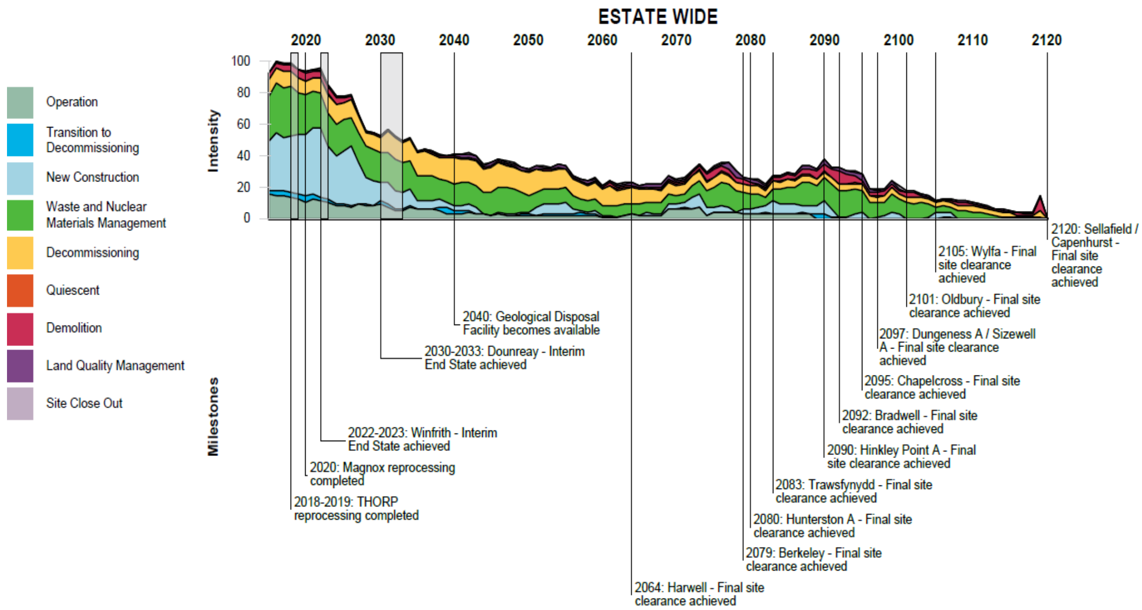


Figure 3: NDA Estate wide resources profile[41]



[40] (NDA 2011).
[41] (NDA 2016b)

3.1.2 France

The decommissioning and waste management programme in France concerns nuclear installations owned by i) EDF, ii) CEA, iii) Areva and iv) a series of smaller organisations (e.g. ANDRA, SOCODEI, GANIL, CISBIO[42], ILL, IONISOS). The first three organisations manage about 99.5% of the French decommissioning budgets[43].

Every three years, the organisations have to issue a report assessing the cost and funding of their decommissioning plans. The data with the end of 2016 values from the main plans[44,45,46] are summarised in Table 2.

Table 2: Decommissioning and waste management budgets in France

Owner	Liability	*2016 discounted (EUR million)*	2016 undiscounted (EUR million)
EDF	Spent fuel management	*10,658*	18,460
	Long-term waste management	*8,966*	29,631
	NPP D&D (Gen1 + Gen 2)[47]	*14,122*	26,616
	Last Cores	*2,287*	4,344
	EDF Subtotal	*36,033*	***79,051***
CEA[48]	D&D cost	*7,166*	9,887
	Fuel management cost	*712*	1,331
	Legacy waste cost	*2,424*	3,207
	Waste management cost	*2,855*	6,176
	Surveillance after disposal closure	*79*	583
	Miscellaneous	*295*	405
	CEA subtotal	*13,531*	***21,589***
Areva	Decommissioning and waste management	*7,233*	13,478
	Areva subtotal	*7,233*	***13,478***
Total budget for France (EDF, CEA and Areva)		*56,797*	**114,118**

The market in France can be evaluated at nearly EUR_{2016} 115 bn. This includes the D&D of:

- EDF's nuclear power plants with a budget of EUR_{2016} 26.62 bn;
- CEA's former fuel cycle facilities and research reactors with a budget of EUR_{2016} 9.89 bn;
- Areva's fuel cycle facilities with a budget of EUR_{2016} 13.48 bn (including waste management);

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[42] Now Curium
[43] (DGEC 2016).
[44] (EDF 2016b).
[45] (Areva 2017).
[46] (CEA 2016).
[47] GEN 1 are the older EDF plants, GEN 2 are the newest ones (the PWR fleet)
[48] According to the "(CEA 2016)", civil funding represents 44% of the overall decommissioning fund. Therefore, the CEA's budget for the decommissioning of its nuclear facilities (including waste management) is about EUR 9.5 bn.

but also the waste management costs arising from these installations.

3.1.3 Germany

The German NPPs decommissioning and waste management market data is taken from an audit performed in 2014 for the German Ministry of Environment and Energy (BMWE)[49]. Data have been escalated to 2016 with a 1.5% inflation factor and are summarised in Table 3.

Table 3: Utilities funded decommissioning and waste management budget in Germany

Owner	Liability	*2014 discounted (EUR million)*	2016 undiscounted (EUR million)
German utilities: E.ON, RWE, Vattenfall, EnBW	D&D	*Values are given as provisions for each of the four main utilities*	20,207
	Waste Management		28,678
	Packaging, Transport, Operational waste		*10,562*
	Intermediate Storage		*5,824*
	Geological disposal KONRAD		*3,940*
	HLW Geological Disposal		*8,354*
Total utilities funded budget for Germany		*38,288*	**48,885**

In Germany, the political decision to phase out of nuclear power was taken at a moment when the waste infrastructures to allow quick decommissioning were not in place. The decision to dispose of any radioactive waste in a deep geological disposal was not yet defined and led to increasing costs for waste management, with detrimental consequences for the (private) utility finances. The situation in Germany has changed with a 2016 law, according to which waste interim storage and final disposal responsibilities are now transferred to 100% state-owned companies (BGZ and BGE), against a EUR_{2016} 23.5 bn *lump sum* paid by the utilities. If the real costs exceed this sum, the Federal government will cover the overruns.

For evaluating the overall D&WM costs in Germany, a series of costs should be added to the ones above, stemming specifically from the publicly-owned nuclear installations D&WM. Additional uncertainties remain for managing the legacy waste of the Asse II and Gorleben repositories, and the possible insufficient capacity of the Konrad repository. The overall EUR 48.9 bn given above is thus a minimum for the overall D&WM costs in Germany[50].

The German NPPs D&D market can be evaluated at nearly EUR_{2016} 20.21 bn.

3.1.4 Other Member States

[49] (Warth 2015).

[50] See "Report on the cost and financing of the disposal of spent fuel and radioactive waste". Federal Ministry for the Environment, Nature Conservation, Building and Safety. 2015

Apart from the budget of the aforementioned States, the most recent data concerning the costs of the D&D of other Member States have been compiled, preferably from the annual accounting documents of the NPPs owners and the Commission's reports. As reported in Table 4, the D&D budget for the 219 NPPs in the EU amounts to about EUR_{2016} 110 bn of which nearly EUR_{2016} 76 bn is due to France, Germany and United Kingdom.

Table 4: Member States' D&D budget for their nuclear power plants[51,52]

Member State	Estimated D&D cost (EUR_{2016} billion)	Number of units
Belgium	7.5	7
Bulgaria	3.0	6
Czech Republic	1.6	6
Croatia	0.3	0.5[53]
Finland	1.0	4
France	26.6	70
Germany	20.2	36
Hungary	1.2	4
Italy	3.9	4
Lithuania	2.6	2
Romania	1.4	2
Slovakia	2.8	7
Slovenia	0.3	0.5
Spain	4.5	10
Sweden	2.5	13
The Netherlands	0.5	1
United Kingdom	30.0	45
TOTAL	**110.0**	**218**

[51] Estimations of the costs of decommissioning commercial nuclear power reactors vary significantly between Member States, technologies, size and location of the reactor and dismantling strategy chosen. For this reason the figures in the table have to be considered as approximations.

[52] Sources of data for Belgium: ENGIE Annual Report 2016 (page 143, paragraph 18.2.4); Bulgaria: for Kozloduy reactors 1-4, Decommissioning plan as referred in Article 4(1)(c) of Regulation (Euratom) No 1368/2013 – Bulgaria - Annex 4 and for Kozloduy reactors 5-6, EC SWD(2017) 158_final; Czech Republic: CEZ Group Annual Report 2016 (page 310); Finland: for Loviisa, the Loviisa nuclear power plant decommissioning plan update 2012 (Link: *http://projects.hrp.no/nks-decom-2013/files/2016/07/LOVIISA_nuclear_NPP_decommissioning_plan_update_fortum_kaisanlathi_paper_nks2013.pdf*) and for Olkiluoto, EC SWD(2017) 158_final (subtraction of the above value from the one given in the total value for Finland in EC SWD(2017) 158_final); France: EDF Document de Référence 2016 (page 389); Germany: Warth& Klein Grant Thornton report 2014 (page 8, Table 2), values escalated to 2016 with 1,5% inflation rate; Hungary: Hungary's national programme for spent fuel and radioactive waste management 2019 and EC SWD(2017) 158_final; Italy: EC SWD(2017) 158_final; Lithuania: Decommissioning plan as referred in Article 4(1)(c) of Regulation (EU) No 1369/2013 – Lithuania Annex 2; Romania: EC SWD(2017) 158_final; Slovakia: for unit V1, Decommissioning plan as referred in Article 4(1)(c) of Regulation (Euratom) No 1368/2013 – Slovakia - Annex 3, for unit A1 report "Comparison among different decommissioning funds methodologies for nuclear installations Country Report Slovakia 2007", for other units than V1 and A1: EC SWD(2017) 158_final; Slovenia: EC SWD(2017) 158_final; Spain: received through the European Commission's Decommissioning Funding Group (of the reported EUR 4,5 bn, about EUR 1,9 bn have been already occurred); Sweden: for Ringhals 4 units "Ringhals Site Study 2013 – an assessment of the decommissioning cost for the Ringhals site (SKB-R-13-05)", 2010 Swedish kronor escalated to 2016 (1,5%/year), and converted into Euros, for Forsmark (3 units) "Decommissioning study of Forsmark NPP (SKB-R-13-03)", same treatment of Swedish kronor than Ringhals, for Oskarshamn (3 units), "Decommissioning Study of Oskarshamn NPP" (SKB-R-13-04)", same treatment of Swedish kronor than above, for Barsebäck (2 Units), "Comparative analysis of the Oskarshamn 3 and Barsebäck site decommissioning studies (SKB R-09-55)", same treatment of Swedish kronor, for Agesta (1 unit) "Ågesta reactor decommissioning cost analysis" V12-1650-002, Rev. 0. 2012, Swedish kronor escalated to 2016; The Netherlands: for Borssele, received through the European Commission's Decommissioning Funding Group. No data is available for the decommissioning of the Dodewaard nuclear power plant; United Kingdom: includes the D&D of the EDF Energy's nuclear fleet in the UK (EUR 15.2 bn) and the D&D of the Magnox and Dounreay (EUR 18.83 bn) reactors. The latter was obtained by assuming that 75% of the budget of these liabilities given in Table 1 (including waste management) is due to the D&D. This assumption is based on the ratio between the D&D and waste management given in EDF Energy's provisions in Table 1.

[53] Shared with Slovenia.

Important remarks:
The figures above must be handled with some caution, because the estimation methodology may differ largely from country to country. For instance, in Belgium, Engie uses the following method[54]:

- costs payable over the long term are calculated by reference to the estimated costs for each nuclear facility, based on a study conducted by independent experts under the assumption that the facilities will be dismantled "in series";
- an inflation rate of 2.0% is applied until the dismantling obligations expire in order to determine the value of the future obligation;
- a discount rate of 3.5% (including inflation of 2.0%) is applied to determine the present value (NPV) of the obligation. This rate is the same as that used to calculate the provision for processing spent nuclear fuel;
- the present value of the obligation when the facilities are commissioned represents the initial amount of the provision. The matching entry is an asset recognized for the same amount within the corresponding property, plant and equipment category. This asset is depreciated over the remaining operating life of the facilities;
- an annual allocation to the provision, reflecting the interest cost on the provision carried in the books at the end of the previous year, is calculated at the discount rate used to estimate the present value of the obligation.

Accordingly, the EUR 7.5 bn amount indicated in the table above for Belgium is the future decommissioning obligation expressed in current euros, taking into account inflation and specific schedules assumptions for the decommissioning operations, and has to be compared with the accounting provisions of EUR 4,6 bn at end-2016. However, this future obligation value cannot be compared with the "overnight" cost (the theoretical cost without inflation and discounting effects) most often used as a yardstick for international comparisons (e.g. with France or UK in the Table 4).

This illustrates again the difficulty to compare figures from different sources without having sufficient details about the estimation methodology used. Hence, the total of about EUR 110 bn must be considered as an approximation.

Available detailed data for NPPs D&D are also used to construct the market model presented in the next chapter.

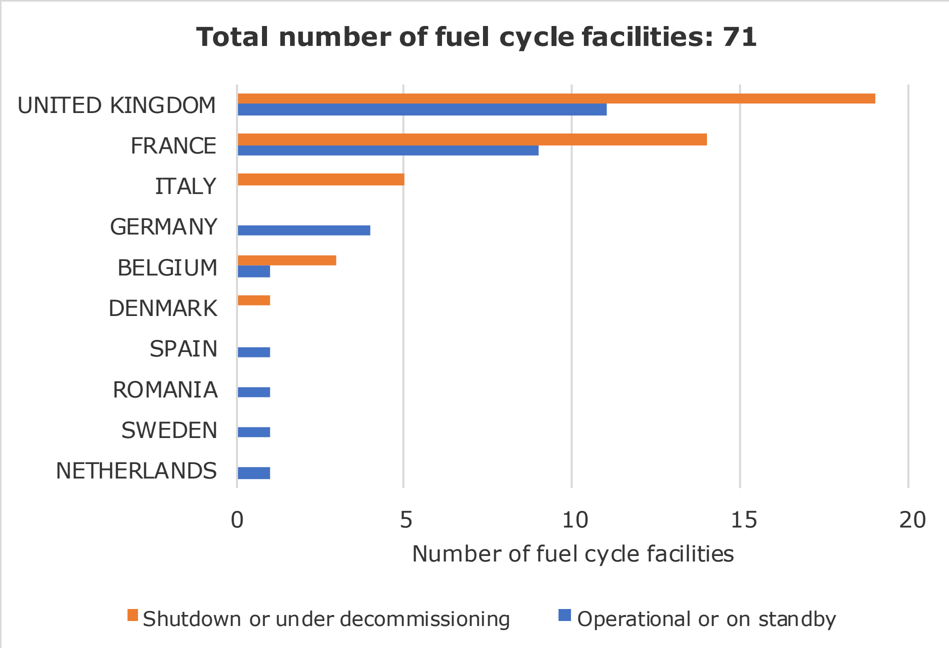
3.2 Fuel cycle facilities

Fuel cycle facilities in the EU cover a wide variety of installations ranging from uranium mining, conversion and enrichment plants to fuel fabrication and spent fuel reprocessing plants or prototype installations (see Appendix 2 for details). Each facility is unique with regard to its radioactive inventory and the decommissioning activities complexity. Given the wide range of installations

[54] See Engie's "2016 Management report and Annual consolidated financial statements", page 143.

and a reduced availability of data, only the most relevant fuel cycle facilities are considered in this report with regard to their decommissioning cost[55]. The total number of those facilities either in operation or in the decommissioning state is shown in Figure 4.

Figure 4: Total number of nuclear fuel cycle facilities in the EU[56]



Combined with a wide diversity of waste types such as "exotic" or highly contaminated with no immediate waste management solutions, the lack of documentation about the initial status of the facility makes evaluating the D&D operations of fuel cycle facilities extremely complicated. Unlike the case of NPPs, there is often no serial effect on the decommissioning of fuel cycle facilities. Each decommissioning programme is often "one-of-a-kind", requiring specific technologies and processes (see Sellafield box below). Consequently, the decommissioning market for fuel cycle facilities is more exposed to risks such as unexpected delays, cost overruns and technical difficulties.

The largest single share of the UK market is represented by the Sellafield programme, for which works have been ongoing for about ten years. The Sellafield decommissioning and waste management programme comprises a great variety of nuclear installations: windscale piles, first generation reprocessing plant, Magnox reprocessing plant, first generation Magnox storage pond (FGMSP), calder hall nuclear power station, cooling towers, windscale advanced gas cooled reactor (WAGR), thermal oxide reprocessing plant, highly active liquor evaporation and storage, waste vitrification plant,

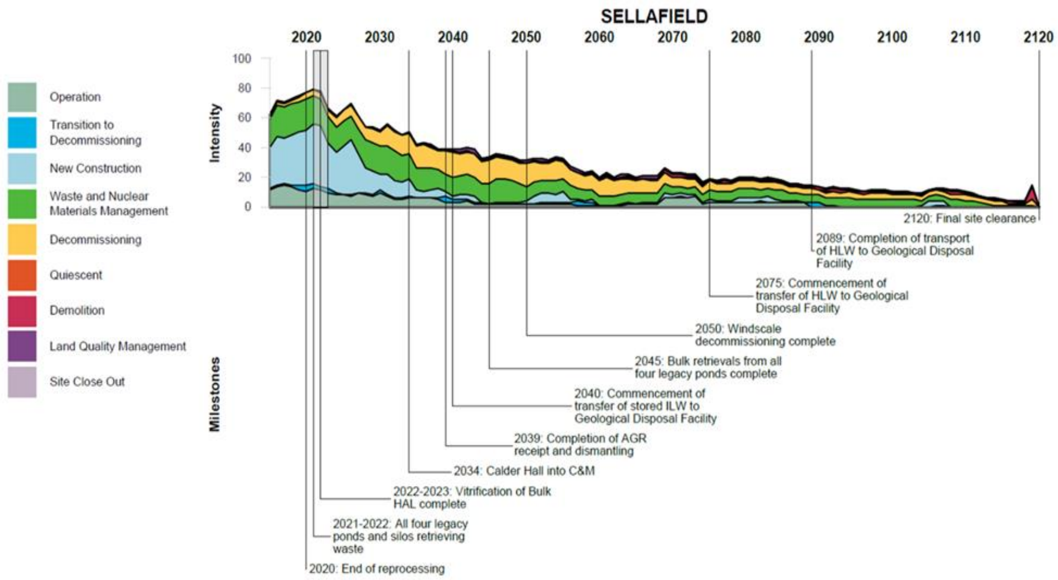
[55] Fuel fabrication plants, spent fuel reprocessing plants, uranium conversion plants, uranium enrichment plants, spent fuel conditioning plants.
[56] Source: authors' elaboration on data IAEA (IAEA 2017b). A detailed list of NPPs by country is given in Appendix 2.

Sellafield MOX plant, enhanced actinide removal plant and radioactive waste stores among others. The programme is required to encompass and coordinate the work on all the installations (as per the logical sequence of Figure 2), while allowing for the erection of new facilities that will treat and store waste originating from decommissioning. The D&D works are only a small part of the total Sellafield D&WM work. This is confirmed by the resources profile showing that new constructions will be the biggest part until the mid-2020 whereupon waste management takes the lead until D&D resources balance waste management between 2035 and 2070 (see Figure 5).

Moreover, defence and civil nuclear installations costs may be mixed together, and publicly available data do not always clearly distinguish between decommissioning and dismantling, waste management and new build budget.

As a result of the abovementioned difficulties, evaluating the D&D market for fuel cycle facilities in the EU cannot be done precisely, although this market is particularly important, as it can be seen from the D&WM budgets of France and the UK (and given in Table 1 and Table 2, respectively). The Sellafield budget alone accounts for nearly one-third of the overall D&WM budgets[57] of France, Germany and United Kingdom altogether, these three countries representing 80% of the European expenses.

Figure 5: NDA Sellafield Resources profile[58]



57 It includes waste management cost.
58 (NDA 2016b).

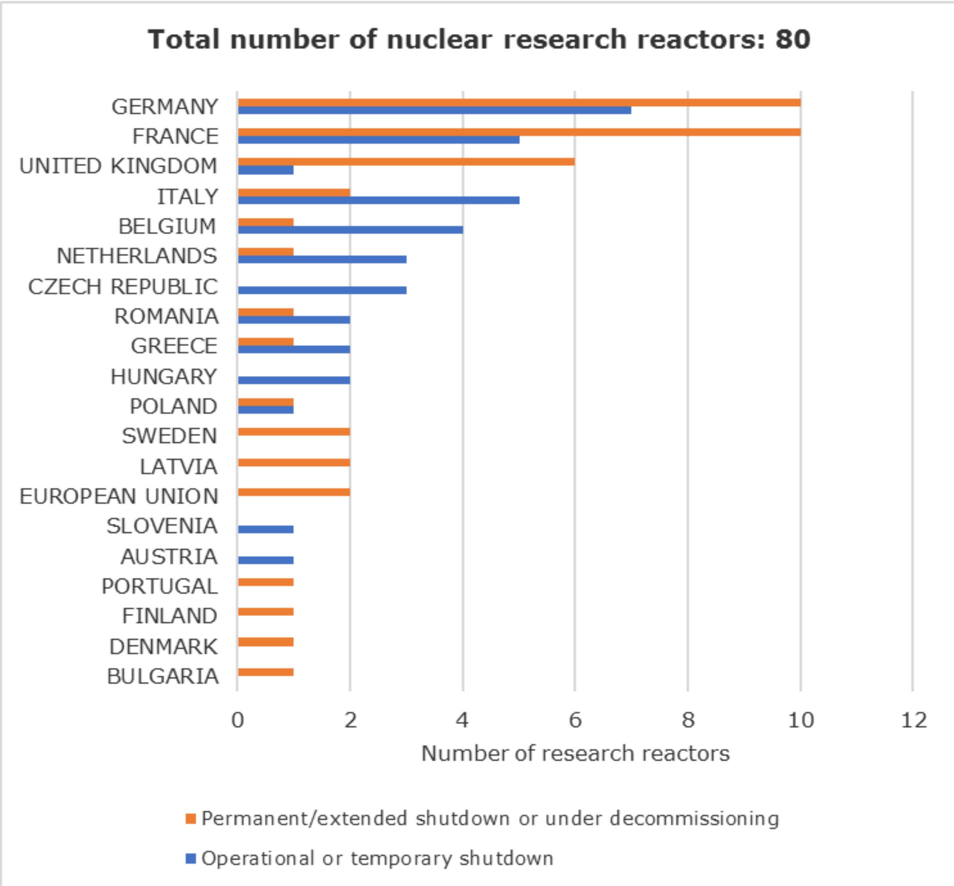
In this report it is assumed that studying only the evolution of fuel cycle facilities D&WM budgets in France (nearly 60 "INB" owned by Areva and CEA) and UK is relevant for deriving useful lessons concerning the overall D&D market growth in Europe.

3.3 Nuclear research reactors

Research reactors are numerically the second largest category of civil nuclear installations in the EU. As shown in Figure 6, there are 80 research reactors in the EU, declared as having "operational", "temporary shutdown", "extended shutdown", "permanent shutdown" or "under decommissioning" status. The complete list of the research reactors is given in Appendix 3.

As in the case of nuclear power plants, France, Germany and United Kingdom represent the largest markets.

Figure 6: Total number of nuclear research reactors in the EU[59]



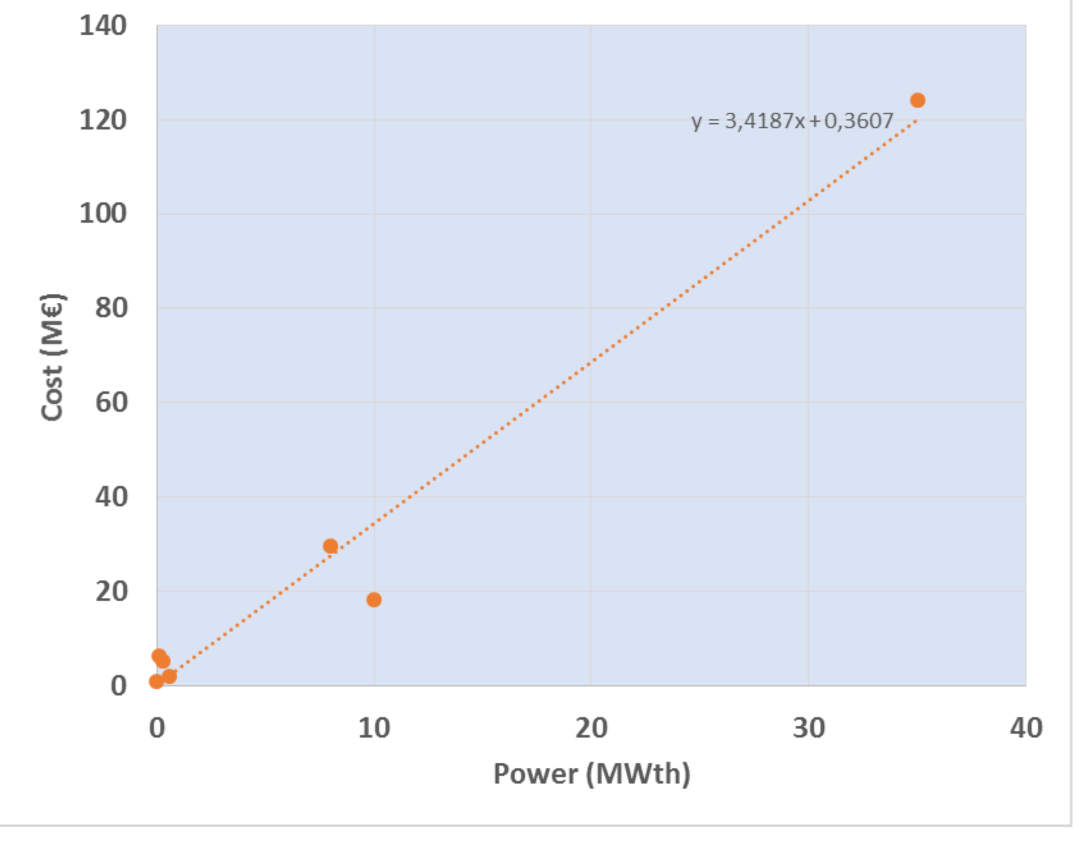
Since detailed cost data of each nuclear research reactor in EU is not available, and in key countries such as France and UK these costs are included in the overall budgets for D&WM (without the possibility to segregate them), the

[59] Source: authors' elaboration on data IAEA (IAEA database: https://nucleus.iaea.org/RRDB/RR/ReactorSearch).

following approach is considered to draw some conclusions on the potential size of the market:

- the realised cost of a selection of completed decommissioned research reactors in the EU is retrieved based on publically available data[60,61], and those costs escalated to 2016 with an annual inflation rate of 2%;
- a chart is plotted by cost and thermal power data of each research reactor (*x* refers to the power of the research reactor in terms of MW_{th} and *y* the estimated D&WM costs in EUR_{2016}) and a linear relation is estimated via simple regression;
- the estimated relation is then applied to a coherent set of research reactors under analysis, that is 58 research reactors when excluding those in France and the United Kingdom whose cost has already been counted respectively in the provisions of Table 1 and Table 2[62,63].

Figure 7: D&WM cost model for nuclear research reactors in the EU



As a result, it is possible to estimate the total decommissioning and waste management cost for the (58) research reactors to be nearly EUR_{2016} 2.0 bn. It is important to note that the estimated value also includes waste management costs.

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[60] Waste management costs are included.
[61] Research reactors: DR-1 (Denmark), Siloette (France), FiR1 (Finland), R-1 (Sweden), Melusine (France), ASTRA (Austria), SILOE (France).
[62] Details are given in Appendix 3.
[63] 22 research reactors located in France and the UK are excluded and considered as a part of fuel cycle segment in Table 5.

<u>Limitations:</u>
The reliability of the estimation method used above may be suffer from some important limitations considering the small number of reference observations available and the factual consideration that research reactors power in Europe may exceed 40 MW (even though only four research reactors in Europe have a rated power greater than 40 MW when excluding France and UK). However, the use of a linear fit may also be seen as conservative approach: a Chilton law $C/C_0=(P/P_0)^x$ with x between 0,6 or 0,7, where C are the costs and P the power, is widely used for comparing the costs of different (research and not) reactors. This relationship, taking into account fixed costs, gives estimations that are higher in amount when compared to the ones stemming from a linear estimation. It also remains valid that a more analytical cost evaluation of the decommissioning of research reactors should be made by taking into account each reactor and its detailed data (e.g. shutdown date, technology and decommissioning cost), when these data will be available.

Nevertheless, even taking into account potential limitations stemming from the estimation methods used, it seems reasonable to conclude that the D&WM budget for nuclear research reactors is somehow negligible when compared to the one for NPPs (about EUR 110.0 bn for D&D only).

3.4 Conclusions

The market analysis by type of installation is summarised in Table 5. While the NPPs D&D market is relatively well-documented and may be evaluated at about EUR_{2016} 110 bn, less is known about the research reactor market. This is because only little information is available regarding the exact status of these smaller installations and of the projects for their D&D programmes. The segment of fuel cycle facilities is the most complicated, with a very wide diversity of installations, often raising specific issues: technical, organisational, scheduling and R&D related. Considering only the UK (Sellafield, Springfields and Capenhurst) and France (Areva and CEA sites), the decommissioning and waste management of the installations in this segment comes to nearly EUR_{2016} 137 bn. However, D&D appears as only a small part of this amount when compared to waste management and new build projects. More transparency allowing a better analytical quantification of this market is hence recommended.

From the analyses carried over in this chapter it can be concluded that:

- France, Germany and United Kingdom are by far the largest D&WM markets in the EU;
- the NPPs D&D market can be evaluated overall to about EUR 110 bn and can be analytically modelled for all of the EU;
- the research reactors D&D market remains relatively small when compared to the NPPs D&D market;
- the fuel cycle facilities D&D is the most complex segment with huge programme including D&D, waste management and new build and in which the D&D part cannot be isolated on the basis on publically available information.

Table 5: Synthesis of market analysis in terms of segmentation of nuclear installations

Type of nuclear installation	Number of installations	"D&D" budgets (EUR_{2016} billion)	"Waste management" budgets (EUR_{2016} billion)	Remarks
NPPs	219	110.0	140.0[64]	Segment mastered, higher standardisation with respect to other installations.
RR (excluding France and the UK)	58	2.0		No standardisation, but value negligible for the purpose of this study.
FC (only for those in France and the UK and their RR)	53 FC and 22 RR. 75 in total	UK: 102.0 (including Sellafield: 99), France: 35.1 (CEA: 21.6 - Areva: 13.5). 139 in total		Wide diversity of installations, each project is one-of-a-kind, higher risks, R&D investment needed.

NPPs: nuclear power plants, RR: research reactor, FC: fuel cycle facility

[64] (EC 2017a)

4. Decommissioning market perspectives in the EU

This chapter presents an analytical model to evaluate the annual D&D market of the NPPs in the EU and the D&D market of fuel cycle facilities in the United Kingdom and France for the coming years. It also goes on to present the key characteristics of the D&D market in the US and in Japan and discusses an estimation of the jobs creation potential in the EU.

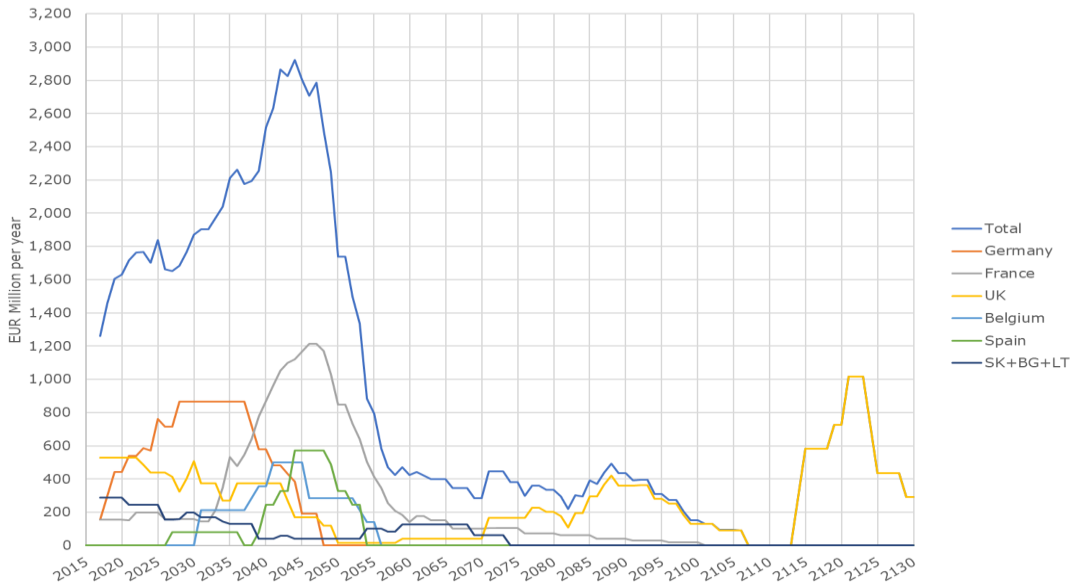
4.1 Nuclear power plants

To evaluate the market analytically, a model has been set up. The overall market results and those of selected Member States are illustrated in Figure 8. In this model, 219 *existing* European NPPs have been individualised. For each unit[65], a D&D budget has been drawn from the best available open sources, as well as the shutdown and start of decommissioning dates. The budget has been averaged by year and linearly distributed over the duration of each D&D programme[66]. The result is a curve giving the yearly European NPP D&D expenses as a function of time.

Major assumptions and parameters underlying the curve in Figure 8 are:

- known policy decisions about phase-outs from nuclear (Germany and Belgium);
- the D&D project duration generally set to 20 years, including a 5 years post-shutdown and pre-decommissioning period (which is representative in particular of the German and French approach);
- the French NPPs fleet lifetime set to 50 years (see also a sensitivity study in Chapter 7);

Figure 8: European NPPs D&D market evolution



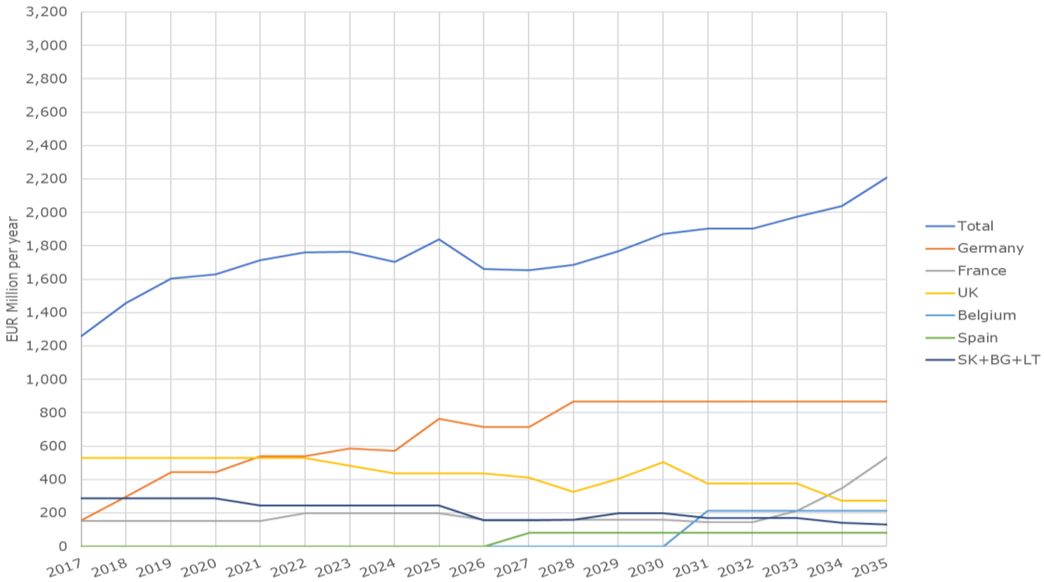
[65] An average budget per unit is assumed for all NPPs fleets.
[66] This approach can suffer from some limitations, as D&D expenses are never constant during the decommissioning period.

As shown in Figure 8, the NPPs D&D market is mainly characterised over the years by the overlapping of the decreasing UK (Magnox) programme and the rise of the German one. When the German programme is about to conclude, the French market will enter in its major rising phase. Finally, when the French programme declines, the overall European D&D market also declines.

The European NPPs D&D market of existing reactors covers more than a century, peaking in 2045 at about EUR_{2016} 3.0 bn per year[67]. When considering the increase of EUR_{2016} 1.8 to 3.0 bn per year over 25 years (2020/2045), the corresponding CAGR[68] is about 2.1%.

A curve like the one shown in Figure 8 extending over a century may be somewhat misleading. The horizon for investors and industrial companies rarely exceeds 20 years. In addition, the curve does not take into account NPPs not yet built. Figure 9 is the zoomed-in plot of Figure 8, which focuses on the years up to 2035. This view depicts a shorter-term specific market evolution, characterised by the smooth decline of the UK and the EU-sponsored Eastern Member State programmes (those of Bulgaria, Lithuania, Slovakia) and the next rise of the German programme.

Figure 9: European D&D market evolution until 2035



4.2 Fuel cycle facilities and research reactors

Evaluating the D&D market also means considering the fuel cycle and research installation perspectives. In the reminder of this paragraph the focus in on France and UK. Considering that these two countries are by far the most important markets, the analysis may be considered sufficient to draw valuable qualitative conclusions on the perspective market growth.

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[67] Two sub-peaks in 2090 and 2120 can also be observed, linked to the NDA's Magnox and EDF AGR programmes that will be resumed in the UK, after their "Care and Maintenance" periods.

[68] "Compound annual growth rate": $\mathrm{CAGR}(t_0, t_n) = (V(t_n)/V(t_0))^{\frac{1}{t_n - t_0}} - 1$

The UK D&WM market is characterised by the prominence of the Sellafield programme. It has been seen that the D&D activities are only part of the Sellafield budget, and the largest parts in the short term being waste management and new build. This project is now in its mature phase, with contractors at work. In addition, this market is waning slightly. Hence, the D&D part of this market is not expected to change the overall market dynamic in terms of growth potential.

Like NDA in the UK, the CEA in France has faced delays in the past with its decommissioning and legacy waste treatment projects, illustrating the risks of fuel cycle installations and research reactors D&WM projects[69]. About EUR 600 to 800 million are devoted to D&WM projects every year and include (like the NDA's budgets) D&D, waste management, new build and own personnel management measures. In the same way as for NDA, CEA now relies on a series of companies experienced in D&D work, leaving only limited accessible market openings and opportunities for new entrants. The relatively constant expenses of the CEA programme should not change either the general trend dominated by the NPPs D&D market and observed above.

Areva, the third significant player in this market, has disclosed information relative to the scheduling of its D&WM operations, suggesting that two-thirds of its D&WM work should take place after 2036, as shown in Table 6.

Table 6: D&WM expenses of Areva according to different periods [70,71]

Years	Expense in EUR_{2016} million
2017	292
2018-2020	1,402
2021-2025	1,592
2026-2035	1,667
2036-	8,525
Total undiscounted provision	**13,478**

For the fuel cycle facilities, only partial data could been retrieved for the D&D share within the D&WM budgets. Several hundreds of million (but the precise amount cannot be identified) should be added to the yearly NPPs D&D market to cover the fuel cycle and research installation D&D activities. However, the D&WM budgets gathered for France and UK suggest a somewhat flat evolution of yearly expenses for the next 20 years.

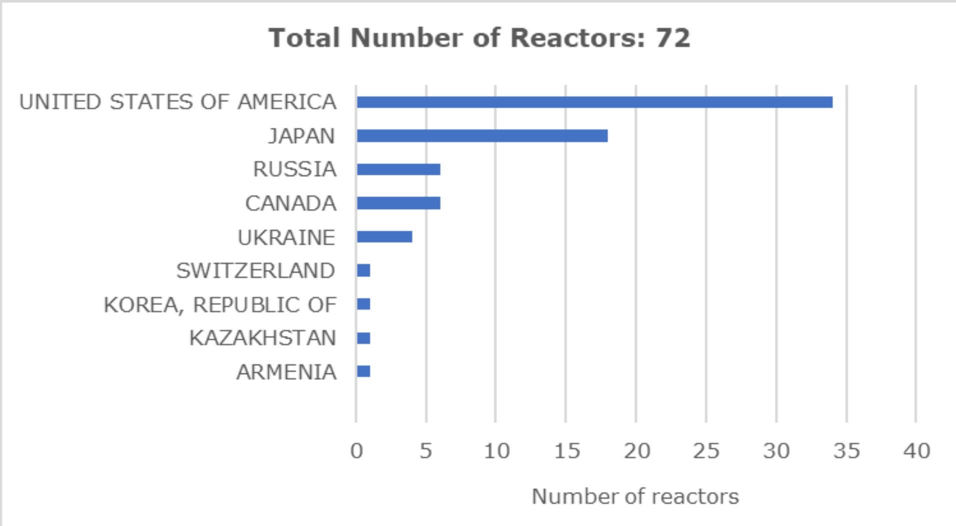
[69] The French Safety Authority requested in 2015 that the CEA reviews its decommissioning and waste management strategy, related priorities, human resources and organisation, and funding. A report was issued at the end of 2016 but it is not yet publically available. In addition, CEA prioritizes now its D&WM projects in the frame of an annual fixed budget, widely based on governmental support.
[70] Retrieved from (Areva 2017).
[71] Waste management cost is included.

4.3 Main foreign markets and possible role of European companies

This paragraph examines whether the export market could act as a growth catalyst for the European industry, capitalising on the experience gained on European domestic projects.

In this respect, Figure 10 shows that the majority of the (current and near future) projects are concentrated in the USA and Japan, which can be hence considered as the two biggest potential export markets for EU companies.

Figure 10: Total numbers of shutdown in non-EU countries[72]



4.3.1 D&D market in the USA

The US D&D market presents major specificities. Specific nuclear, environmental and social regulations, as well as the availability of affordable waste disposal routes (for ILW, LLW and conventional waste, with interim solutions for spent fuel) heavily characterise the D&D projects. Existing practices reduce the project time-dependent costs (e.g. project management, site support, fees, insurances, taxes, consumables) when compared to the EU programmes.

The US D&D market is mature, based on an extensive experience, a low CAGR, and it is very competitive.

For the workforce intensive share of the D&D activities, posting a high number of people from Europe to the US seems not easily practicable. Therefore, the main segment where European companies can compete is the "high skills" or "niche" D&D segment, such as reactor vessel segmentation, decontamination processes and offsite waste treatment (see also the tasks defined in paragraph 2.3.2). In practical terms, this means being partner to local US contractors or relying on their own local subsidiary.

New innovative procurement strategies are also emerging in the US, consisting in the utilities temporarily "selling" the site to a waste or D&D specialist. This is

[72] Derived from (IAEA2017a).

currently the case for the Zion Unit 1 and 2 project. This strategy was chosen in 2010 by Exelon, the twin-unit Zion NPP owner. The operating license and liability for the entire Zion site has been transferred to ZionSolutions[73] until the end of the D&D project[74]. Exelon retains the surveillance of its assets. Entergy reached a similar decision when it sold the permanently shut down Vermont Yankee to an industrial waste remediation and demolition company (NorthStar Services Group), which will assume all decommissioning responsibilities. The main advantage of such strategy is that a waste specialist, which owns an LLW repository (like EnergySolutions), can implement a fully "waste driven" D&D process[75]. This may be a harbinger of similar arrangements for licensees that decide to shut down their units in the US. More detailed information on this model is provided in Appendix 5. European companies are currently studying this opportunity, in competition or partnership with large US companies already active in the market.

4.3.2 D&D market in Japan

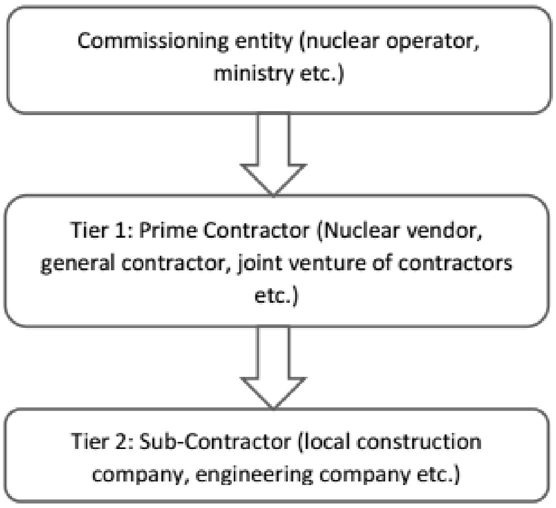
The largest D&WM programme in Japan is Fukushima, quoted at about EUR_{2016} 60 bn. Apart from this key project, four D&WM programmes[76] concerning nuclear power reactors (Tokai-1, Hamaoka-1 and -2, and Fugen NPPs) are ongoing, at a relatively slow pace (20-30 years duration, with budgets of EUR 400-600 million per unit). Other D&D programmes announced include five reactors[76]. Therefore, nine nuclear power reactors will be in the decommissioning mode in the next decade.

Perspectives for the remaining part of the Japanese fleet are unclear for the moment. According to the Amendment to Nuclear Regulation Act (2012), the plants lifetime is 40 years, but the Japanese Nuclear Regulatory Authority can grant a "less-than-20-years" extension. According to the overall trend towards life extension observed in a number of countries, it is possible that life extensions will be granted, leading to a spread out (delayed) D&D market growth.

The Japanese nuclear operators generally do not have sufficient engineering and R&D capabilities of their own to conduct most of the D&WM activities. While the nuclear utilities, also owners of the power plants, prepare the decommissioning plan since they are entirely responsible, most of the technical work requires the action of the corporations, which originally supplied the reactors. These corporations, Toshiba, Mitsubishi Heavy Industries (MHI) and Hitachi, are also main contractors (Tier 1) for the D&D projects. D&D services in Japan are hence essentially limited to these three large nuclear reactor vendors and their affiliates. Tier 1 contractors then employ various subcontractors (Tier 2) to supply manpower, services and products (Tier 2 contractors). This arrangement, described in Figure 11, is unlikely to change in the near future.

[73] A special purpose vehicle of Energy Solutions, specialist of waste management and owner of LLW disposal installations.
[74] Until NRC license termination. See Appendix 2 for more details.
[75] Waste driven means that LLW is shipped offsite as soon as possible after its generation during the D&D project. Logistics burden stemming from the huge VLLW-LLW waste quantities are reduced and efficiency of the D&D works increased.
[76] (JAPC 2015).

Figure 11: General workflow of decommissioning-related projects in Japan[77]



Except for government-funded projects, such as Fukushima, which are announced in the Japanese official gazette, the Tier 1 companies usually do not disclose tenders for decommissioning-related services and products. Yet, most of the services and products for decommissioning are not procured directly by the nuclear utilities but by the Tier 1 companies.

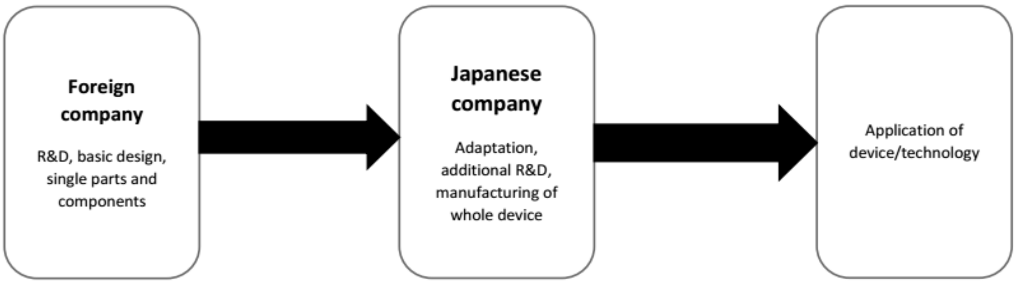
Moreover, the strong relationship and mutual trust existing between the Tier 1 corporations and their subcontractors play an important role in the Japanese nuclear market. The close buyer-supplier relationships and the preference of domestic Tier 2 companies often do not enable international companies to secure a direct and easy access to the Japanese market.

Nevertheless, the Japanese D&D market also shown signs of openness. American companies such as GE Hitachi Nuclear Energy (GEH), Bechtel and EnergySolutions and European companies like Areva, Cavendish Nuclear or Siempelkamp already have minor presence in the Japanese market. Foreign companies try to enter the Japanese D&D market by providing design services or specialised components and equipment. Nevertheless, a Japanese Tier 1 company usually implements the project by adapting and manufacturing the imported technology (this process illustrated in

Figure 12). It seems that the Japanese nuclear industry values foreign *products* rather than foreign *services*. Hence, market entry is somewhat easier for those companies providing highly specialised products and for those entering the Japanese market through a joint venture.

[77] (Schmittem 2016).

Figure 12: Adaptation of foreign originated product in a common Japanese market[77]



For all the above-mentioned reasons, the Japanese D&D market still seems a challenging market for western companies, even though signs of increasing openness can also be observed.

4.4 Consequences on employment

This paragraph presents a first assessment on the possible impacts of the growth of the D&D market on the employment levels in the European nuclear industry.

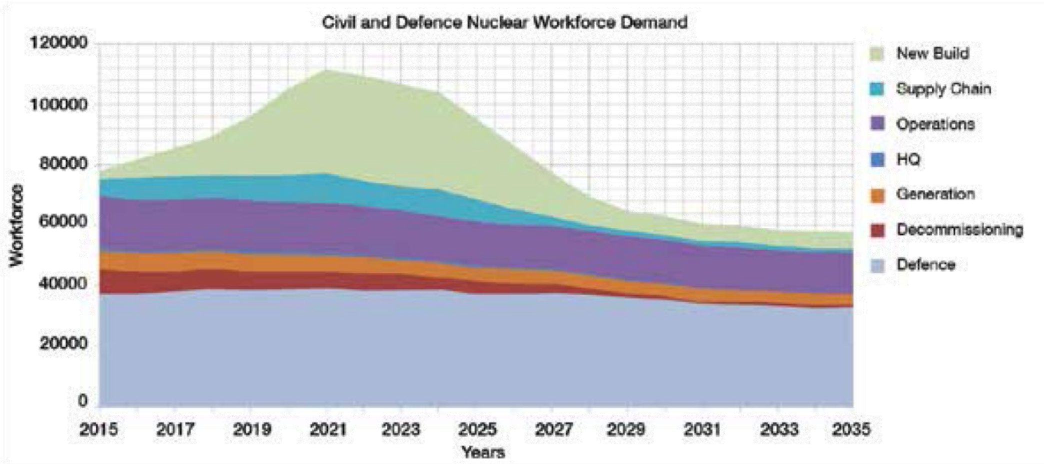
4.4.1 United Kingdom

According to the NDA[78]: "*even though the overall demand for skills is forecast to drop over the coming decades* (see Figure 13)*, the predicted impact of an ageing workforce and competition from nuclear new build, major national and international infrastructure projects and from other regulated industries will lead to a 35% increase in the civil and defence nuclear workforce by 2021. To address these challenges, we need to grow workforce capability and attract and retain a mobile, skilled and versatile workforce*".

However, the increase in workforce needs does not concern directly the D&D sector (red part in Figure 13). To the contrary, the "decommissioning" workforce in decreases and is only a fraction of the overall figures when compared to "new build" staff needs, and a small fraction when compared to "operations" needs.

[78] (NDA 2016b).

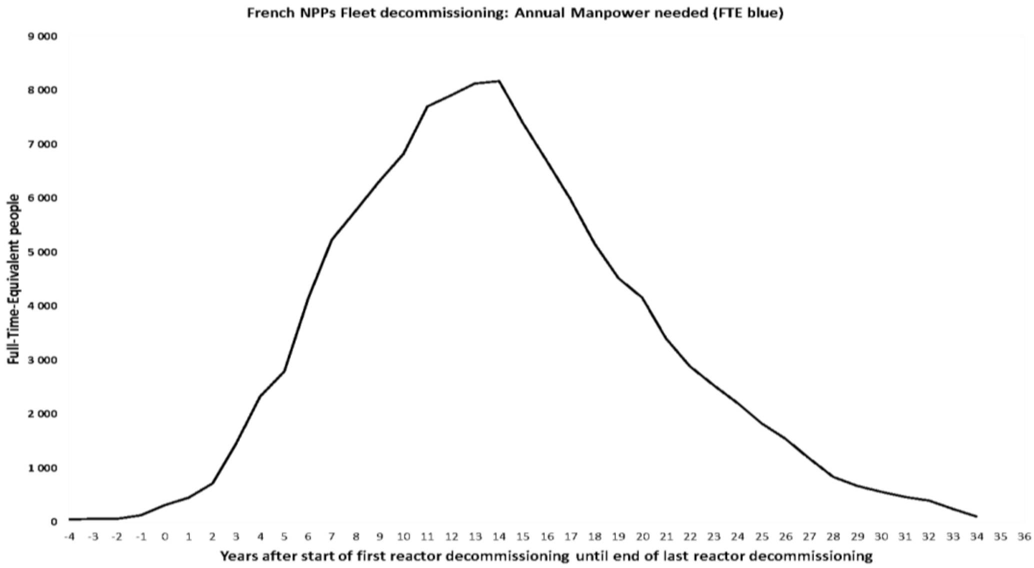
Figure 13: Human resources needs in the British nuclear jobs market[78]



4.4.2 France

A profile of human resources needs for the D&D of the French nuclear power plants has been analysed. The results are reported in Figure 14[79].

Figure 14: HR needs for the French NPPs fleet D&D[79]



This figure considers the existing operating French fleet D&D, that is 58 reactors being decommissioned. In order to get an idea of the upper limit of the D&D total manpower needs over time it is assumed that the D&D activities for each reactor start as soon as the reactor reaches the end of a 40 year life

[79] (NucAdvisor 2014a).

cycle[80,81]. On these assumptions, the total manpower needed for the D&D of the whole French fleet peaks at about 8,000 FTE (full time equivalent) 15 years after start of the decommissioning of the first NPP. In comparison, the average number of contractors working today on the same 58 EDF operating reactors for operation and maintenance (O&M) works varies between 17,500 and 20,000[82] FTE. Their skills are in some cases comparable to those required by the several D&D tasks. Hence, D&D-induced jobs in France will amount to a maximum of 40% of O&M jobs for the same fleet of plants (but of course with large differences within the D&D programme timeframe).

The assumption that all French reactors will enter into decommissioning after 40 years of operation certainly conveys a possible limitation. Life extensions, new plants construction[83] and schedules optimisations may change drastically the D&D HR needs profile shown above.

A second estimation can be made using a single reactor as a basis of reference and absolute labour needs (without a profile over time). In this respect, it can be assumed that a single reactor D&D project requires at the maximum 5,400,000[84] man-hours to be completed, including owner's hours. An effort like this would have to be deployed over about 20 years (in Europe). In comparison, the typical EDF O&M contractors (excluding owner's personnel) working on the same reactor for the same period of time can be evaluated at 9,950,000 man-hours[85] on average. With this yardstick, D&D jobs (including owner's personnel) are about 54% of O&M jobs (but without owner's personnel).

For France, as for other Member States, D&D activities can result in a significant and positive increase in the employment levels in the nuclear industry as a whole. In fact, depending of the specific energy policies that will be undertaken, it is possible that the nuclear energy generation outputs will stabilise (or increase) over time, resulting in D&D employment to be fully additional to the one for O&M.

4.4.3 Germany

Recent reliable data concerning the number of jobs per D&D project in Germany are not publicly available, even though D&D activities are expected to gain substantial momentum in the next few years. However, after the government decision to phase-out from nuclear, the main German utilities set up important "social plans" in order to adapt their structures to the changed scenario (see also box below)[86,87,88].

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[80] In other parts of this document (e.g. in Chapter 4), a 50 years lifetime is assumed for French reactors instead of 40 years as is the case in Figure 14. In the real life, the overlapping of the D&D projects would certainly be optimized (i.e. better spread out over time) for using the resources better. Hence, the manpower peak in Figure 14 must be seen as a maximum.
[81] In the real life, the overlapping of the D&D projects would certainly be optimized (i.e. better spread out over time) for using the resources better. Hence, the work force peak in Figure 14 must be seen as a maximum.
[82] (EDF 2011).
[83] Even in the case where the share of nuclear electricity would be reduced in France
[84] Recorded on Maine Yankee (USA): 5,400,000 hours. Maine Yankee Decommissioning Experience Report. EPRI. This is a maximum given that the site was a single-unit site. In France, multi-units sites allow for learning effects and optimization of the manpower.
[85] Assuming 1650 hours worked per year. 9,950,000=17,500 FTE * 20 years *1,650 hours per year / 58 reactors.
[86] (Finanzen 2013).

Excerpts from the final report of the German "Commission for the Evaluation of the Financing of the Nuclear energy phase-out"[89]:

1.4 Economic situation of the operators
…/… In a market economy, State warranties should not exist for private companies' survival. However, the condition for the implementation of the polluter-pays principle is that the responsible party remains present and solvent. …/… All operators, not only the listed companies, are in a worse situation than before the Energy transition. At that time they held a dominant position on the energy market. With their debt level and their market share shrinking, the rating agencies have degraded their rating. This increases their cost of borrowing and their access to the capital needed for investing. The uncertainties related to the very long-term waste-related duties increases the difficulties of accessing the financial markets. In addition, the current low interest situation necessitates an increase of accounting provisions, in the same way as for retirement costs, for instance …/… Despite the losses, they have continued to provide dividends to their shareholders in the years preceding 2016, but this may not continue after 2016 due to the economic situation.

1.5. Situation of the employees
210 000 persons work currently *(May 2016)* for the operators. The sensitive economic situation of the operators has already led to the loss of a number of jobs. Further jobs losses are not excluded. In order to implement orderly Nuclear energy phase-out, the future of the operators and their employees is of the utmost importance. Decommissioning and waste management must be implemented in compliance with the regulations and with the highest Safety level. To achieve this goal, a trained workforce is mandatory during the entire process. Legal warranties must be given to the employees concerned in compliance with the current labour standards. In this regard, the commission proposes that, for the implementation of the Waste consensus between the Federal State and the operators, a binding agreement is settled for securing the future of the workers. This agreement should comprise:

- participation of the workers representatives in the process of transformation of the operators from plant operators to decommissioning companies;
- secure the jobs and the future working conditions through employment of own current employees in the decommissioning and interim storage activities;
- secure the skills level needed through adequate company agreements;
- secure the workers future in case of modification of company structure or ownership;
- compensate materially or financially workers for disadvantages.

[87] (EnBW 2012) and (Roider 2014).
[88] (Höning 2012).
[89] (KFK 2016) in German, unofficial translation by Nucadvisor.

4.4.4 Short-term skill shortages risks?

As seen above, UK D&D market should slowly decrease in the coming years, whereas Germany should experience an increase of the resources needed due to the number of plants to be decommissioned in the next 20 to 30 years. The question may be raised of the adequacy of the human resources for facing the future needs.

Indeed, retirements in the nuclear industry and some signs of disaffection of European students for nuclear-related careers may raise the threat of a skilled workforce to manage sophisticated nuclear activities becoming progressively unavailable. This risk also concerns the long-lasting European D&D programmes. This issue has been assessed in an EC/JRC/EHRO-N study[90]. In this study, EHRO-N concludes that an urgent action is needed regarding "suppliers" of nuclear human resources for the nuclear energy sector in the EU when considering that:

- nearly half of the nuclear experts employed in 2012 in the NPPs in the EU will need to be replaced by 2020;
- the supply of nuclear experts coming from the relevant higher education institutions (some 2,800 graduates per year) is not sufficient to cover the yearly needs (about 4,000 nuclear experts):
    - in the most optimistic case, only 70% of the demand for nuclear experts is covered by the supply of the relevant higher institutions in the EU;
- ageing problems seem much more important for nuclear than for other relevant fields.

In addition, it should be considered that:

- the job needs in the nuclear sector are certainly quantitatively greater in operations, defence and new build than in D&D, but this latter activity is indeed non negligible in terms of human resources absorption;
- D&D jobs necessary for decommissioning a plant are less than 50% of the jobs needed for operation, but they could be deemed "additional" for the nuclear industry as a whole for countries that are not planning of phasing out from nuclear;
- nuclear D&D seems not to be prised by university studies and not yet correctly publicised by universities and the nuclear industry.

If the plants are decommissioned rapidly after their shutdown, the challenge facing the operator is essentially to retain and motivate the existing personnel with operational experience and with the best knowledge of the installation. The additional personnel needed for D&D could be former O&M personnel with suitable retraining, combined with construction and demolition personnel coming from the non-nuclear sector.

For that purpose, on 2 December 2016 the Commission launched a training and knowledge-sharing initiative to prepare specialists for the dismantling of present and future obsolete nuclear plants in Europe as they reach their end-of-life. Led by the JRC, the European Learning Initiatives for Nuclear Decommissioning and Environmental Remediation (ELINDER) will be implemented in cooperation with 14 partners with expertise in the nuclear field.

[90] (Simonovska 2012).

5. European decommissioning industry mapping

This chapter presents an analysis of the D&D industrial landscape in five key EU Member States (France, Germany, Italy, Slovakia and United Kingdom). For each of them the industrial players are identified and ranked according to the ISDC. This analysis allow to take a fair snapshot of the composition of nuclear industry in terms of demand and supply. A more granular information of the industrial landscape is contained in Appendix 4.

5.1 United Kingdom

The UK nuclear D&WM market is mainly dominated by two organisations:

- Nuclear Decommissioning Authority (NDA);
- EDF Energy Nuclear Generation Limited.

While EDF Energy is responsible for the D&WM of its nuclear power plants in operation, NDA manages the D&WM of 12 Magnox reactors that have already been shut down. This is in addition to other installations as described in Table 7 (which also summarises the current organizational structure of NDA). The largest portion of spending on the D&WM market in the UK is through the NDA[91].

Table 7: The market organisation of the NDA

Site	Owner of Site Licence Company	Remarks
Magnox	Magnox Limited operated by Parent Body Organisation: Cavendish Fluor Partnership Ltd - Contract awarded September 2014. Contract breached, to be terminated in September 2019.	Magnox Ltd is responsible for the decommissioning of already shutdown Magnox reactors. NDA declares that it will delay the dismantling of the reactor vessels and initially establish a phase of safe containment. This phase, called "Care and Maintenance", will last 85 years. Dismantling of the reactors takes place after the safe enclosure. Same strategy is also applied to the AGR plants owned by EDF Energy.

[91] NDA's initial industrial model was to subcontract the operation of each site to a Site Licence Company (SLC). The SLC has temporary private shareholders (Parent Body Organization, PBO, ruled by a specific contract with NDA), introducing private sector expertise. For instance, Nuclear Management Partners (URS Division Washington, AMEC, AREVA-NC) started working as PBO in Sellafield in November 2008. However, after six years running the PBO model at Sellafield, the NDA made a significant decision move, taking direct ownership of the Sellafield SLC (Sellafield Limited) as a subsidiary. The decision was taken after detailed consideration and engagement with the UK government on the most appropriate model for the management and operation of the site given the uncertainties and complexities in the work required. NDA also experienced some issues with other private companies. For instance, the Magnox PBO contract with Cavendish Fluor Partnership (CFP) has just been terminated by anticipation, with CFP approval. According to the NDA: "*there is a significant mismatch between the work that was specified in the contract as tendered in 2012 and awarded in 2014, and the work that actually needs to be done*". NDA will establish arrangements for a replacement contracting structure to be put in place when the current contract ends (2019). These two examples illustrate the difficulty to specify precisely the D&WM works and find an adequate industrial organization, especially for complex research and fuel cycle installations D&WM.

Site	Owner of Site Licence Company	Remarks
Dounreay	Dounreay Site Restoration Limited (DSRL) operated by Parent Body Organisation: Cavendish Dounreay Partnership Ltd (Cavendish Nuclear, CH2M Hill, URS) - Contract awarded 2012.	A new Decommissioning Services Framework is currently being prepared by DSRL. The new framework is scheduled for award in June of 2018 and could be a source of potential EPC contracts in the future. It is predicted the ILW Waste Treatment Plant (£12 million), Sodium Disposal Plant (£14 million) and Flask Loading Facility Design and Build (£30 million) are all expected to be tendered in 2018 via this route. Dounreay remains a market that could provide opportunities for companies in the UK to fill short term and medium-term turnover gaps.
Sellafield	NDA - Decommissioning Delivery Partnership (DDP) - Partners are: -Lot 1: Integrated Decommissioning Solutions (Atkins, Energy Solutions EU Ltd, Hertel (UK) Ltd, North West Projects Ltd and Westlakes Engineering Ltd), Nexus (Costain),AREVA-Doosan-Atkins, Cumbria Nuclear Solutions Ltd (Shepley Engineers, James Fisher Nuclear Ltd, REACT Engineering Ltd, Jacobs Stobbarts, Westinghouse Electric Company UK Ltd, WYG Engineering Ltd). - Lot 2: The Decommissioning Alliance (Jacobs, Atkins, Energy Solutions EU Ltd), Westinghouse Electric Company). - Lot 3: Amec Foster Wheeler, Hertel (UK) Ltd, Shepley Engineers.	DDP set up at the beginning of 2016. A key advantage of the DDP is that it allows work to be initiated quickly, with tasks up to the value of £5 million directly allocated to any one of the framework partners. This could reduce the time it takes to procure work by around 6 months.
Springfields	Westinghouse Electric UK Limited	NDA permanently transferred ownership of the company to Westinghouse Electric including the freedom to invest for the future under the terms of a new 150-year lease. SFL is contracted to provide decommissioning and clean up services to the NDA to address historic liabilities ongoing prior to the sale. A planned expenditure for 2017/18 - £34 million.
Capenhurst	Capenhurst Nuclear Services owned by URENCO UK Limited	The company provides decommissioning and remediation works for redundant facilities of former uranium enrichment plant. A planned expenditure of £61million in 2017/18

NDA and EDF Energy Nuclear Generation procurement and project management processes characterise most of the UK D&D market and allow the participation of prominent UK as well as foreign companies through competition.

It is a priority of the UK government to develop a local nuclear supply chain while the new build programme is being launched (for instance, the Decommissioning Delivery Partnership (DDP) framework, a public procurement project for Sellafield, focuses on facilitating business access to local SMEs.

5.2 Germany

Germany is one of the Member States in the EU that has already completed the D&D of different types of nuclear installations. Through these projects, the German industry has gained substantial experience. Solutions and techniques have been developed inside the utilities, at German research centres and even in small-medium sized enterprises. These actions were funded by the utilities and by the Federal Ministry of Education and Research[92]. Therefore, Germany now relies upon a qualitatively strong decommissioning industry, which includes many of the largest companies in the market as well as numerous efficient SMEs.

Analysing the German experience[93], where four large NPPs including Gundremmingen A, Würgassen, Obrigheim and Stade have been decommissioned or are being decommissioned, it is possible to state that D&D is a fully mastered activity. All necessary technologies are available, as well as experienced contractors. Nevertheless, two main aspects still features the German market: the lack of adequate disposal for the different types of waste and a complex, regional, multi-step regulatory process.

The German D&D industrial landscape is mainly structured around:

- the four main private utilities and players including EON (now PreussenElektra), RWE, EnBW, Vattenfall (referred to in the following as “the nuclear utilities”), working with their subsidiary GNS[94], and its subsidiaries such as WTI[95];
- EWN and its subsidiaries (WAK GmbH, ZLN GmbH, AVR GmbH);
- Nukem technologies (a Rosatom subsidiary);
- Areva GmbH;
- Babcock Noell (Bilfinger subsidiary);
- a series of other noteworthy and well-placed experienced companies like Sat. Kerntechnik GmbH, STEAG Energy Services GmbH, Westinghouse Electric Germany GmbH, Studsvik GmbH & Co. KG, Brenk Systemplanung GmbH.

Several of these companies contribute to work on the most complex and specific tasks of the dismantling process such as inside of the reactor building. These tasks involve the highest requirements in radiation protection and D&D processes, as well as careful planning and preparatory work (for instance, the licensing documents). For such tasks, plant-specific know-how, specific tools and lessons learned are valuable assets for respecting schedule, quality and costs. Companies specialised in waste management services and products exist (such as GNS). In the same way, decontamination works as well as clearance measurements are assured by specialised actors. The remaining activities, such as the dismantling of non-contaminated plant components or demolition of building structures require less specific knowledge, and are performed by non-nuclear specialised companies, often civil construction and demolition enterprises.

[92] (Weigl 2008).
[93] (Bernd 2013).
[94] Waste reduction, conditioning methods, packaging and casks, transport, interim storage (until 2017) and disposal equipment and concepts.
[95] Services from packaging design for radioactive waste to documentation services of waste packages for interim and final storage.

Nevertheless, Germany may face a growth challenge in the near future. A large decommissioning resource capacity will be needed as most of the projects until now have been managed as one-offs on a smaller scale and not as parallel, large, multi-site programmes.

Because of its expected fast growing D&D market and the stable macroeconomic conditions, Germany appears to be an attractive market for both domestic and foreign investors. Nevertheless, the specific regulatory regime and the presence of a concentrated and well developed domestic industry may represent substantial hurdles for potential new entrants.

5.3 France

The French nuclear industry is characterised by three main companies: EDF, CEA and Areva. They are also main players in the D&WM market and have concrete global ambitions[96].A network of qualified subcontractors is currently available in France to provide the services required by the three main players. As in the UK and Germany, the French industry has a proven expertise on key D&D activities such as remediation, characterisation and implementation of high-tech dismantling phases.

Similarly to Germany, significant barriers to entry can exist for the French D&D market as:

- a full scope of competencies exist within domestic (incumbent) companies;
- the main domestic industrial players benefit from a privileged position given by the "proximity" to the operations of the NPPs to be decommissioned;
- these industrial players can already dispose of subsidiaries with core competencies for nuclear D&D, including for civil works.

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Currently, the CEA installations D&D represent one of the largest projects in France. CEA's annual budget is about EUR 600 - 800 million for its decommissioning and waste management programme, with 37 installations to dismantle. CEA is currently reviewing its D&D priorities in the frame of this budget.

R&D Programmes

Unlike the D&D of NPPs, for which the necessary technologies and contractors already exist and are proven, the D&D of fuel cycle facilities needs R&D efforts to cope with the particularities of these one-of-a-kind projects.

For instance, CEA, associated with Areva and EDF, sponsor an R&D programme (50 people, about EUR 10 million per year) relative to these

[96] Areva has developed a D&D business Unit, providing capacities to the French and foreign markets, and is particularly active in the USA through its local subsidiary. EDF is building capacities within its own teams as well as through acquisitions (Studsvik in 2017): see EDF Cyclife web site.

technologies and processes, aimed at reducing schedules, costs and waste while increasing safety.

Such R&D programmes typically cover:

- initial, current and final radiological characterization of the installations and the soil: installation mapping, hot spots detection, radioelement identification, activity evaluation, through gammametry (concrete contamination), alpha cameras (Pu in glove boxes, optimised sampling methods, etc.;
- operations in hostile environments: remote operations with robotic arms, thick part laser cutting, underwater operations, virtual reality simulator for dose reduction, etc.;
- structures and soil decontamination: numerous techniques are available or under development, including:
    - chemical decontamination: chelation and organic acids, strong mineral acids and related materials, chemical foams and gels, oxidizing and reducing agents;
    - physical decontamination technologies: strippable coatings, centrifugal shot blasting, concrete grinder, concrete shaver, concrete spaller, dry ice blasting, dry vacuum cleaning, electro-hydraulic scrabbling, robotic wall scabbler, grit blasting, high pressure water, soft media blast cleaning (sponge blasting), Steam vacuum cleaning;
    - more exotic techniques: bio-decontamination, electrokinetic decontamination, microwave scabbling, laser, light or photon ablation, etc.
- effluents and waste treatment: waste conditioning, optimized cement formulations, evaporators, hydro-thermal oxidization, plasma torch incineration, etc.;
- waste characterization: non-destructive analysis, α and γ techniques, optimized gamma spectrometry (IT developments, high γ intensities, high γ energies, Long life β emitter's analysis, miniaturisation).

5.4 Italy

Italy has many nuclear legacies to be dismantled since the early phase-out of its nuclear programme. Being mandated to manage the decommissioning programme in Italy, SOGIN is the main and only actor responsible for D&D programme management.

Details of the contractual structure of the D&D projects (players, competitors, contract values) are publically available for Italy and Slovakia. This can give valuable insights concerning the D&D contractual practices in these countries.

All contracts between 2014 and 2017 awarded by SOGIN are published on its website[97]. Departing from thisinformation, Table 8 presents the typical industry

[97] For 2017: (SOGIN 2017)

players in Italy and the contracts awarded, sorted according to a simplified segmentation:

- project management such as core activities support activities including engineering services;
- works in the controlled area and supporting equipment/installations supply such as tools supply, decontamination, dismantling works, waste characterization and packaging, offsite waste treatment;
- more mundane D&D activities.

SOGIN manages the EUR 180 million annual budget for decommissioning in Italy, of which about 50% is contracted to:

- several Italian companies which survived the dormancy period of the nuclear industry in Italy, like Ansaldo Nucleare, as well as SOGIN's subsidiary, Nucleco, for the project management supporting activities, in addition to many Italian SMEs for environmental impact assessment;
- several companies associated with the "works in controlled area" including decontamination, equipment removal, waste management (treatment, characterisation, sorting, packaging as well as off-site waste treatment), and equipment suppliers:
    - this segment is generally linked to highly skilled foreign companies that are capable of implementing specific processes like waste incineration and reactor primary circuit dismantling;
- most Italian companies, often from the civil engineering sector, work on more mundane projects:
    - most of the relatively high value contracts in this segment come from the construction and/or refurbishment of interim storage facilities for radioactive waste generated by D&D works and legacy waste resulting from the dormancy period of the Italian nuclear installations.

Finally, the absence of the required storage and/or disposal sites for the waste is reported to increase the cost of the decommissioning programme in Italy through licensing procedures and construction works. These storage facilities will also be dismantled by the end of the decommissioning activities.

Table 8: Typical industrial players in Italian D&D market with some representative contracts

Simplified segmentation	Company	Typical contracts
	Project Management	
PM core activities	SOGIN	State-owned and main company responsible for the decommissioning program in Italy. Sogin overall budget to reach green field status and to manage all related wastes is EUR 6,5 bn. Sogin's budget in 2016 is valued at around EUR 182 million (-18% compared to 2015): • EUR 96.5 million for procurement and subcontracting; • EUR 82 million for employee salaries; • EUR 3 million due to tax and social security.

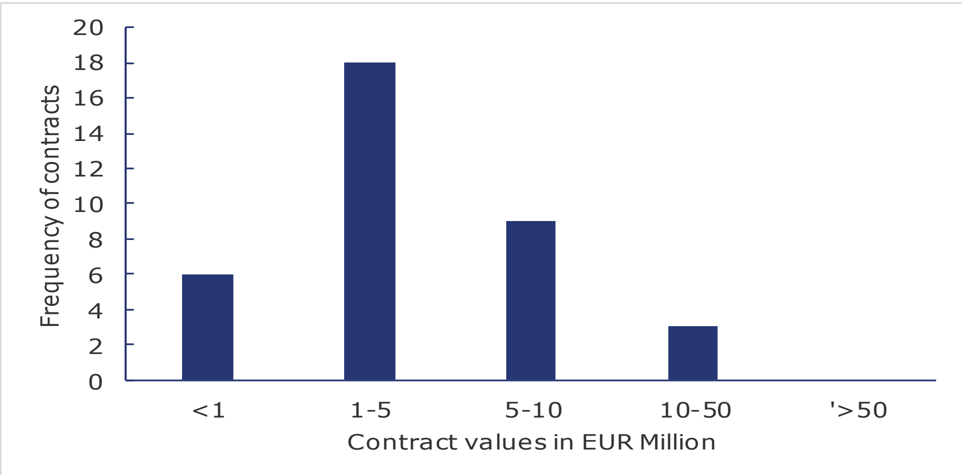
Simplified segmentation	Company	Typical contracts
PM supporting activities	Nucleco	Owned by Sogin (60%) and ENEA (40%). Nucleco's budget in 2016 valued at around EUR 30 million, and includes: • EUR 13.5 million to the suppliers; • EUR 13.9 million for employees' salaries; • Around EUR 2 million due to tax and social security.
		Radiological characterisation and measurements in spent fuel pool at Caorso site valued at EUR 5 million.
		Repair and archiving of the Sogin Sites Documentation valued at EUR 4.4 million.
		Supporting radiation protection at the Sogin sites valued at EUR 4.6 million.
		Environmental survey for all sites valued at EUR 2.8 million.
		Support services for surveys and waste management for Trino plant valued at EUR 2.7 million.
		Radiological characterization of materials to be removed from the Garigliano plant valued at EUR 2.25 million.
		Engineering services for the design and manufacture of a transportable system of supercompacting and waste conditioning valued at EUR 340,000.
	Ansaldo Nucleare	Integrated Decommissioning Management Tools (IDMT), namely MIRAD and DECOM, for dismantling and waste management operations for the NPPs including Caorso, Garigliano and Trino.
	Servizi di Ricerche e Sviluppo (SRS Group)	Multidisciplinary engineering services to Sogin valued at EUR 3.3 million.
		Engineering services related to technical surveillance assistance for the construction of the CEMEX facility valued at EUR 881K (as a JV with CCR Internazionale SCRL).
	Many companies specialized in environmental engineering, inspection and measurement.	Depending on the works contracted, most of the projects valued at below EUR 100,000.
Works in controlled area		
Decontamination	Areva NP	Full System Decontamination (FSD) in 2004 for Caorso BWR and Trino PWR using the HP/CORD UV concept.
	Nukem and Energy Solutions	EUREX pool decontamination with Wall & Floor Washer™, SAFE™ and ElectroCoagulation process.
Dismantling works in controlled area	Equipos Nucleares and GD Energy Services (GDES)	Contract in 2016 to dismantle primary circuit and auxiliary systems excluding vessel and internals of the Trino plant. Project duration is expected to be 3 years with a value of nearly EUR 8 million.
Waste treatment	Nucleco	Sorting, treatment, characterization and super-compaction of radioactive waste arising from the decommissioning of the Garigliano plant valued at EUR 4.7 million.
		Characterisation of contaminated samples of steel, concrete and other materials from the systems and components of the Garigliano plant valued at EUR 3.6 million.
Equipment supply	Research Consorzio Stabile with 5 local companies and 2 foreign companies: Chemcomex Praha (Czech Republic), UJV Rez (Slovakia)	Design and construction of a modular radioactive waste conditioning system, called SiCoMoR in Trino plant (about EUR 9.5 million).
	Siempelkamp (Germany)	Supply of an evaporation system to the Garigliano plant valued at EUR 1.6 million.

Simplified segmentation	Company	Typical contracts
	MBRAUN (Germany)	Supply and installation of glove box system for the treatment and repackaging of waste at IPU and OPEC sites valued at EUR 1.5 million.
	GNS (Germany)	Supply of waste containers (10 MOSAIK casks for ILW with handling equipment, SBoX for packing core components) for the waste arising from the Caorso plant valued at nearly EUR 1.5 million.
	Ansaldo	Design, supply and testing of a transportable system for the super-compaction of LILW valued at nearly EUR 4 million.
		Installation and commission of a Phosphoric Acid Decontamination (PHADEC) facility at Caorso plant valued at nearly EUR 11.7 million (In cooperation with Babcock Noell).
	Carlo Gavazzi Impianti SPA and SAEET Impianti S.R.L.	Construction of a new radioactive liquid effluent treatment system, including the dismantling of the existing system valued at EUR 200,000.
Offsite waste treatment	Studsvik (Sweden)	Treatment and conditioning of organic waste arising from the decommissioning of the Caorso plant in Sweden valued at nearly EUR 7.6 million.
	Javys (Slovakia) with Ansaldo	Incineration of spent ion exchange resins arising from the decommissioning of the Caorso plant abroad valued at nearly EUR 34 million.
More mundane D&D tasks		
Dismantling works outside controlled area	General Smontaggi (as a consortium comprising 6 local companies)	Decontamination (scrapping) and demolition of the cooling tower and construction of a new tower at Garigliano plant site valued at EUR 8.6 million.
	Despe, Guerrato, Ansaldo and Onet Technologie (France)	Dismantling of the systems and components of the turbine building of the Garigliano NPP in 2016 valued at nearly EUR 22 million.
	Despe, Ansaldo and Techint	Dismantling of the systems and components of the turbine building of the Caorso NPP valued at nearly EUR 10 million.
	Carlo Gavazzi Impianti (as a consortium comprising 3 local company) and Pöyry Germany:	Dismantling of the auxiliary systems of the reactor building of Garigliano plant with a value of nearly EUR 4 million.
	Belli	A contract to remove asbestos from the Bosco Morengo plant in 2015. The total amount of the project valued at EUR 1.2 million.
	Nucleco	Removal of asbestos and insulation which were contaminated.
	Castellano Costruzioni	Removal and transport of contaminated soil from the Garigliano plant valued at EUR 775,000.
	AR.CO. Lavori	Construction of material handling station for steam generators valued at EUR 11.3 million.
	Consortium of S.A.L.C, DAF, Stradali and Siderpiombino	Renovation of two old storage facilities, ERSBA1 and ERSBA2, at Caorso NPP, valued at EUR 8.9 million for 5 years.
	Monsud with its subsidiaries	Construction of temporary storage for the legacy and decommissioning waste arising from the Garigliano and Saluggia site (valued at EUR 7.1 million and EUR 1.4 million, respectively).
	Consortium between Monsud and Ansaldo	Executive design and construction of Effluent Treatment Plant at the Latina plant valued at nearly EUR 6.5 million.
	Fratelli Omini	Adjustment of turbine building to a temporary waste storage at Caorso NPP, valued at nearly EUR 2 million for 14 months contract.

Simplified segmentation	Company	Typical contracts
	Giordano	Construction of new control room at Latina NPP, valued at EUR 286K for 8 months contract.
	Italwork Consorzio	Construction of a new temporary storage room in existing building at Garigliano NPP, valued at EUR 1.6 million for 28 months contract.
	Siritec	Reconfiguration of existing fire detecting system, EUR 706,000 for 10 months contract.
	In addition to these companies, there are many construction companies together with site support equipment (fire detection, ventilation, electric system) suppliers that were qualified by SOGIN. The contract value of most of the projects is below EUR 200,000	

The contracts listed in Table 8 add up to nearly EUR 200 million (spread over several years). Their distribution as shown in
Figure 15 indicates that a large majority of the contracts are valued at less than EUR 10 million and most of the contract values are between EUR 1 and 5 million. This is without allowing for the many very small value contracts, typically less than EUR 0.25 million. The result is that many Italian companies are engaged in a competition for relatively low-value contracts.

Figure 15: Distribution[98] of contracts in terms of their value class in Italy



5.5 Slovakia

Currently, there are two different D&D programmes in Slovakia (Bohunice A1 and Bohunice V1). Owing to the availability of valuable data in the EBRD annual procurement reports[99], the same kind of analysis as was done for Italy can be applied to the Bohunice V1 D&D programme in Slovakia. The contracts listed in
Table 9 show that:

- there is one national player, Javys, managing decommissioning programmes in Slovakia;

[98] In this table, "X" values are the limits of the class, "Y" values are the number of contracts in this class. For instance, 18 contracts are valued between EUR 1 and 5 million, 5 contracts are between EUR 0,2 and 1 million and none are over 40.
[99] (EBRD 2016).

- several foreign companies contribute to the controlled Area D&D work such as decontamination, equipment removal, waste management (characterisation, sorting, packaging), equipment suppliers and offsite waste treatment contractors;
- most Slovakian companies, often from the Civil Works sector, contribute to more mundane tasks.

In contrast to the industry landscapes in France, Germany, UK or even in Italy, the Bohunice V1 decommissioning programme relies on a number of foreign companies to cope with the lack of sufficient domestic capabilities.

Table 9: Typical industrial players in Slovakian D&D market with some representative contracts

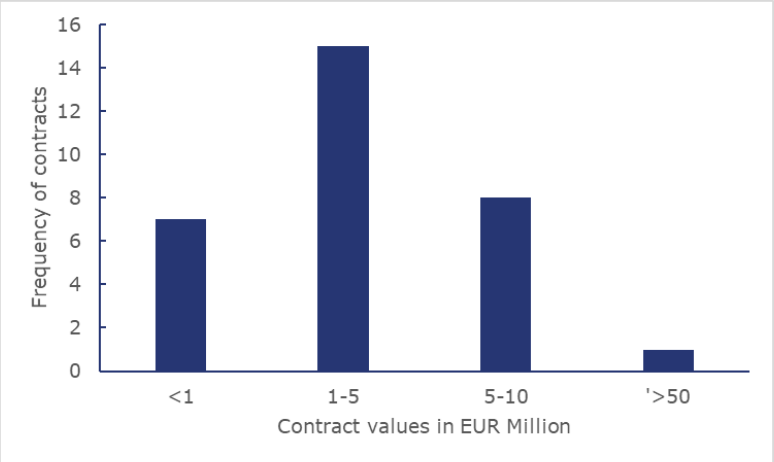
Simplified segmentation	Company	Typical contracts
Project Management		
PM core activities	Javys (Slovak Republic)	A state owned company is responsible for radioactive waste and spent fuel management in addition to the safe decommissioning of A1 NPP and V1 NPP. The main activities are covered by the funds provided by National Nuclear Funds (NNF), and the funds provided by BIDSF and its sales and revenues derived from commercial activities. The NNF budget for decommissioning and waste management in 2016 was nearly EUR 70 million. The revenue in 2016 was nearly EUR 35.5 million which resulted from radioactive waste and spent fuel management and sales of unnecessary recoverable properties from the decommissioning of A1 NPP and V1 NPP.
PM supporting activities	Consortium of Iberdrola, INDRA and Empresarios Agrupados (Spain)	Project Management Unit supporting the project owner, Javys. The value of the contracts varies and it is up to EUR 5 million per year.
	Sogin (Italy)	Project Management Unit supporting the project owner, Javys. The value of the contract is about EUR 3 million per year.
	Energiewerke Nord GmbH, (Germany), AMEC Slovakia and STM Power (Slovak Republic)	Decommissioning database development in order to support the planning valued at nearly EUR 2.4 million.
	Inypsa (Spain)	Environmental Impact Assessment Report of 2nd Stage of V1 NPP Decommissioning valued at EUR 402,000.
	AITEN (Subsidiary of VUJE)	Decommissioning database - technological upgrade valued at nearly EUR 600,000.
	VUJE (Slovak Republic)	General contractor of the decommissioning of A1 NPP Stage I and II.
		The V1 NPP Decommissioning 1st Stage Plan & Other Documentation valued at EUR 3.4 million.
	Westinghouse (Germany) with Tractebel (Belgium)	The V1 NPP Decommissioning 2nd Stage Plan & Other Documentation valued at nearly EUR 5 million (Unsuccessful tenderers: Nukem, Nuvia UK, Specialus Montazas, AMEC, Gas Natural Fenosa Spain).
	UJV Rez (Czech Republic)	Decommissioning support surveys valued at almost EUR 2.2 million in 2017. (Unsuccessful tenderer was Areva Germany GmbH).

Simplified segmentation	Company	Typical contracts
	Specialus Montazas NTP (Lithuania)	Feasibility study for the management of the Bohunice V1 NPP primary circuit components valued at almost EUR 900K (Unsuccessful tenderers: Nuvia UK, Westinghouse and Nukem).
Works in controlled area		
Decontamination	ONET Technologies (France) with ROBO Piešťany and Chemcomex Praha (Czech Republic)	Decontamination of the primary circuit valued at almost EUR 6.5 million (Project failed).
	VUJE (Slovak Republic)	Decontamination and dismantling of underground tanks of the A1 NPP with high water jet.
	Westinghouse (Germany)	Decontamination of the V1's primary circuit valued at EUR 3.83 million. Westinghouse was directly selected as a replacement of the consortium led by ONET Technologies.
	Amec Foster Wheeler Nuclear Slovakia	Decontamination of spent fuel pools and other contaminated tanks in the V1 NPP valued at EUR 1.15 million (Unsuccessful tenderer: GD Energy Services Spain).
Dismantling works in controlled area	Westinghouse Electric Spain/Sweden with VUJE (Slovak Republic)	Dismantling of the reactor coolant system of Bohunice V1 valued at almost EUR 117.5 million in 2017.
	Metrostav (Czech Republic)	Dismantling of systems outside the hermetic zone boundaries valued at almost EUR 5.3 million in 2017 (Unsuccessful tenderers are Despe Italy and GD Energy Services Spain).
Equipment	Canberra Packard (Austria)	Refurbishment of the radiation protection monitoring equipment valued at almost EUR 4 million.
	VF Slovakia	Releasing materials from decommissioning of the V1 NPP, equipment installation for monitoring, valued at almost EUR 9 million.
	VF Czech (Czech Republic)	Construction of electrochemical and ultrasonic decontamination facility at V1 valued at almost EUR 5.1 million.
Waste management	Amec UK	Treatment of legacy waste - sludge and sorbents arising from the V1 valued at almost EUR 9.5 million (Unsuccessful tenderers: Chemocomex CZ, ONET France).
	VUJE (Slovak Republic)	Metallic RAW Melting Facility (Supply & Installation) valued at EUR 9.4 million.
		Waste processing and transport to a disposal site (Waste arising from the primary circuit dismantling) valued at EUR 600,000.
More mundane D&D tasks		
Dismantling works outside of controlled area	Metrostav (Czech Republic)	Diesel group dismantling of the V1 NPP valued at EUR 780,000.
		Dismantling of insulation in the V1 NPP controlled area valued at almost EUR 900,000.
	Vion Slovakia	Dismantling and demolition of V1 NPP external buildings valued at EUR 975K (Unsuccessful tenderers: Porr Bau Ag Austria, Metrostav Czech, Zipp Bratislava, Petr Brezina - Apb Plezen Czech).
	EZ-Elektromont Slovakia	Dismantling of Electric Power Supply Systems valued at almost EUR 2.2 million (Unsuccessful tenderers: Vuje, SAG Slovak, PPA Energo Slovak, OHL ZS Czech, Zipp Slovak, Metrostav Czech).
	Despe (Italy)	Dismantling and demolition of V1 NPP cooling towers valued at almost EUR 8 million (Unsuccessful tenderers: APB Plzen, Hochtief from CZ).

Simplified segmentation	Company	Typical contracts
	ROBO Piešťany (Slovak Republic)	Removal of auxiliary buildings system valued at EUR 1.5 million. (Unsuccessful tenderers: Metrostav, Chemcomex Praha, Amec, Skoda).
		Dismantling of insulation in V1 NPP Turbine Hall valued at almost EUR 1.3 million.
	Chemcomex Praha (Czech Republic)	Dismantling of the technical equipment in the V1 NPP turbine hall valued at EUR 7.5 million. (Unsuccessful tenderers: Metrostav, Zipp Bratislava Slovak, Hochtief Cz, CKD Praha Czech, Skoda Power Sro Slovak, Vuje A.S.).
	PKE Electronics AG (Austria)	Reconstruction of the physical protection system at the site of the power plant – AKOBOJE valued at almost EUR 10 million.
	EFACEC Sistemas de Electronica (Portugal)	Modification of the JAVYS power supply scheme after V1 final shutdown valued at almost EUR 9 million.

As shown in Figure 16 as concerns the contract value distribution, the situation appears to be similar as for Italy: many companies are engaged in a competition for relatively low value contracts, and contracts valued at more than EUR 10 million are rare.

Figure 16: Distribution of contracts in terms of their value class in Slovakia



Tendering procedures implemented by the EBRD are highly transparent and awarded contract details, identifying unsuccessful bidders, are publicly available in the EBRD's annual procurement reports. The tenders, prepared in English by the Project Management Unit (PMU), which has also been selected from foreign decommissioning-experienced organisations, resulted in higher number of international players in the Bohunice V1 D&D programme, in comparison with the other countries studied.

5.6 Conclusions

There is a wide spectrum of industrial companies on the European D&D market. A few of them are focused in project management activities and others are actively involved in on-site operations.

The core project management activities are ensured by a very few large companies, generally installation operators and/or owners. These tasks are generally not subcontracted. SOGIN, JAVYS, the four German nuclear utilities and EDF, Areva and CEA usually keep this task internally. NDA does the same for the Sellafield programme. These companies have often set up dedicated D&D divisions ensuring project management tasks. When their internal resources are insufficient, these large companies rely on numerous contractors ensuring specific support tasks (e.g. engineering, licencing, planning, procurement specifications, quality control). These supporting tasks usually require thorough knowledge and experience of the Member State's regulations and rules. Thus, the project management supporting activities are often reserved to relatively small domestic engineering or consulting firms[100].

With regard to on-site operations, three different company types may be observed. The first group comprises relatively large specialised companies capable of dealing with specific expertise and having the capacity to implement high value-added processes. These activities are technically and financially risky and usually require working in controlled areas of the installation: cutting of the reactor vessel and internals, decontamination, waste treatment (either on-site or off-site such as incineration and melting) as well as the supply of niche equipment such as spent fuel casks or evaporation/compaction equipment for waste volume reduction. In this segment, competition is mostly based on technology and expertise readiness. From the industrial map in Appendix 4, it can be seen that several companies intervening in D&D projects are companies that are called in to work with the utility during the operations phase.

The second group of companies spans from small to large companies competing for what might be called "low skill-level activities" such as component dismantling and waste processing. Competition is keen and prices are relatively low. The operations in this segment are based on local workforce and no high level specific technologies are necessary.

The third group of companies comes from non-nuclear industries. They attempt to enter the low skill-level activity market and capture revenue from the second group of companies. The activities that they can perform include basic waste processing, conventional component dismantling and building demolition. These more basic tasks requiring a greater workforce generally take place outside the controlled area, or in the support to the companies operating in the previous segments. This third set of activities is the privileged segment for domestic suppliers.

The great majority of companies working on the D&D market compete on their domestic markets, at least in Western Europe, the largest future market. For most of the companies holding the largest share of the budgets, except the ad

[100] A significant exception is Slovakia.

hoc owner companies, D&D projects do not represent a large share of their revenues.

The value distribution of the contracts awarded in the D&D projects shows that most of the contracts are less than EUR 5 million. Such relatively modest values may discourage new entrants to make commercial investments (e.g. technology readiness, local representations, local regulations expertise). It may represents a barrier to entry unless new entrants already have a subsidiary working in the local nuclear market or who is partner to a local company.

Even though only little evidence emerges from the analysis conducted in the previous paragraphs, an argument can be made according to the idea that international presence and competition may be higher for D&D programmes to be carried over in Eastern European countries than for the ones in Western Europe. This may be triggered by the lack of predominant domestic (incumbent) nuclear industrial players and it may be limited to the (key) segments of the highly specialised D&D services and products.

6. Quantification of the D&D market by segment

This paragraph contains a structured attempt to identify and quantify the different market segments composing the nuclear D&D market.

Quantification of the relative size of the costs of the different project segments generates several challenges. D&D project budgets (for completed projects or estimated budgets) are significantly different from one project to another, for various reasons: processes used, scope, type of nuclear installation, applicable regulations, waste management strategy, multi-unit sites, cost of manpower. Furthermore, the costs structures of the diverse projects rarely use a standardised approach such as ISDC. This makes the comparison of the different projects difficult.

Further, little cost data of completed projects are generally unavailable. In the following analysis, five D&D cost estimations from US, Sweden, Switzerland, Slovakia and France have been considered for the appraisal of the *relative weight (%)* of the different segments. Such an approach has the advantage to (at least partially) address the problem of the large scattering of the projects absolute costs that can be often observed. When the publically available costs items were not reported as following the ISDC structure, a "conversion" has been made[101].

6.1 TLG estimation

The US decommissioning cost estimation structure is based on a different methodology[102] than the ISDC. Nevertheless, a possible conversion of this structure to the ISDC is given in Table 10[103].

Table 10: Percentage distribution of ISDC Level 1 items for the TLG methodology

ISDC Level 1		Cost share[104]
1	PRE-DECOMMISSIONING ACTIONS	2%
2	FACILITY SHUTDOWN ACTIVITIES	3%
4	DISMANTLING ACTIVITIES WITHIN THE CONTROLLED AREA	15%
5	WASTE PROCESSING STORAGE AND DISPOSAL	23%
6	SITE SECURITY SURVEILLANCE AND MAINTENANCE	18%
7	CONVENTIONAL DISMANTLING DEMOLITION AND SITE RESTORATION	9%
8	PROJECT MANAGEMENT ENGINEERING AND SITE SUPPORT	28%
10	FUEL AND NUCLEAR MATERIALS	0%
11	MISCELLANEOUS EXPENDITURES	3%
TOTAL		**100%**

[101] Authors' estimation. As a matter of fact, due to the lack of granular and reliable data, converting specific project cost structures to ISDC may convey some estimation error.
[102] (TLG 2013).
[103] Data retrieved from (NEA 2016).
[104] Simple total of all items may not be 100% due to rounding.

6.2 Ringhals site estimation

The results of the assessment of the decommissioning cost for the Ringhals site in Sweden as of 2013[105] are summarised in Table 11, according to the ISDC.

Table 11: Percentage distribution of ISDC Level 1 items for the Ringhals site

ISDC		Cost share
1	**PRE-DECOMMISSIONING ACTIONS**	**3%**
1.01	Decommissioning planning	2.39%
1.03	Safety. security and environmental studies	0.21%
1.04	Waste management planning	0.18%
1.05	Authorisation	0.11%
2	**FACILITY SHUTDOWN ACTIVITIES**	**3%**
2.01	Plant shutdown and inspection	1.68%
2.04	Radiological inventory characterisation to support detailed planning	0.93%
4	**DISMANTLING ACTIVITIES WITHIN THE CONTROLLED AREA**	**36%**
4.01	Procurement of equipment for decontamination and dismantling	8.30%
4.02	Preparations and support for dismantling	1.43%
4.03	Pre-dismantling decontamination	4.14%
4.05	Dismantling of main process systems. structures and components	11.30%
4.06	Dismantling of other systems and components	4.32%
4.07	Removal of contamination from building structures	1.38%
4.09	Final radioactivity survey for release of buildings	5.12%
5	**WASTE PROCESSING. STORAGE AND DISPOSAL**	**10%**
5.01	Establishing the waste management system	2.34%
5.08	Management of decommissioning intermediate-level waste	0.73%
5.09	Management of decommissioning low-level waste	7.10%
5.1	Management of decommissioning very low-level waste	0.18%
6	**SITE SECURITY. SURVEILLANCE AND MAINTENANCE**	**8%**
6.01	Site security operation and surveillance	1.33%
6.03	Operation of support systems	4.28%
6.04	Radiation and environmental safety monitoring	2.00%
7	**CONVENTIONAL DISMANTLING.DEMOLITION.AND SITE RESTORATION**	**20%**
7.02	Dismantling of systems and building components outside the controlled area	6.80%

[105] (Ringhals 2013).

ISDC		Cost share
7.03	Demolition of buildings and structures	12.64%
7.04	Final clean-up. landscaping and refurbishment	0.84%
7.05	Final radioactivity survey of site	0.10%
8	**PROJECT MANAGEMENT. ENGINEERING AND SITE SUPPORT**	**18%**
8.02	Project management	6.70%
8.03	Support services	9.84%
8.04	Health and safety	1.68%
11	**MISCELLANEOUS EXPENDITURES**	**2%**
11.01	Owner costs	1.08%
11.03	Insurances	0.86%
TOTAL		**100%**

When the ISDC items of 1, 2, 6, 8 and 11, as well as items like 4.09[106] are considered as "Project Management" activities, its cost share will substantially exceed 30%, as observed in the US. The share of the site works that are comprised in the ISDC 4 and ISDC 7 items is 56%. However, these items include also some project management activities such as procurement and final surveys. Finally, the share of waste management (ISDC 5) onsite is quoted to 10%.

6.3 Swissnuclear estimation

Even though the Swissnuclear costs evaluation based on the Gösgen site[107] is particularly difficult to convert into the ISDC format and caution should be used, a structured attempt is given in Table 12.

It appears that the owner costs, considered as including engineering, site support and operation during the decommissioning period as well as miscellaneous costs (e.g. taxes and insurances) may be as high as 67% for decommissioning a single unit like Gösgen[108].

Accordingly, the practical dismantling works account only for one-third of the cost, including 10% for material and waste management[109].

[106] All these tasks are generally performed directly by the owner personnel; thus, they could be referred to as tasks to be performed within "Project Management" category.
[107] (Kostenstudie 2011).
[108] The duration of the shutdown phase is an important parameter. In this evaluation, it is assumed to last 5 years.
[109] Disposal cost is excluded.

Table 12: Gösgen decommissioning cost evaluation and percentage distribution of ISDC Level 1 items

		Cost item	Cost share	ISDC equivalent	Cost share
Shutdown period		Owner personal costs	18.44%	1 & 8	40%
		Maintenance	7.09%		
		Supply & consumables	3.02%		
		Land and buildings	2.24%		
		ENSI costs	2.94%		
		Insurances	1.28%		
		Taxes	0.53%		
		G&A	4.17%		
		Operating waste (w/o packaging)	0.34%		
		Interim storage operation	0.63%	6 & 8	26%
Dismantling Period	**Owners costs**	Owner personal costs	14.09%		
		Supply & consumables	8.48%		
		Security	2.48%		
		ENSI & experts costs	1.94%	11	3%
		Insurances	1.17%		
	D&D activities	Project Management and Authorizations	1.90%	8	2%
		Preparatory works	3.93%	1	4%
		Dismantling Pressure Vessel & Internals	3.53%	4	10%
		Dismantling Concrete protection	0.35%		
		Dismantling Controlled area	2.16%		
		Other Controlled area dismantling	1.15%		
		Decontamination & Clearance buildings	3.30%		
		Material management and disposal	10.09%	5	10%
		Dismantling outside controlled area and demolition	4.72%	7	5%
TOTAL			**100%**		**100%**

ISDC	Cost share
1, 2, 6, 8	72%
4	10%
5	10%
7	5%
9	0%
10	0%
11	3%

6.4 Bohunice V1 estimation

Table 13 shows the cost breakdown of V1 NPP decommissioning in Slovakia[110]. The ISDC items from 4 to 8 are the main cost drivers of the V1 NPP D&D budget. Items 1, 2, 6, 8 and 11, which can be qualified as "extended" project Management activities, account for about 50% of the budget.

Table 13: Bohunice V1 NPP D&D cost breakdown

ISDC Level 1 for V1 NPP Decommissioning		Cost share[111]
1	PRE-DECOMMISSIONING ACTIONS	5%
2	FACILITY SHUTDOWN ACTIVITIES	3%
4	DISMANTLING ACTIVITIES WITHIN THE CONTROLLED AREA	13%
5	WASTE PROCESSING STORAGE AND DISPOSAL	25%
6	SITE SECURITY SURVEILLANCE AND MAINTENANCE	18%
7	CONVENTIONAL DISMANTLING DEMOLITION AND SITE RESTORATION	12%
8	PROJECT MANAGEMENT ENGINEERING AND SITE SUPPORT	21%
10	FUEL AND NUCLEAR MATERIALS	2%
11	MISCELLANEOUS EXPENDITURE	2%
TOTAL		**100%**

On a more qualitative analysis[112] of the Bohunice D&D, it can be argued that D&D budget is driven mainly by[113]:

- activity dependent costs (amount of waste, level of contamination, unit prices);
- period dependent costs (duration of implementation, labour cost);
- collateral costs (level of preparedness for decommissioning);
- contingencies, uncertainties (level of the know-how, experience, statistic factors).

6.5 EDF estimation

The typical D&D breakdown for EDF's NPPs is given in the table below. As for the other cases presented above, the "extended" project management part of the budget is valued at about 46% (summing PM including engineering, shutdown preparation and site exploitation) whereas the "practical D&D" works may be valued at 44% (summing dismantling in controlled area, dismantling in non-controlled area, building and site decontamination and demolition). The onsite waste management cost excluding the final disposal yields almost 10%.

[110] Data retrieved from (Kukan 2017).
[111] Simple total of all items may not be 100% due to rounding.
[112] NucAdvisor experts' point of view.
[113] It is worth to consider such costs categorisation, because it highlights the period dependent costs, impacted by the particularly long duration of the D&D projects in Europe.

Table 14: EDF's typical NPPs D&D cost breakdown[114]

EDF's D&D activities	Cost share
PM including engineering	22%
Shutdown preparation	9%
Dismantling in controlled area	19%
Dismantling in non-controlled area	11%
Building and site decontamination	8%
Demolition	6%
Onsite waste management	10%
Site exploitation	15%
TOTAL	**100%**

6.6 Quantification of ISDC segments

Owner costs (or "extended" project management activities) represent a very large share of the D&D costs. The precise definition of project management activities is often variable from one country to another. Some of them include in this item strictly the project management team (e.g. Switzerland). Others include also more extensively engineering as well as site support under this item, counting from the definitive shutdown of the plant (US) or from the start of D&D operations after the 4-year transition phase (EDF[115]).

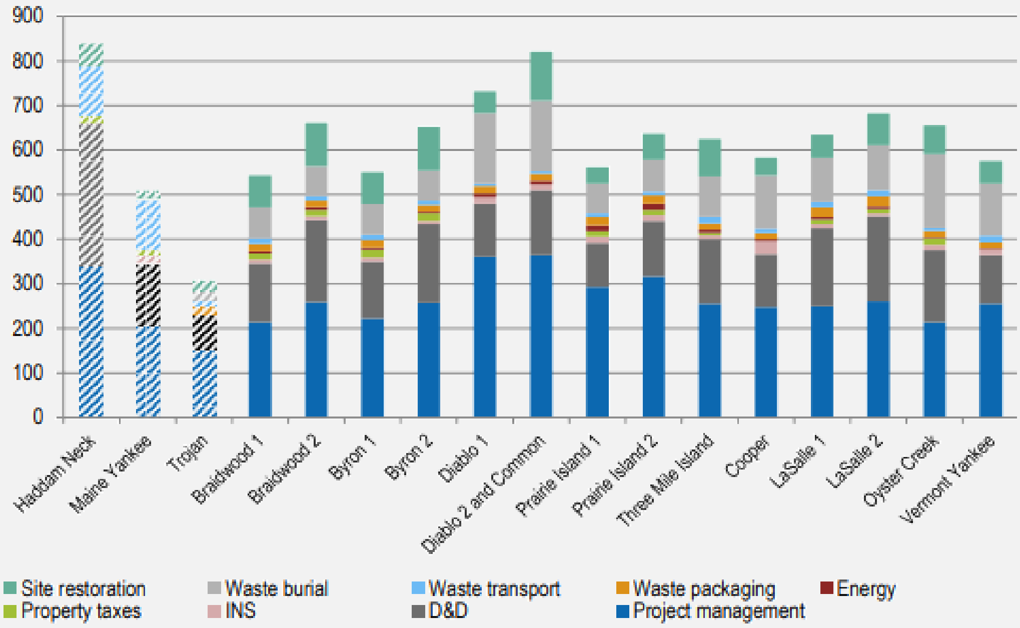
From the ISDC point of view, project management activities depend on time: once the project has started, the definition of project management (ISDC item 8) is extensive whereas project management activities before the D&D operations really start are accounted for in ISDC item 1 "Pre-decommissioning actions" or in ISDC item 2 "Facility shutdown activities". These multiple definitions help to explain, at least in part, the large differences in the project management activity quotes.

From an industrial point of view, however, it might be preferable to consider under the project management item all actions under direct supervision of the utility, whether or not the decommissioning operations have actually started. This "extended" project management segment can be defined as the activities including engineering, environmental assessments and other owner costs (own personnel salaries and wages, site O&M services during D&D, supporting ancillary services, surveillance, miscellaneous fees, taxes and consumables, etc.).

[114] Source: NucAdvisor estimations.
[115] The immediate post-shutdown period costs are accounted for in the operations budgets.

Scale of project management in decommissioning programmes:

The figure below[116] illustrates the share that project management activities (engineering, radioprotection, security, procurements, etc.) represent in the D&D costs in the US. While the project management part of the programmes in the USA represents almost 50% of the decommissioning budgets, the "practical" D&D activities are a small fraction, typically 20%-25%, and are of about the same order of magnitude as the "waste" item.



In the EU, some large utilities like EDF and E-ON have developed in-house project management and engineering capabilities. Devoted to their own projects, these competencies are also marketed more widely, for instance in competition with large civil engineering companies, also interested in D&D project management. For smaller utilities however, the question of innovative industrial organizations remains open and the experience feedback of the new USA experiences (see Appendix 5) will be interesting although the differences in the nuclear legal and licensing environment between the two continents and the risks involved may obstruct such solutions in the EU.

Table 15 summarises the different decommissioning cost estimations and shows the overall quantification of the D&D market in the EU. The EUR 1.8 bn per year market as it stands today as a reference is used along with the EUR 3 bn per year at the peak in 2045 market as established in Chapter 4.

[116] The decommissioning cost estimation data reported per unit in USD_{2013} million are based on the work breakdown structure for data provided by two different companies: TLG Inc and Energy Solutions. The figure is taken from (NEA 2016). While Haddam Neck, Maine Yankee and Trojan are completed projects, the others represent the estimated cost breakdown.

Referring to these two values, “extended” project management activities (including ISDC items 1, 2, 6, 8 and 11) would amount to EUR 800 million per year and EUR 1.5 bn per year.

The remaining segments are shared among many companies, leading to a rather competitive and fragmented D&D market:

- more mundane D&D tasks (ISDC 7) with almost 10% of the budget today amount to EUR 180 million per year and EUR 300 million per year at its peak;
- relatively more specialised high-skill D&D tasks (ISDC 4) with a 25% of the budget would currently yield EUR 450 million and EUR 800 million per year;
- the market for on-site waste management activities (ISDC 5) would amount from EUR 300 million to EUR 500 million per year.

6.7 Conclusions

The budget devoted to “extended” project management activities (almost 50%) is captured by few national state-owned or privately-owned Tier 1 companies which manage the decommissioning programmes in the states where they are based. Hence, this segment is usually difficult to access for foreign companies, except for Member States which have a limited domestic nuclear industry and need foreign engineering expertise.

As concerns other market segments:

- the D&D activities in the non-controlled area (about 10% of the budgets) are generally work-force intensive, very competitive and typically reserved for domestic and local companies which are able to mobilise the necessary personnel and the site works tools (e.g. cranes, trucks);
- the D&D activities in the controlled area (about 25% of the budget) are less competitive and mostly reserved for a few specialised companies which are able to use remote controlled manipulators and high tech tools;
- the on-site waste management activities (about 15% of the budget) are relatively competitive and reserved to domestic companies mastering local waste management regulations. A few international specialised companies providing specific waste treatment processes may also compete in this segment.

For all the segments, the contracts with a value in excess of EUR 10 million are rare (as can be seen in Chapter 5) and they concern essentially new build constructions and very specialised tasks like primary circuit component segmentation, handling and packaging and special waste treatment services such as incineration and melting. Most of the contracts are below EUR 5 million or even far less in the engineering services, as shown in the Italian and Slovakian examples, leading to a very fragmented market. All the contracts extend generally over several years, leading to relatively low annual revenues. One practical consequence of this is that a large majority of the suppliers and subcontractors in D&D programmes remain domestic companies in France, Germany and UK, and to a lesser extent in Italy. On the contrary, there is a greater amount of international presence in Bohunice V1 D&D programme in Slovakia.

Table 15: Different D&D cost estimation arranged according to the ISDC with average range and quantification of market segments

<table>
<tr><th colspan="2">ISDC items</th><th>Ringhals</th><th>Gösgen</th><th>Bohunice V1[117]</th><th>USA (TLG)[1173]</th><th>EDF</th><th>Range</th><th>Industrial Landscape</th><th>EUR 1.8 bn/year</th><th>EUR 3.0 bn/year</th></tr>
<tr><td>8</td><td>Project management, engineering and site support</td><td>18%</td><td rowspan="4">72%</td><td>21%</td><td>28%</td><td>22%</td><td rowspan="5">33% to 75%
~50%</td><td rowspan="5">Owners costs are the budget lion's share, with few large companies per Member State: Slovakia (JAVYS), Italy (SOGIN), UK (NDA & EDF Energy) France (EDF, CEA, Areva), Germany (4 Utilities). These companies are supported by a number of specialized companies (engineering, project management & licensing, O&M, site surveillance, works surveillance or preparatory actions like decontamination, new constructions, etc.) often the companies already working with the owners during operations.</td><td rowspan="5">0.9</td><td rowspan="5">1.5</td></tr>
<tr><td>1</td><td>Pre-decommissioning actions</td><td>3%</td><td>5%</td><td>2%</td><td rowspan="2">9%</td></tr>
<tr><td>2</td><td>Facility shutdown activities</td><td>3%</td><td>3%</td><td>3%</td></tr>
<tr><td>6</td><td>Site security, surveillance and maintenance</td><td>8%</td><td>18%</td><td>18%</td><td>15%</td></tr>
<tr><td>11</td><td>Miscellaneous expenditures</td><td>2%</td><td>3%</td><td>2%</td><td>3%</td><td>-</td></tr>
<tr><td>4</td><td>Dismantling activities within the controlled area</td><td>36%</td><td>10%</td><td>13%</td><td>15%</td><td>29%</td><td rowspan="2">15% to 56%
~35%</td><td>Highly skilled technological companies for critical works (decontamination, activated or contaminated equipment removal): Areva, Westinghouse, Siempelkamp, EWN, etc.</td><td rowspan="2">0.6</td><td rowspan="2">1.1</td></tr>
<tr><td>7</td><td>Conventional dismantling, demolition and site restoration</td><td>20%</td><td>5%</td><td>12%</td><td>9%</td><td>14%</td><td>More mundane craft intensive works (disassembly, handling, logistic and demolition): generally performed by domestic companies which are able to mobilize the manpower and heavy equipment.</td></tr>
<tr><td>5</td><td>Waste processing, storage and disposal</td><td>10%</td><td>10%</td><td>25%</td><td>23%</td><td>10%</td><td rowspan="2">10% to 27%
~15%</td><td rowspan="2">Specialised companies (radioprotection, waste characterisation, onsite or offsite treatment, decontamination and cask supply and packaging).</td><td rowspan="2">0.3</td><td rowspan="2">0.5</td></tr>
<tr><td>10</td><td>Fuel & nuclear material</td><td>-</td><td>-</td><td>2%</td><td>-</td><td>-</td></tr>
</table>

[117] ISDC item 5 includes waste disposal cost whereas other approaches do not take into account the majority of the waste management cost.

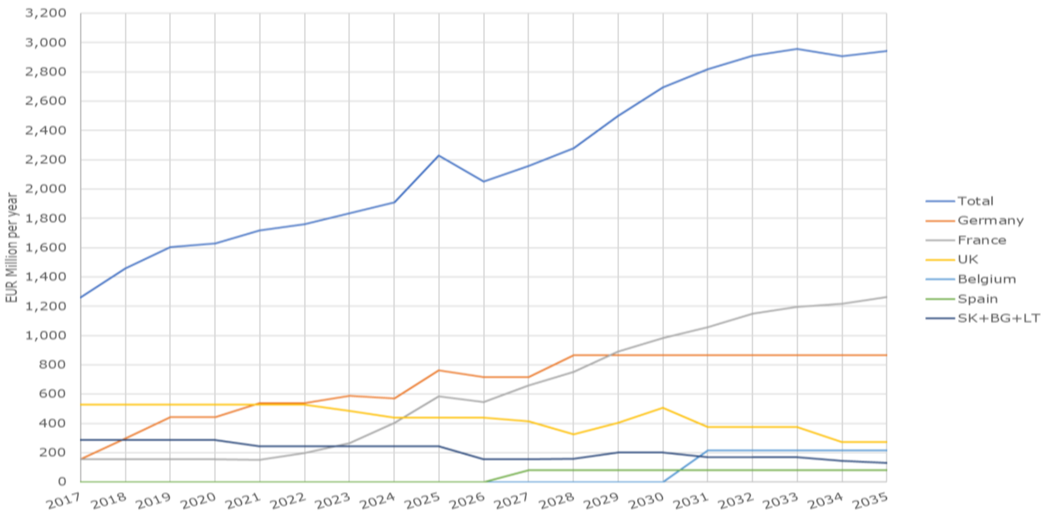
7. Understanding the market drivers

This sections portraits the main features of the determinants of the D&D market in Europe. In this respect, the reported analysis contributes to the understanding on the possible actions to be undertaken to foster a fast-growing, open and safe D&D in the EU.

7.1 NPPs lifetime extension

The lifetime of the NPPs is a first obvious main market driver. For instance, if the French lifetime of the PWR is set to 40 years instead of 50[118], the overall European NPPs D&D market growth rate (CAGR) over the 2020-2035 period will be considerably higher (3.5% instead of 2.1%), and reaching the EUR 3.0 bn per year peak 10 years earlier.

Figure 17: D&D market growth with 40 years lifetime for NPPs in France



Nevertheless, there is an overall trend in nuclear countries towards NPPs lifetime extension over 40 years. Lifetime extension up to 50 years is the set goal in Sweden or in the UK for the newest plants. Furthermore, EDF Energy in the UK expressed its aim to extend the lifetime of Sizewell B reactor (currently the only PWR in the UK) for 20 years, which would yield 60 years in total. In the US, some plants operators are even preparing a "Second License Renewal" filing in order to extend the lifetime to 80 years, while going beyond 40 years remains an open option in Japan.

Indeed, lifetime extension of existing NPPs is the most cost-effective way to produce electricity: the installations are largely amortised, and their O&M costs remain competitive despite the appropriate safety updates investments. Consequently, anticipated plant shutdowns as Germany experienced in 2011

[118] In the analytical model above, a 50 year lifetime has been assumed for French NPPs because EDF's annual report (EDF 2016) considers a 50 years amortization period for these plants, without prejudging the outcomes of the coming 40 years Safety Reviews.

seem unlikely in other countries. Conversely, future additional life extensions may lead to flattening the market growth.

7.2 D&D programme duration

The comparison of the US and the European D&D projects reveals that the NPPs D&D projects duration in Europe is generally longer than in the US (see Figure 18, which compares US and Germany).

According to the decommissioning cost analysis for Oconee Nuclear Station by TLG[119], nearly 50% of the decommissioning cost is deemed "period (time) dependent", that is proportional to the project duration. These "period-dependent costs" include:

- insurances;
- property taxes;
- heavy equipment rental;
- plant energy budget;
- corporate A&G (administrative and general expenses);
- site O&M (operations & maintenance);
- security and utility staff cost.

The "period-dependent costs" lead the US utilities to accelerate the decommissioning programmes, which can be backed by "responsive" regulations, availability of LLW transportation and disposal solutions and human resources policies allowing to the staff levels to be adapted quickly to the needs.

Conversely, the longer project duration in the EU can be explained by:

- different regulatory regimes in place;
- length of the post-shutdown phase (before D&D starts);
- lack of waste disposal solutions.

Figure 18: Comparison of completed/ongoing D&D projects in Germany and USA[120]

[119] (TLG 2013)
[120] NucAdvisor analysis of public documents relative to the different projects.

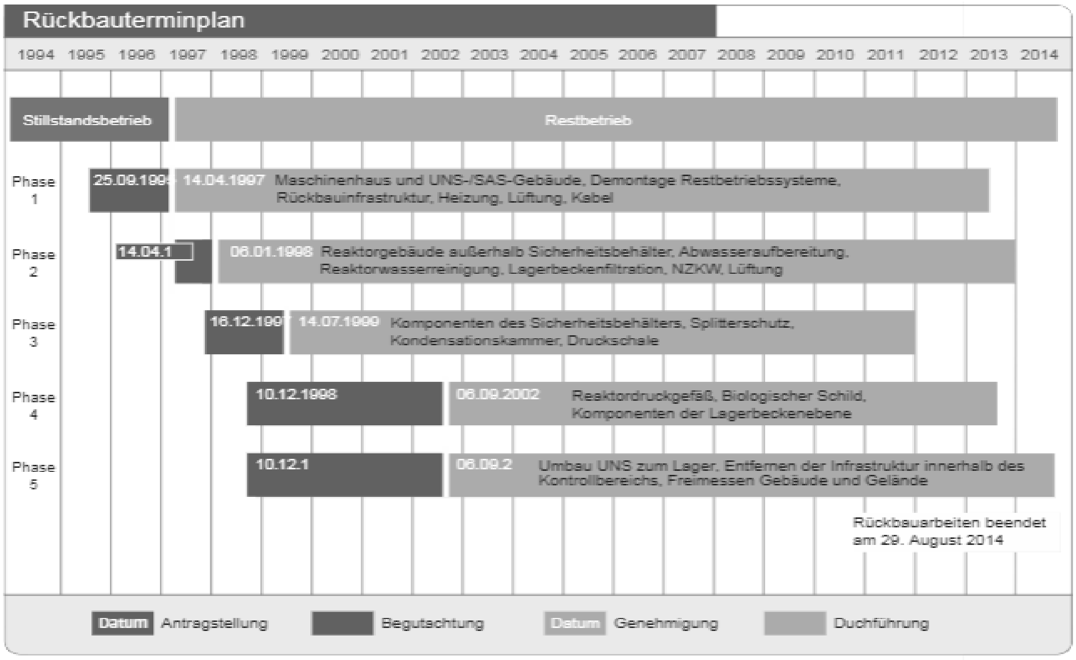
7.3 Regulatory impact

The current regulatory framework for D&D activities in Europe is the most advanced in the world and guarantees the highest standards of safety, security and radiological protection.

In this section, Germany is taken as a first reference because its large NPP D&D experience is one of the most extensive over Europe. In this country, regional rules and authorities play a leading role in the licensing process, even if national rules and authorities set the general licensing frame. The experts chartered by the various regional authorities are present at each step of a 4- or 5-step licensing process (described in Figure 19 for the Würgassen NPP[121]).

This complexity of this process has some direct impact on scheduling, may reduce the possible learning effects and the possibility of standardising the projects (engineering works, D&D processes, etc.). Up to present, each project in Germany may be considered at a larger extent a "one-of-a-kind project", with a specific industrial organisation.

Figure 19: The schedule of the D&D of the Würgassen NPP[122]



Legend: «Antragsstellung» means File submission to Authorities, «Begutachtung» means Authorities examination, «Genehmigung» is the date when the authorization is granted, «Durchführung» is the realization of the corresponding decommissioning step.

The Stade NPP D&D programme had to deal with the same type of licensing steps as Würgassen.**Error! Not a valid bookmark self-reference.** illustrates that the licensing process for the Stade NPP, compared to Maine Yankee (US), does not favour a rapid project pace and induces delays and additional burden.

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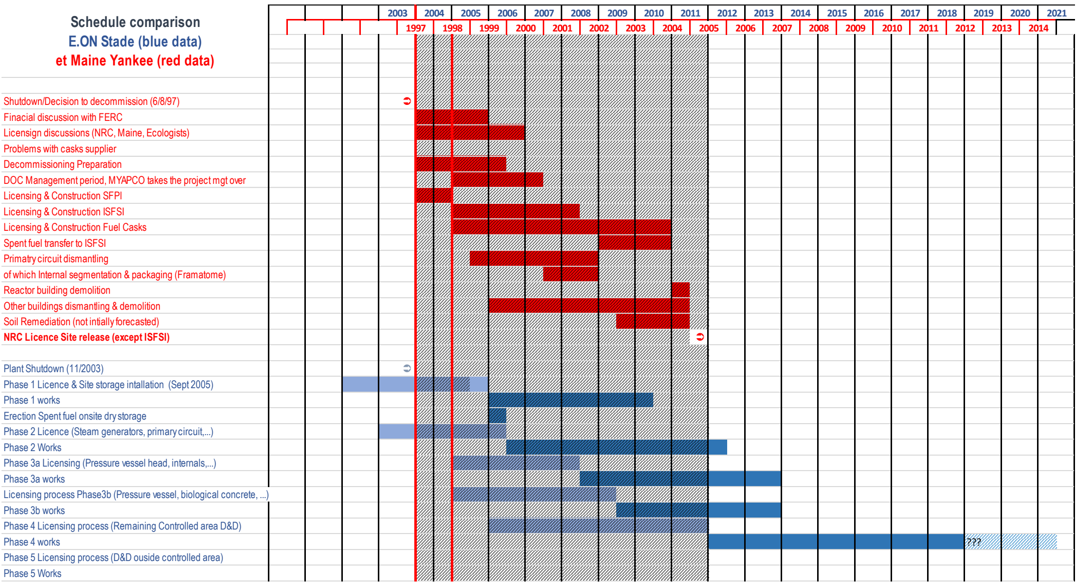
[121] Würgassen project was terminated in 2014, the buildings not being demolished ("brownfield status").
[122] Source: EON.

Given the large share that time-dependent costs represent in the D&D projects, overall costs are also higher.

Figure 20: Comparison of Stade and Maine Yankee D&D schedules[123]



In the EU, the regulatory regime applicable in the EU to the installations being decommissioned is highly Member State-specific. It represents a key driver of the D&D costs for the utilities, a possible source of uncertainty for contractors and may contribute to foster a "wait and see" trend on the D&D market.

<u>FURTHER DETAILS ON THE REGULATORY PROCESS IN GERMANY</u>

<u>Licensing process for the Stade NPP decommissioning</u>

Phase 1 with public consultation (11/11/2003):

- 1st authorization granted on 7/9/2005 for Plant part no longer needed for operations during decommissioning, preparation for next phases, and construction of necessary infrastructures (Interim storage for LLW/MLW, etc.).

Phase 2:

- 2nd authorization granted on 15/2/2006 for Removal of large components from the Reactor Building;
- authorization on 7/3/2008 for packaging and limited storage of waste coming from Würgassen NPP.

Phase 3:

- authorization #3A on 14/5/2008: Dismantling of reactor pressure vessel head, of reactor pressure vessel internals, of concrete around the pressure vessel;
- authorization # 3B on 14/5/2009 for removal and dismantling of

[123] Source: NucAdvisor analysis of Stade (E.ON) and Maine Yankee (EPRI) publications.

the Reactor pressure vessel.

Phase 4:

- authorization on 2/7/2010 stating that an environmental assessment is not mandatory.
- 4th authorization on 4/2/2011 for dismantling of the remaining contaminated equipment, with definition of the process for clearing the plant from the nuclear licensing regime (10 μSv/a – Concept[124]).

For the time being, phase 4 is not yet complete. Phase 5 (demolition of the buildings) is far from having been started.

Each of the above authorizations granted by the competent regional authority[125] calls for prior writing of a licensing file and lengthy discussions with the experts chartered by the authority.

FURTHER DETAILS ON THE REGULATORY PROCESS IN US

Differently to the German situation, the licensing process in the US is a 2-step process, with two main documents submitted to a national Authority (US NRC): the PSDAR and the LTP, allowing for works optimization (like overlapping tasks to shorten the schedule). This process is characterized by stable national rules within the limits of which a major responsibility falls on the utility or the owner, notwithstanding a close surveillance by the Safety Authority.

D&D licensing process in the USA

Decommissioning funds

Each nuclear power plant licensee must report to the NRC every two years the status of its decommissioning funding for each reactor or share of a reactor that it owns. The NRC staff performs an independent analysis of each of these reports to determine whether licensees are providing reasonable "decommissioning funding assurance" for radiological decommissioning of the reactor at the permanent termination of operation.

Phases of decommissioning

The requirements for power reactor decommissioning activities may be divided into three phases: (1) initial activities; (2) major decommissioning and storage; and (3) license termination activities.

1) Initial activities

When a nuclear power plant licensee shuts down the plant permanently, it must submit a written certification of permanent cessation of operations to the NRC within 30 days. When radioactive nuclear fuel is permanently removed from the reactor vessel, the operator must submit another written certification to the NRC, surrendering its authority to operate the reactor or load fuel into the reactor vessel. This eliminates the obligation to adhere to certain

[124] The 10 μSv/a – Concept for clearing building and soils is particularly constraining as compared to the US situation (see next box and Appendix 6) and could lead to very big additional decontamination efforts and/or large amounts of concrete and soil declared as "radioactive waste", raising the question of the final LLW storage capacity

[125] Niedersächsisches Ministerium für Umwelt und Klimaschutz

requirements needed only during reactor operation.
Within two years after submitting the certification of permanent closure, the licensee must submit a Post-Shutdown Decommissioning Activities Report (PSDAR) to the NRC. This report provides a description of the planned decommissioning activities, a schedule and an estimate of the expected costs. The report must discuss the reasons for concluding that environmental impacts associated with the site-specific decommissioning activities have already been addressed in previous environmental analyses. Otherwise, the licensee must request a license amendment for approval of the activities and submit to the NRC details on the additional impacts of decommissioning on the environment.
After receiving the report, the NRC publishes a notice of receipt in the Federal Register, makes the report available for public review and comment, and holds a public meeting in the vicinity of the plant to discuss the licensee's intentions.

2) Major decommissioning activities
Ninety days after the NRC receives the PSDAR, the owner can begin major decommissioning activities without specific NRC approval. These include permanent removal of such major components as the reactor vessel, steam generators, large piping systems, pumps, and valves. However, decommissioning activities conducted without specific prior NRC approval must not:

- prevent release of the site for possible unrestricted use,
- result in there being no reasonable assurance that adequate funds will be available for decommissioning,
- cause any significant environmental impact not previously reviewed.

If any decommissioning activity does not meet these terms, the licensee is required to submit a license amendment request, which would provide an opportunity for a public hearing.

3) License termination activities
The operator is required to submit a license termination plan within two years of the expected license termination. The plan addresses each of the following: site characterization, remaining site dismantlement activities, plans for site remediation, detailed plans for final radiation surveys for release of the site, updated estimates of remaining decommissioning costs, and a supplement to the environmental report describing any new information or significant environmental changes associated with the final clean-up. Most plans envision releasing the site to the public for unrestricted use, meaning any residual radiation would be below NRC's limits of 25 millirem (250 μSv) annual exposure and there would be no further regulatory controls by the NRC. Any plan proposing release of a site for restricted use must describe the site's end use, public consultation, institutional controls, and financial assurance needed to comply with the requirements for license termination for restricted release.
The license termination report requires NRC approval of a license amendment. Before approval can be given, an opportunity for hearing is published and a public meeting is held near the plant site. The NRC uses a standard review plan (NUREG-1700, "Standard Review Plan for Evaluating Nuclear Power Reactor License Termination Plans") to ensure high quality and uniformity of the license termination plan reviews. If the remaining dismantlement has been performed in accordance with the approved LTP and the NRC's final survey demonstrates that the facility and site are suitable for release, the NRC issues a letter terminating the operating license.

FURTHER DETAILS ON OTHER REGULATORY PROCESS IN FRANCE

In formal terms, the licensing process in France resembles the US process: a "Dossier de DEM", a PSDAR-like document, and a final site release, to be submitted to a single authority, with the possibility of a learning effect for subsequent projects. As in the US, the operator continues to bear major responsibilities, including the proposal for the final site status. Unlike the US practice, but like in Germany, irreversible works cannot actually begin before the decommissioning authorisation has been granted (3 to 5 years after the PSDAR-like document has been submitted), and many safety files will need to be updated during the project, under the close scrutiny of the competent authority. The situation is similar for the other segments of the D&D market (fuel cycle and research installations).

7.4 Post-shutdown phase

The post-shutdown phase is intended to adapt the plant to the technical needs of the D&D project. It also offers a way of managing the social aspects of plant shutdowns, that is the future of the plant personnel and of the region where the plant is located.

This is a daunting problem facing utilities and owners. The shutdown of the plant may engender social difficulties, both internally within the utility (corporate and local level) and also on the local employment market. These social aspects have major impacts on the D&D costs, the industrial organisation of the projects and their pace.

For utilities like EDF, owning large nuclear plant fleets and multi-unit sites, it is slightly easier to redeploy the staff after a shutdown. This is also the case in countries with very flexible HR policies like in the US[126], where the social consequences of the shutdown can be mitigated at the least cost for the utility. In the majority of the European countries however, where nuclear fleets of each utility are limited to a few units, most often on single remote sites where the utilities are the main local employer and tax contributors, such mitigation is hardly possible. The problem is similar for fuel cycle and research installations.

The consequence is that project duration in Europe may be driven, at least in the first years, by the necessity to cope with changing human resource needs, eventually involving retirement and social plans (which may in same cases also be detrimental to project optimisation, as experienced in the Greifswald case in Germany).

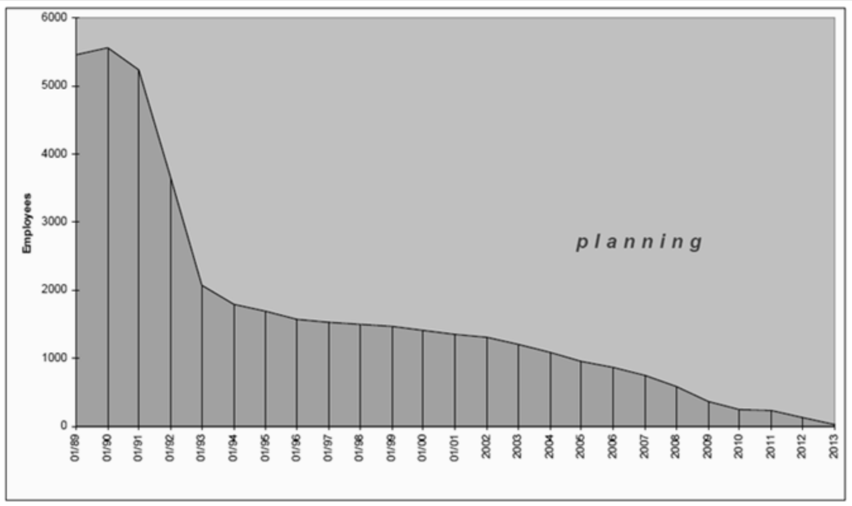
[126] In the US, social effects of a plant closure on plant personnel and in the region where the plant is located are also high. But, for instance, the owner headcount personnel for Trojan NPP was reduced within one year (1993), from 984 to 217 during the post-shutdown phase. Such a Human Resources policy is hardly conceivable in deprived regions of the EU and without very high costs.

The Greifswald case

In 1990, just after the German reunification, the operating VVER units Greifswald 1-4 were shut down. The commissioning of Greifswald unit 5 as well as the construction works on units 6 to 8 was also stopped. In 1991, there were some 5000 employees on the site, plus 1000 in the Berlin, Rossendorf and Leipzig offices. About 8000 other members of staff, who were employed for the construction of units 6-8, had already left the site.

Facing the social problem in this deprived region of Germany, the new owner, Energie Werke Nord (EWN, 100% State owned) decided to perform the D&D with its own operation personnel. But operating a plant is very different from dismantling it. EWN tested numerous different D&D processes and could not find an optimised way of carrying through the project. The headcount remained constantly far higher than was actually necessary as shown in Figure 21, which explains a considerable share of the huge Greifswald D&D costs.

Figure 21: Greifswald headcount evolution[127]



This is not an isolated case. For Stade (Germany), as well as in the Swiss nuclear estimation, the D&D costs include a very high owner personnel headcount for the entire duration of the D&D projects. For instance, 33% of the total D&D costs are owner personnel salaries in the Gösgen NPP D&D cost evaluation KS11[107].

Social aspects of plant shutdowns should be hence considered as major cost and schedule driver for D&D projects in Europe. Indeed, a plant shutdown often leads to social consequences for the plant personnel and for the region where the plant is located. It is generally impossible to get ready for downsizing before shutdown, in particular for safety reasons. Hence, the shutdown period is used for personnel adaptation and can last up to five years.

[127] (EWN 2011).

Nevertheless, owners are usually encouraged to confirm their own personnel for the D&D activities whenever possible to avoid a loss of site-specific knowledge[128].

7.5 Waste management strategies

Even if waste disposal costs are generally handled separately from D&D costs, waste management strategies have a strong impact on the D&D costs and schedules, on the industrial organisation of the projects and on the decisions to proceed by the utilities.

It is very risky to enter decommissioning projects without having a clear view of the regulations, of decontamination strategies and of waste disposal routes to be applied. It is therefore of the utmost importance to know before entering a decommissioning project what the decontamination strategy will be:

- which criteria will be considered for the clearance of the buildings and materials?
- will the selected processes be adequate or not for obtaining the desired results?
- what is the volume of waste going to be and where can it be stored and disposed of?

These parameters will influence characterisation, packaging, onsite interim storage, and ultimately, costs, schedule and evaluation of the risks. Strategies and regulations in this domain remain largely country-specific for the time being.

7.5.1 Spent fuel and HLW strategy

In most cases world-wide, there is no solution available now for the final disposal of long-life or high-level radioactive waste. Final disposal projects are all ongoing. In many EU countries, it will be necessary to set up interim storage solutions, for instance by isolating the fuel storage pool from the remainder of the plant to be decommissioned or building an on-site or centralised interim storage facility (ISF). These heavy licensing costs for construction and operation costs and schedules are part of the D&D burden for the European utilities[129].

The Obrigheim case[130]

Interim dry storage for spent fuel casks was planned and an application for a licence according to paragraph 6 AtG (German Atomic law) was filed with the BfS on 22 April 2005. Up to 2013, no construction permit was issued at the Obrigheim site. An alternative by taking the fuel elements to the Neckarwestheim interim storage facility was hence imagined. The application for the modification to the storage licence was submitted to the BfS on 10 December 2013. The case resulted in several authorisation procedures and

[128] It can be argued that this owner preference for people already working on the site can result in a possible limitation of competition when it comes to select contractors for D&D activities. This has allowed many US utilities to claim for liquidated damages related to the construction and operation of the ISF and win cases against the DOE for not taking delivery of spent fuels.

[129] This is not the situation in the US where the takeover of the HLW has been, since 1997, a legal Governmental responsibility (Nuclear Waste Policy Act 1982).

[130] (Bredberg 2014).

delays in the Obrigheim project, which were to increase the costs for the utility.

7.5.2 VLLW - LLW strategy

Disposal of very low level-, low level- or intermediate level- waste (VLLW, LLW, ILW) is subject to different policies depending on the various Member States. For example, in France, VLLW, LLW and ILW short-life waste is disposed of in surface repositories, while in Germany or Switzerland the choice was made to dispose of any radiological waste in deep geological repositories independently of its activity. As deep geological repository disposal is far more expensive than surface disposal (repository construction, operation and packaging costs), these countries tend to implement an extensive but very costly use of the "clearance process" (characterisation, decontamination, measurement, re-decontamination when appropriate), allowing most of the VLLW to be cleared for unconditional public release. As a consequence, amounts of waste administratively declared as radioactive are may differ from one state to another (e.g. reduced in Germany and Switzerland as compared to France), but at the expense of:

- typically, more than doubling the onsite waste management costs and the other offsite clearing or volume reduction process costs (e.g. melting)[131];
- longer onsite waste management schedule;
- and other problems to be solved[132].

In the same way as for licensing, applicable rules and regulations for characterising and clearing waste, for waste acceptation at disposal sites as well as for transportation also vary largely across Europe.

7.5.3 Site release criteria

There are major differences between the US and Europe relative to site "clearance" criteria, i.e. radiological criteria applying to the decommissioned site for subsequent use.

According to the USNRC rule (10CFR 20.1402), "*a site is considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a TEDE*[133] *to an average member of the critical group that does not exceed 25 mrem (0.25 mSv, or 250 μSv) per year including that from groundwater sources of drinking water, and if residual radioactivity has been reduced to levels that are as low as reasonably achievable (ALARA)*".

Even if these criteria may occasionally be strengthened after discussion with the US Environmental Protection Agency or local Authorities[134], they are far less constraining than the criteria typically used in Europe, based on the 10 μSv/year rule (RP113, RP122). Application of such criteria in Europe leads to a potentially huge increase in VLLW radioactive waste produced (concrete and

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[131] Proprietary analysis.
[132] For example, conventional disposal sites refused recently to accept "cleared" wastes originating from the Stade NPP due to public reluctance.
[133] Total Effective Dose Equivalent: The sum of the effective dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures).
[134] As was the case for Maine Yankee.

soils) to be processed and disposed (see Appendix 6 for more details). Even assuming that disposal capacities are available, which may not always be the case everywhere in Europe, this is also detrimental to the costs and schedule of the projects. This might contribute to explaining why large NPP decommissioned sites in the US usually reach “greenfield” status within what is typically a 10-year period whereas this is not the yet the case in Europe.

Waste strategies applicable in Europe to the D&D wastes as well as clearance rules for equipment and sites are highly country-specific. They are a key driver behind D&D costs and schedules for the utilities and owners and a source of risks for contractors. The waste-related risks are not conducive to a rapid pace of D&D projects in Europe.

7.6 Main barriers to entry

The barriers to entry on the market are summarised and sorted according to the ISDC. In Table 16, the intensity of the barrier to entry on the market is rated high (highlighted in red), moderate (highlighted in orange) or low (highlighted in green). Barriers to entry are generally high for non-domestic suppliers on the most attractive segments of the market, and moderate for domestic candidates.

The largest share of each national D&D budget is reserved for a few major national companies like the German utilities, EDF, Areva, NDA, SOGIN and JAVYS. These companies may be tempted to develop foreign business, but risks are high because they would have to deal with numerous local, technical, regulatory, financial, social, and often political problems. The only practical way to proceed is therefore to team up with a local company (assuming that teaming up opportunities exist).

International competition already exists for dismantling activities within the controlled area but is practically reserved for existing nuclear companies, relying on a proven record in mastering delicate operations.

Competition may take place:

- for the more mundane skill-intensive activities, but is practically reserved to domestic companies able to mobilise the manpower and the site works tools needed;
- to a lesser extent, for niche activities in the waste processing, storage and disposal activities where knowledge of local regulations and the mastery of logistics is essential.

The above applies mainly to Western Europe, encompassing the biggest D&D markets. There are certain specific considerations applicable to the Eastern countries market. According to the PINC, adding the NPPs D&D budgets of Bulgaria, Czech Republic, Hungary, Lithuania, Romania, Slovakia and Slovenia account for about EUR 11.0 bn, representing 9% of the European NPP D&D budget. A characteristic of this market is the duration of the projects. Ignalina D&D for example, extends from 2000 to 2038, Bohunice from 2003 to 2025, Kozloduy from 2003 to 2030, in the nominal case, without counting any possible delays due for instance to future funding gaps[135]. This leads to

[135] Despite EU financing support

relatively modest yearly expenses (between EUR 45 and 112 million for Ignalina and between EUR 30 and 50 million for Kozloduy). International competition is generally keener than in western countries due to insufficient local resources, but also results in the fragmentation of the market[136].

Table 16 : Main barriers to entry in the D&D market

ISDC items		Industrial Landscape	Possible new entrant	Main barrier to entry
8	Project management, engineering and site support	Owners costs are the budget lion's share, with few large companies per Member State: Slovakia (JAVYS), Italy (SOGIN), UK (NDA & EDF Energy) France (EDF, CEA, Areva), Germany (4 Utilities). These companies are supported by a number of specialized companies (engineering, project management & licensing, O&M, site surveillance, works surveillance or preparatory actions like decontamination, new constructions) often the companies already working with the owners during operations.	Large foreign companies having D&D experience, i.e. EON, EnBW, EDF, SOGIN, JAVYS, etc. Waste specialist similar to the US "Zion model"	-Expertise of the local regulations, mastering the language - Knowledge of the installation (use operator personnel) - Readiness to take lump sum contractual risks and to settle local social questions related to plant shutdown - Knowledge of the domestic industrial sector - Possible only for a contractor owning a domestic VLLW/LLW disposal - Adequate public acceptance and local transportation regulations needed
1	Pre-decommissioning actions			
2	Facility shutdown activities			
6	Site security, surveillance and maintenance		Any domestic services supplier	- Need of local manpower
			Maintenance: existing O&M suppliers	- Knowledge of the plant is mandatory
11	Miscellaneous expenditures		-	-
4	Dismantling activities within the controlled area	Highly skilled technological companies for critical works (decontamination, activated or contaminated equipment removal): Areva, Westinghouse, Siempelkamp, EWN, etc.	International competition already exists	- Mastering adequate technologies: practically open to only nuclear specialists
7	Conventional dismantling, demolition and site restoration	More mundane skill intensive works (disassembly, handling, logistic and demolition): Generally performed by domestic companies able to mobilize manpower and heavy site works equipment	Civil works, demolition companies	- Need for local manpower and site works heavy tools: practically open only to domestic companies
5	Waste processing, storage and disposal	Specialized companies (radioprotection, waste characterisation, onsite or offsite treatment, decontamination and cask supply and packaging)	Waste treatment specialised companies	- Knowledge of local regulations (waste characterization, clearance, packaging, transportation, etc.) - Master local waste disposal routes (radioactive & conventional) - Need for local manpower and logistics means

[136] See also paragraph 5.5.

In the same way as in the Western countries:

- a major share of the expenses continues to be oriented towards local industry;
- local regulations, local industry and language, different reactor technologies play also a large role, requiring new entrants to team up with local companies.

These characteristics make also the Eastern countries market somewhat difficult, uncertain and risky for foreign companies.

8. Conclusion and proposal for measures

Some conclusions can be drawn from the analyses carried over.

- D&D for nuclear power plants in Europe is a mastered activity. Companies with the necessary expertise, competences and technology exist. Processes, even though they can be streamlined and, to a lesser extent, standardised, have been developed.
- The industrial D&D landscape extends from large international companies to local domestic small and medium enterprises and from high-level technicians to low-skill, manpower-intensive contractors. Various industrial organizations can be observed but a predominant role (and corresponding budget) is often kept for the personnel of the utilities/operators/owners in charge of the programme.
- The D&D market is expected to grow significantly in the long term. The total yearly expenditure for D&D activities for existing NPPs may still remain somewhat contained up to 2035 (up to EUR 2.2 billion per year), but this expenditure should increase more emphatically afterwards to peak at about EUR 3.0 billion per year in 2045.
- D&D market characteristics lead to a handful of large companies capturing a dominant market share of the tier-one contracts across Europe (characterised by highly technical activities). These companies (and their often specialized nuclear-market subsidiaries) are progressively building on the experience and references acquired in their original domestic markets.
- The major cost drivers of D&D projects (project duration, regulations, and availability of waste routes and management of human resources) often make the market highly country-specific and exposed to a certain level of uncertainty.
- Small and medium enterprises face fierce competition in the segments in which they operate (in particular activities requiring low-level skills, technology and know-how) and are confronted with high barriers to entry in the other market segments and in foreign markets. In this scenario, a significant exception is given by providers specialised in delivering engineering, licensing, planning and procurement services.

A series of actions as possible enablers of a fast-developing, safe and affordable D&D market in Europe can be identified as a result of this study. Some of these actions are long-term, others are short-term initiatives.

8.1 Long-term actions

It has been shown above that i) the matter of the applicable regulations and ii) the matter of the waste strategy are among the most decisive impediments to the market development, making costs and schedules uncertain. Acting on these two obstacles must continue to be seen as an objective for the long term even if it is a daunting challenge.

8.1.1 Harmonize the D&D applicable regulations in Europe

Applicable regulations (licensing, transports, waste, environment, etc.), codes and standards are significantly different among the EU Member States and contribute to make it difficult for new non-domestic competitors to enter the market.

The following long-term measures could help opening the D&D European market:

- harmonisation of nuclear licensing, transports and environmental regulations for D&D, as well as industrial codes and standards[137], including mutual recognition by regulatory authorities;
- streamlining of design approval and harmonised classification schemes;
- standardisation whereby a common reference could be established between all the actors involved in the licensing of the decommissioning projects.

European regulation harmonisation would be a long-term undertaking. In this respect, WENRA launched an action like this in 2002. Harmonisation is progressing but still has a long way to go (see Appendix 7) before it can be assessed whether the WENRA approach allows D&D projects to reach a faster pace.

8.1.2 Convergent waste management strategies in Europe

VLLW and LLW management is different in each Mamber State, and generally more constraining in Europe than in the US (see chapter 7, and Appendix 6 for more details). As a consequence, VLLW and LLW waste management is deemed a major risk by the utilities and owners, due to the huge potential volumes involved and the uncertainties about the radioactive and conventional disposal routes. Accordingly, utilities and owners may hesitate to go ahead with the building demolition phase, because of:

- the large volumes of waste to be handled and processed onsite;
- the potentially large VLLW volumes thus generated to be disposed of in VLLW disposal facilities (deep geological or surface according to each Member State policy), and whose capacity may be insufficient;
- the even bigger cleared resulting volumes to be disposed of in conventional depositories, which may raise public acceptance concerns.

Better convergence of the VLLW and LLW waste management strategies (waste classification, clearance criteria, clearance processes, disposal routes) should be encouraged in Europe to reach a stable situation, beneficial to the decisions to launch D&D projects and opening more widely international access to D&D domestic markets[138].

8.2 Short-term actions: Support non-domestic and SMEs access to D&D markets

White Papers

Each Member State could be encouraged to prepare a White Paper relative to the D&D programmes in the country. The main items covered by such a document should be the applicable regulations, the waste management system in place and information on the forthcoming D&D projects. White Papers would allow to spread operational knowledge of each national landscape and would allow potential investors to better understand the opportunities given by the market.

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[137] Like waste cask design or acceptance criteria in disposal facilities for instance

[138] WENRA started for waste management the same type of harmonization actions as for regulations (see WENRA Report "Waste and Spent Fuel Storage Safety Reference Levels". April 2014. In the same way as for regulations, it will be a long time before an assessment can be made regarding the extent to which the WENRA approach addresses the utility concerns.

Centres of Excellence

Nuclear industry associations where companies and other stakeholders in the nuclear supply chain can develop common and complementary approaches as well as address common issues are being developed across the EU. Similar organisations can be encouraged as concerns D&D, by means of "Centres of Excellence". In these organisations, several D&D companies (eventually also involving IT partners) would group together to implement specific innovative projects with the aim to foster product or process innovation. Such organisation may also support actively and participate in the European Learning Initiatives for Nuclear Decommissioning and Environmental Remediation (ELINDER).

Increasing transparent and converging procurement processes

Competition would be fostered through a higher level of transparency as concerns future accessible open procurement procedures (e.g. in the case of owners announcing intended future procedures to be launched over the next 12 to 18 months). Similarly, higher harmonisation of the bidding criteria for similar projects would make it easier for companies to enter a specific market (by avoiding the need to deal with Member State or project specific bidding criteria, sometimes requiring particular supplier qualifications).

Framework contracts

Interesting initiatives backed by the use of framework contracts are taken in some procurement approaches such as the DDP ("Decommissioning Delivery Partnership") in the UK for the Sellafield project, and they could be further analysed to test their possible advantages if used on a wider scale. A key advantage of the DDP programme is that it allows work to be started rather quickly, with projects of up to GBP 5.0 million being directly allocated to any one of the framework partners. This could reduce the time it takes to procure work by around 6 months and reduce the bidding burden for SMEs. This is also one of the first examples of public procurement projects that intends to guarantee benefits "for the local community, including jobs, apprenticeships and work for small and medium-sized businesses". Every partner in the framework is actively involved in supporting the community around Sellafield to help develop skills in Cumbria, as "well as building and promoting cooperation amongst small and medium-sized enterprises (SME's) and the local supply chain". Everyone in the "framework" is committed to achieving the best possible socio-economic outcomes in areas such as building skills for young people and ensuring "small to medium sized enterprises also benefit from this major investment in decommissioning the site."

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Appendix 1: Nuclear power plants in the EU[139]

In the table below, the European nuclear power plant are listed. Their status is also indicated. "In decommissioning process" means that their status is somewhere between the submission of the decommissioning licensing file for approval and the end of decommissioning operations. This process can last a very long time, like in the UK, for instance, where the plants are first put in "Care and maintenance" status before the decommissioning operations start 50 years later. Other plants are already partly decommissioned. Only a very few of them are in the "Licence terminated" status (the legal act at the end of the decommissioning), and even less fully dismantled with their site in the "greenfield" status.

Country	Name	Type	Status
Belgium	DOEL-1	PWR	Operational
	DOEL-2	PWR	Operational
	DOEL-3	PWR	Operational
	DOEL-4	PWR	Operational
	TIHANGE-1	PWR	Operational
	TIHANGE-2	PWR	Operational
	TIHANGE-3	PWR	Operational
Bulgaria	KOZLODUY-1	PWR	In decommissioning process
	KOZLODUY-2	PWR	In decommissioning process
	KOZLODUY-3	PWR	In decommissioning process
	KOZLODUY-4	PWR	In decommissioning process
	KOZLODUY-5	PWR	Operational
	KOZLODUY-6	PWR	Operational
Czech Republic	DUKOVANY-1	PWR	Operational
	DUKOVANY-2	PWR	Operational
	DUKOVANY-3	PWR	Operational
	DUKOVANY-4	PWR	Operational
	TEMELIN-1	PWR	Operational
	TEMELIN-2	PWR	Operational
Finland	LOVIISA-1	PWR	Operational
	LOVIISA-2	PWR	Operational
	OLKILUOTO-1	BWR	Operational
	OLKILUOTO-2	BWR	Operational
	OLKILUOTO-3	PWR	Under Construction
France	BELLEVILLE-1	PWR	Operational
	BELLEVILLE-2	PWR	Operational
	BLAYAIS-1	PWR	Operational
	BLAYAIS-2	PWR	Operational
	BLAYAIS-3	PWR	Operational
	BLAYAIS-4	PWR	Operational
	BUGEY-1	GCR	In decommissioning process

139 Source: IAEA PRIS database (consulted in august 2018).

Country	Name	Type	Status
	BUGEY-2	PWR	Operational
	BUGEY-3	PWR	Operational
	BUGEY-4	PWR	Operational
	BUGEY-5	PWR	Operational
	CATTENOM-1	PWR	Operational
	CATTENOM-2	PWR	Operational
	CATTENOM-3	PWR	Operational
	CATTENOM-4	PWR	Operational
	CHINON A-1	GCR	In decommissioning process
	CHINON A-2	GCR	In decommissioning process
	CHINON A-3	GCR	In decommissioning process
	CHINON B-1	PWR	Operational
	CHINON B-2	PWR	Operational
	CHINON B-3	PWR	Operational
	CHINON B-4	PWR	Operational
	CHOOZ B-1	PWR	Operational
	CHOOZ B-2	PWR	Operational
	CHOOZ-A (ARDENNES)	PWR	In decommissioning process
	CIVAUX-1	PWR	Operational
	CIVAUX-2	PWR	Operational
	CRUAS-1	PWR	Operational
	CRUAS-2	PWR	Operational
	CRUAS-3	PWR	Operational
	CRUAS-4	PWR	Operational
	DAMPIERRE-1	PWR	Operational
	DAMPIERRE-2	PWR	Operational
	DAMPIERRE-3	PWR	Operational
	DAMPIERRE-4	PWR	Operational
	EL-4 (MONTS D'ARREE)	HWGCR	License terminated
	FESSENHEIM-1	PWR	Operational
	FESSENHEIM-2	PWR	Operational
	FLAMANVILLE-1	PWR	Operational
	FLAMANVILLE-2	PWR	Operational
	FLAMANVILLE-3	PWR	Under Construction
	G-2 (MARCOULE)	GCR	In decommissioning process
	G-3 (MARCOULE)	GCR	In decommissioning process
	GOLFECH-1	PWR	Operational
	GOLFECH-2	PWR	Operational
	GRAVELINES-1	PWR	Operational
	GRAVELINES-2	PWR	Operational
	GRAVELINES-3	PWR	Operational
	GRAVELINES-4	PWR	Operational
	GRAVELINES-5	PWR	Operational
	GRAVELINES-6	PWR	Operational
	NOGENT-1	PWR	Operational
	NOGENT-2	PWR	Operational
	PALUEL-1	PWR	Operational
	PALUEL-2	PWR	Operational
	PALUEL-3	PWR	Operational

Country	Name	Type	Status
	PALUEL-4	PWR	Operational
	PENLY-1	PWR	Operational
	PENLY-2	PWR	Operational
	PHENIX	FBR	In decommissioning process
	ST. ALBAN-1	PWR	Operational
	ST. ALBAN-2	PWR	Operational
	ST. LAURENT A-1	GCR	In decommissioning process
	ST. LAURENT A-2	GCR	In decommissioning process
	ST. LAURENT B-1	PWR	Operational
	ST. LAURENT B-2	PWR	Operational
	SUPER-PHENIX	FBR	In decommissioning process
	TRICASTIN-1	PWR	Operational
	TRICASTIN-2	PWR	Operational
	TRICASTIN-3	PWR	Operational
	TRICASTIN-4	PWR	Operational
Germany	AVR JUELICH	HTGR	In decommissioning process
	BIBLIS-A	PWR	In decommissioning process
	BIBLIS-B	PWR	In decommissioning process
	BROKDORF	PWR	Operational
	BRUNSBUETTEL	BWR	In decommissioning process
	EMSLAND	PWR	Operational
	GRAFENRHEINFELD	PWR	In decommissioning process
	GREIFSWALD-1	PWR	In decommissioning process
	GREIFSWALD-2	PWR	In decommissioning process
	GREIFSWALD-3	PWR	In decommissioning process
	GREIFSWALD-4	PWR	In decommissioning process
	GREIFSWALD-5	PWR	In decommissioning process
	GROHNDE	PWR	Operational
	GUNDREMMINGEN-A	BWR	In decommissioning process
	GUNDREMMINGEN-B	BWR	Permanent Shutdown
	GUNDREMMINGEN-C	BWR	Operational
	HDR GROSSWELZHEIM	BWR	License terminated
	ISAR-1	BWR	In decommissioning process
	ISAR-2	PWR	Operational
	KNK II	FBR	In decommissioning process
	KRUEMMEL	BWR	In decommissioning process
	LINGEN	BWR	In decommissioning process
	MUELHEIM-KAERLICH	PWR	In decommissioning process
	MZFR	PHWR	In decommissioning process
	NECKARWESTHEIM-1	PWR	In decommissioning process
	NECKARWESTHEIM-2	PWR	Operational
	NIEDERAICHBACH	HWGCR	License terminated
	OBRIGHEIM	PWR	In decommissioning process
	PHILIPPSBURG-1	BWR	In decommissioning process
	PHILIPPSBURG-2	PWR	Operational
	RHEINSBERG	PWR	In decommissioning process
	STADE	PWR	In decommissioning process
	THTR-300	HTGR	In decommissioning process
	UNTERWESER	PWR	Permanent Shutdown

Country	Name	Type	Status
	VAK KAHL	BWR	License terminated
	WUERGASSEN	BWR	In decommissioning process
Hungary	PAKS-1	PWR	Operational
	PAKS-2	PWR	Operational
	PAKS-3	PWR	Operational
	PAKS-4	PWR	Operational
Italy	CAORSO	BWR	In decommissioning process
	ENRICO FERMI	PWR	In decommissioning process
	GARIGLIANO	BWR	In decommissioning process
	LATINA	GCR	In decommissioning process
Lituania	IGNALINA-1	LWGR	In decommissioning process
	IGNALINA-2	LWGR	In decommissioning process
Netherlands	BORSSELE	PWR	Operational
	DODEWAARD	BWR	In decommissioning process
Romania	CERNAVODA-1	PHWR	Operational
	CERNAVODA-2	PHWR	Operational
Slovakia	BOHUNICE A1	HWGCR	In decommissioning process
	BOHUNICE-1	PWR	In decommissioning process
	BOHUNICE-2	PWR	In decommissioning process
	BOHUNICE-3	PWR	Operational
	BOHUNICE-4	PWR	Operational
	MOCHOVCE-1	PWR	Operational
	MOCHOVCE-2	PWR	Operational
	MOCHOVCE-3	PWR	Under Construction
	MOCHOVCE-4	PWR	Under Construction
Slovenia	KRSKO	PWR	Operational
Spain	ALMARAZ-1	PWR	Operational
	ALMARAZ-2	PWR	Operational
	ASCO-1	PWR	Operational
	ASCO-2	PWR	Operational
	COFRENTES	BWR	Operational
	JOSE CABRERA-1	PWR	In decommissioning process
	SANTA MARIA DE GARONA	BWR	Permanent Shutdown
	TRILLO-1	PWR	Operational
	VANDELLOS-1	GCR	In decommissioning process
	VANDELLOS-2	PWR	Operational
Sweden	AGESTA	PHWR	In decommissioning process
	BARSEBACK-1	BWR	In decommissioning process
	BARSEBACK-2	BWR	In decommissioning process
	FORSMARK-1	BWR	Operational
	FORSMARK-2	BWR	Operational
	FORSMARK-3	BWR	Operational
	OSKARSHAMN-1	BWR	In decommissioning process
	OSKARSHAMN-2	BWR	In decommissioning process
	OSKARSHAMN-3	BWR	Operational
	RINGHALS-1	BWR	Operational
	RINGHALS-2	PWR	Operational
	RINGHALS-3	PWR	Operational
	RINGHALS-4	PWR	Operational

Country	Name	Type	Status
UK	BERKELEY-1	GCR	In decommissioning process
	BERKELEY-2	GCR	In decommissioning process
	BRADWELL-1	GCR	In decommissioning process
	BRADWELL-2	GCR	In decommissioning process
	CALDER HALL-1	GCR	In decommissioning process
	CALDER HALL-2	GCR	In decommissioning process
	CALDER HALL-3	GCR	In decommissioning process
	CALDER HALL-4	GCR	In decommissioning process
	CHAPELCROSS-1	GCR	In decommissioning process
	CHAPELCROSS-2	GCR	In decommissioning process
	CHAPELCROSS-3	GCR	In decommissioning process
	CHAPELCROSS-4	GCR	In decommissioning process
	DOUNREAY DFR	FBR	In decommissioning process
	DOUNREAY PFR	FBR	In decommissioning process
	DUNGENESS A-1	GCR	In decommissioning process
	DUNGENESS A-2	GCR	In decommissioning process
	DUNGENESS B-1	GCR	Operational
	DUNGENESS B-2	GCR	Operational
	HARTLEPOOL A-1	GCR	Operational
	HARTLEPOOL A-2	GCR	Operational
	HEYSHAM A-1	GCR	Operational
	HEYSHAM A-2	GCR	Operational
	HEYSHAM B-1	GCR	Operational
	HEYSHAM B-2	GCR	Operational
	HINKLEY POINT A-1	GCR	In decommissioning process
	HINKLEY POINT A-2	GCR	In decommissioning process
	HINKLEY POINT B-1	GCR	Operational
	HINKLEY POINT B-2	GCR	Operational
	HUNTERSTON A-1	GCR	In decommissioning process
	HUNTERSTON A-2	GCR	In decommissioning process
	HUNTERSTON B-1	GCR	Operational
	HUNTERSTON B-2	GCR	Operational
	OLDBURY A-1	GCR	Permanent Shutdown
	OLDBURY A-2	GCR	Permanent Shutdown
	SIZEWELL A-1	GCR	In decommissioning process
	SIZEWELL A-2	GCR	In decommissioning process
	SIZEWELL B	PWR	Operational
	TORNESS-1	GCR	Operational
	TORNESS-2	GCR	Operational
	TRAWSFYNYDD-1	GCR	In decommissioning process
	TRAWSFYNYDD-2	GCR	In decommissioning process
	WINDSCALE AGR	GCR	In decommissioning process
	WINFRITH SGHWR	SGHWR	In decommissioning process
	WYLFA-1	GCR	Permanent Shutdown
	WYLFA-2	GCR	Permanent Shutdown

Appendix 2: Fuel cycle facilities in the EU[140]

Member State	Facility Name	Facility Type
Belgium	Belgonucleaire PO Plant	Fuel Fabrication (MOX Pellet-Pin)
Belgium	Eurochemic (Belgoprocess Site)	Spent Fuel Reprocessing
Belgium	FBFC International - LWR Fuel Fabrication Plant	Fuel Fabrication (U Assembly)
Belgium	FBFC International - MOX	Fuel Fabrication (MOX Assembly)
Denmark	Danish Decommissioning	Fuel Fabrication (Research Reactors)
France	Areva NC La Hague - UP2-400	Spent Fuel Reprocessing
France	Areva NC La Hague - UP2-800	Spent Fuel Reprocessing
France	Areva NC La Hague - UP3	Spent Fuel Reprocessing
France	Areva NC Melox	Fuel Fabrication (MOX Assembly)
France	AREVA NC MOX (AREVA Cadarache; CEA - ATPu)	Fuel Fabrication (MOX Assembly)
France	Areva NC TU5	Re-Conversion to U3O8 (Rep. U)
France	Areva NC W Plant	Re-Conversion to U3O8 (Dep. U)
France	Atelier Pilote	Spent Fuel Reprocessing
France	Building 18	Spent Fuel Reprocessing
France	Comurhex Malvesi (UF4)	Conversion to UF4
France	Comurhex Pierrelatte (Rep. U)	Conversion to UF6
France	Comurhex Pierrelatte (UF6)	Conversion to UF6
France	Eurodif (Georges Besse)	Uranium Enrichment
France	Experimental Reprocessing Facility (Building 211)	Spent Fuel Reprocessing
France	FBFC - Pierrelatte	Fuel Fabrication (U Assembly)
France	FBFC - Romans	Fuel Fabrication (U Assembly)
France	Georges Besse II	Uranium Enrichment
France	La Hague - AT1	Spent Fuel Reprocessing
France	Marcoule - UP1	Spent Fuel Reprocessing
France	SICN	Fuel Fabrication (U Assembly)
France	SICN GCR Fuel Fabrication	Fuel Fabrication (U Assembly)
France	TU2 Cogema	Conversion to UO2
France	TU2 Cogema Reprocessing Line	Re-Conversion to U3O8 (Rep. U)
Germany	Advanced Nuclear Fuels GmbH Lingen Plant	Fuel Fabrication (U Assembly)
Germany	Enrichment Technology Company Ltd. Zweigniederlassung Deutschland	Uranium Enrichment
Germany	Gorleben Pilot Conditioning Plant	Spent Fuel Conditioning

[140] Source: IAEA database (consulted in August 2018).

Member State	Facility Name	Facility Type
Germany	Urenco Germany GmbH	Uranium Enrichment
Italy	Eurex SFRE (MTR)	Spent Fuel Reprocessing
Italy	Eurex SFRE (Oxide)	Spent Fuel Reprocessing
Italy	Eurex SFRE (Pu Nitrate Line)	Spent Fuel Reprocessing
Italy	ITREC	Spent Fuel Reprocessing
Italy	Plutonium Laboratory	Fuel Fabrication (MOX Assembly)
Netherlands	Urenco Nederland	Uranium Enrichment
Romania	Nuclear Fuel Plant Subsidiary Pitesti (FCN Pitesti)	Fuel Fabrication (U Assembly)
Spain	Fabrica de combustible	Fuel Fabrication (U Assembly)
Sweden	Westinghouse Electric Sweden AB	Fuel Fabrication (U Assembly)
United Kingdom	Miscellaneous Pellet Plant	Fuel Fabrication (U Pellet-Pin)
United Kingdom	NDA Pu Residues Recovery Plant	Spent Fuel Reprocessing
United Kingdom	NDA Reprocessing Plant	Spent Fuel Reprocessing
United Kingdom	NDA Conversion Plant	Conversion to U Metal
United Kingdom	NDA Coprecipitation Plant	Fuel Fabrication (MOX Assembly)
United Kingdom	NDA Dry Granulation Production	Fuel Fabrication (U Assembly)
United Kingdom	NDA Fuel Fabrication Plant	Fuel Fabrication (Research Reactors)
United Kingdom	NDA Magnox Reprocessing	Spent Fuel Reprocessing
United Kingdom	NDA Magnox Reprocessing Pilot Plant	Spent Fuel Reprocessing
United Kingdom	NDA MOX For FBR	Fuel Fabrication (MOX Assembly)
United Kingdom	NDA Plutonium Finishing Line III	Co-conversion to MOX Powder
United Kingdom	NDA Plutonium Operating Corridors	Spent Fuel Reprocessing
United Kingdom	NDA Reprocessing Plant, MOX	Spent Fuel Reprocessing
United Kingdom	NDA Reprocessing Plant, MTR	Spent Fuel Reprocessing
United Kingdom	NDA Sellafield MDF (MOX Demonstration Facility)	Fuel Fabrication (MOX Assembly)
United Kingdom	NDA Sellafield MOX Plant (SMP)	Fuel Fabrication (MOX Assembly)
United Kingdom	NDA Solvent Regeneration Plant	Spent Fuel Reprocessing
United Kingdom	NDA Thorp	Spent Fuel Reprocessing
United Kingdom	NDA Thorp Miniature Pilot Plant (TMPP)	Spent Fuel Reprocessing
United Kingdom	NDA Uranium Purification Plant	Spent Fuel Reprocessing
United Kingdom	Springfields Enr. U Residue Recovery Plant	Conversion to UO2

Member State	Facility Name	Facility Type
United Kingdom	Springfields IDR Plant	Conversion to UO2
United Kingdom	Springfields Line 4 Hex Plant	Conversion to UF6
United Kingdom	Springfields Magnox Canning Plant	Fuel Fabrication (U Assembly)
United Kingdom	Springfields Main Line Chemical Plant	Conversion to UF4
United Kingdom	Springfields OFC AGR Line	Fuel Fabrication (U Assembly)
United Kingdom	Springfields OFC IDR UO2 Line	Conversion to UO2
United Kingdom	Springfields OFC LWR Line	Fuel Fabrication (U Assembly)
United Kingdom	Springfields U Metal Plant	Conversion to U Metal
United Kingdom	Urenco UK Ltd	Uranium Enrichment

Appendix 3: Nuclear research reactors in the EU

The table presents research reactors as well as subcritical assemblies[141].

Member State	Facility Name	Type	Thermal Power (MW)
Austria	TRIGA II VIENNA	TRIGA MARK II	0.25
Belgium	BR-1	GRAPHITE	4
Belgium	BR-2	TANK IN POOL	100
Belgium	BR-3	PWR	10
Belgium	VENUS-F	SUBCRIT	0.0001
Belgium	VENUS-F		0
Bulgaria	IRT-Sofia	POOL, IRT	2
Czech Republic	LVR-15 Rež	TANK WWR	10
Czech Republic	VR-1	POOL	0.005
Czech Republic	LR-0	POOL - VARIABLE CORE	0.005
Denmark	DR-3	HEAVY WATER	10
European Union	ESSOR Nuclear Plant	HEAVY WATER	43
European Union	ECO (Orgel Critical Experiment)	CRIT FAST	0.002
Finland	FIR-1	TRIGA MARK II	0.25
France	Isis	POOL	0.7
France	ILL High Flux Reactor	HEAVY WATER	58.3
France	Cabri	POOL	25
France	Orphee	POOL	14
France	Masurca	CRIT FAST	0.005
France	Pegase	TANK	30
France	Silene	HOMOG (L)	0.001
France	Alizee	CRIT ASSEMBLY	0.0001
France	G-1	GRAPHITE PILE	46
France	Ulysse	ARGONAUT	0.1
France	Minerve	POOL	0.0001
France	Rapsodie	FAST, POWER	40
France	Éole	TANK IN POOL	0.0001
France	Osiris	POOL	70
France	Phebus	POOL	38
Germany	SUR Furtwangen	HOMOG (S)	0
Germany	AKR-2	HOMOG (S)	0.000002

[141] Source: authors' elaboration on data IAEA research reactor database (consulted in August 2018). "Delphi" in the Netherlands is not a 'nuclear research reactor' but part of the inventory of the HOR research reactor in Delft. The costs of disposal of Delphi will therefore be part of the decommissioning costs of the HOR. The subcritical assemblies or near zero power assemblies should be removed. However, as the model used in this study for estimating the decommissioning costs of the research reactors uses their power, the result would be unchanged.

Member State	Facility Name	Type	Thermal Power (MW)
Germany	FRMZ	TRIGA MARK II	0.1
Germany	SUR Stuttgart	HOMOG (S)	0
Germany	SUR Ulm	HOMOG (S)	0
Germany	BER-II	POOL	10
Germany	FRM II	POOL	20
Germany	SUR Aachen	HOMOG (S)	0
Germany	SUR Hannover	HOMOG (S)	0
Germany	RFR	TANK WWR	10
Germany	FRN	TRIGA MARK III	1
Germany	FMRB	POOL	1
Germany	FRG-2	POOL	15
Germany	FRM	POOL	4
Germany	FRG-1	POOL	5
Germany	FRJ-2 (DIDO)	HEAVY WATER	23
Germany	FR-2	TANK	44
Greece	GR-B Subcritical Assembly	SUBCRIT	0
Greece	Demokritos (GRR-1)	POOL	5
Greece	NTU	SUBCRIT	0.0001
Hungary	Nuclear Training Reactor	POOL	0.1
Hungary	Budapest Research Reactor	TANK WWR	10
Italy	LENA, TRIGA II PAVIA	TRIGA MARK II	0.25
Italy	TRIGA RC-1	TRIGA MARK II	1
Italy	RSV TAPIRO	FAST SOURCE	0.005
Italy	AGN-201 Costanza	HOMOG (S)	0.00002
Italy	SM-1 Subcritical Assembly	SUBCRIT	0
Italy	ISPRA-1	HEAVY WATER	5
Italy	L-54M	HOMOG (L)	0.05
Latvia	RKS-25	POOL	0.000025
Latvia	SRR Salaspils Research Reactor	POOL	5
Netherlands	HFR	TANK IN POOL	45
Netherlands	HOR	POOL	2.3
Netherlands	Delphi	SUBCRIT	0
Netherlands	LFR	ARGONAUT	0.03
Poland	MARIA	POOL	30
Poland	EWA	TANK WWR	10
Portugal	RPI	POOL	1
Romania	TRIGA II Pitesti - SS Core	TRIGA DUAL CORE	14
Romania	TRIGA II Pitesti - Pulsed	TRIGA DUAL CORE	0.5
Romania	VVR-S Bucharest	TANK WWR	2
Slovenia	TRIGA- MARK II LJUBLJANA	TRIGA MARK II	0.25
Sweden	R-2	TANK	50

Member State	Facility Name	Type	Thermal Power (MW)
Sweden	R2-0	POOL	1
United Kingdom	Neptune	POOL	0.0003
United Kingdom	VIPER	FAST BURST	0.0005
United Kingdom	VULCAN	PWR	0
United Kingdom	DIDO	HEAVY WATER	26
United Kingdom	PLUTO	HEAVY WATER	26
United Kingdom	Dragon	HE COOLED	20
United Kingdom	BEPO	GRAPHITE, AIR	6.5

Appendix 4: D&D Industrial mapping in Europe

ISDC N°	ISDC Item	Italy	Slovakia	Germany	France	United Kingdom
1	**Pre-decommissioning actions**					
1.1	Decommissioning planning	SOGIN, Ansaldo, Nucleco, Servizi di Ricerche e Sviluppo	Javys, STM Power, Amec Slovakia, Vuje, Tractebel, Inypsa	Nuclear Utilities: PreussenElectra; RWE Power AG; Vattenfall; EnBW GNS Gesellschaft für Nuklear-Service together with WTI GmbH EWN-Energiewerke Nord GmbH	CEA, EDF, AREVA + COMEX Nucléaire (ONET Technologie), NUVIA PROCESS, STMI (AREVA), Ortec, Asteralis, Veolia, Cerap, SGS, Daher	Nuvia, Hydrock NMCL, Oxand, Nuclear Technologies (TUV Sud), Wood (AMEC), Cavendish, Frazer Nash, AECOM,C9Jacobs, Areva, Doosan, Atkins, REACT Engineering, James Fischer Nuclear, Shepley Engineers, Hertel, North West Projects, Westlakes Engineering, Costain, Mott Macdonald, NG Bailey, Squibb, Westinghouse
1.2	Facility characterisation	Nucleco				Nuvia, Aroura, Matom, Radwise, Wood (AMEC), RSK Group, Studsvick, ESG, Cavendish

<table>
<tr><th>ISDC N°</th><th>ISDC Item</th><th>Italy</th><th>Slovakia</th><th>Germany</th><th>France</th><th>United Kingdom</th></tr>
<tr><td>1.3</td><td>Safety, security and environmental studies</td><td>Ansaldo, Nucleco, AMBIENTE S.C., TÜV (safety)</td><td rowspan="3"></td><td rowspan="2"></td><td>CEA, EDF, AREVA + ONET Technologie, STMI (AREVA), ALTRAN Technologie, AMEC FOSTER WHEELER, ASSYSTEM, ASTARE, ATR Ingénierie, BURGEAP, D7. MILLENIUM, SOM, SPIE DEN, TRACTEBEL, WESTINGHOUSE, OAKRIDGE, SEGULA</td><td>Nuvia, Corporate Risk Associates, Wood (AMEC), Atkins Nuclear Technologies (TUV Sud), Areva RMC, Jacobs</td></tr>
<tr><td>1.4</td><td>Waste management planning.</td><td>Ansaldo, Nucleco</td><td rowspan="2">CEA, EDF, AREVA</td><td>Nuvia, Nuclear Technologies (TUV Sud), Cavendish Wood (AMEC), EDF Cyclife, LLWR, Jacobs, PC Richardson</td></tr>
<tr><td>1.5</td><td>Autorisation</td><td>Sogin, Ansaldo</td><td>Nuclear Utilities: PreussenElectra; RWE Power AG; Vattenfall; EnBW
Engineering Support: GNS Gesellschaft für Nuklear-Service together with WTI GmbH, Brenk Systemplanung GmbH, NIS Ingenieurgesellschaft mbH, SAT-Kernkraft GmbH, TÜV Nord EnSys Hannover GmbH & Co KG, TÜV Rheinland Industrie Service GmbH, TÜV SÜd Energietechnik GmbH; NCC nuclear control &</td><td>Nuvia, CRA, Cavendish, Wood (AMEC), Atkins</td></tr>
</table>

ISDC N°	ISDC Item	Italy	Slovakia	Germany	France	United Kingdom
				consulting GmbH; Poyry Deutschland GmbH + numerous other engineering experts rented by Authorities		
1.6	Preparing management group and contracting	Sogin		Nuclear Utilities: PreussenElectra; RWE Power AG; Vattenfall; EnBW+E3+E8		Jacobs, Wood (AMEC), Atkins, Bechtel, AECOM, Hydrock NMCL
2	**Facility shutdown activities**					
2.1	Plant shutdown and inspection			Nuclear Utilities: PreussenElectra; RWE Power AG; Vattenfall; EnBW	CEA, EDF, AREVA	Rolls-Royce, Doosan Babcock, WSP, Wood (AMEC) Cavendish, Jacobs, Areva, Westinghouse, Atkins WYG
2.2	Drainage and drying of systems	Nucleco, Nukem	Vuje; AMEC Slovakia, ROBO Piešťany	Nuclear Utilities: PreussenElectra; RWE Power AG; Vattenfall; EnBW	CEA, EDF, AREVA, sous traitants: Nuvia; OTND, BCSN	Nuvia, Inutec, Doosan Babcock, Cavendish, Wood (AMEC), Rolls Royce
2.3	Decontamination of closed systems for dose reduction	Nucleco, Areva, Energy Solutions		AREVA Germany; Westinghouse; NUKEM Simpelkamp; POLIGRAT GmbH	COMEX Nucléaire (ONET Technologie), NUVIA PROCESS, STMI (AREVA), Ortec, Asteralis	Nuvia, Inutec, Doosan Babcock, Cavendish, Wood (AMEC)
2.4	Radiological inventory characterisation to support detailed planning	Nucleco		Nuclear Utilities: PreussenElectra; RWE Power AG; Vattenfall; EnBW+E3+E8klear-Service together with WTI GmbH+ EWN-Energiewerke Nord	COMEX Nucléaire (ONET Technologie), NUVIA PROCESS, STMI (AREVA), Daher, Cerap (Endel), SGS	Nuvia, Inutec (TradeBe), Cavendish, Wood (AMEC) Studsvik, Cyclife, Socotec (ESG), NSG

ISDC N°	ISDC Item	Italy	Slovakia	Germany	France	United Kingdom
2.5	Removal of system fluids, operational waste and redundant material	Nucleco		GmbH	COMEX Nucléaire (ONET Technologie), ONET Technologie, NUVIA PROCESS, STMI (AREVA), AMALIS (AREVA), ASTERALIS (VEOLIA), BCSN (Bouygues), COFELY ENDEL (ENGIE), D et S, DAHER Nuclear technologie, DERICHEBOURG Services et ingénierie nucléaire, GDES, PRESTOSID, ROUMEAS Services, SAT France, SECHE Energie, SNEF; SPIE DEN, SRA SAVAC, Westinghouse, Effinor, Ponticelli, ADF Tarlin, Sigedi, Boccard, Bilfinger	Nuvia, NSG, Cavendish, Inutec, LLWR, Cyclife TradeBe, DDP Consortia
3	**Additional activities for safe enclosure or entombment**					WSP, ARUP, Atkins, Nuvia, AREVA
4	**Dismantling activities within the controlled area**					

ISDC N°	ISDC Item	Italy	Slovakia	Germany	France	United Kingdom
4.1	Procurement of equipment for decontamination and dismantling	Sogin, Ansaldo	Javys, Vuje	PreussenElectra; RWE Power AG; Vattenfall; EnBW GNS Gesellschaft für Nuklear-Service together with WTI GmbH, EWN-Energiewerke Nord GmbH	CEA, EDF, AREVA	Nuvia, Cavendish, Wood (AMEC), Doosan Babcock, Jacobs, Atkins, NIS, Aquila, Assystem, James Fisher Nuclear, Costain, Bilfinger, Frazer Nash, Vinci Construction, Balfour Beattie, Sir Rober McCalpine, Mott McDonald, DDP Consortia
4.2	Preparations and support for dismantling	Nucleco, SALC Group, Fratelli Omini, Italwork Consorzio, Siritec, Carlo Gavazzi Impianti, ArCo Lavori, Demont, Monsud, EDILEM, Sider Piombino, DAF Costruzioni, Stradali, EUROTEND, Giordano	Vuje, ROBO Piešťany, VF Czech, STM Power, Strabag (Zipp Bratislava), EFACEC Sistemas de Electronica, Energomont, MicroStep-MIS, PPA Controll, PKE Electronics AG	PreussenElectra; RWE Power AG; Vattenfall; EnBW GNS Gesellschaft für Nuklear-Service together with WTI GmbH, EWN-Energiewerke Nord GmbH, E-On Anlagen Service; Hinneburg GmbH; Gamma Service Recicling GmbH; HEUREKA-Gamma AG; BRENK Systemplanung GmbH; Studsvik GmbH & Co. KG; BIG Entsorgungstechnologien GmbH	CEA, EDF, AREVA, Msys, Asteralis, Cerap, Local small companies non-specific to dismantling; Onet, Atalian, ADF, Boccard, Nordon, Bilfinger, ACPP, Efinor, Neom (ex CMS), SAT	
4.3	Pre-dismantling decontamination	Demont, Nucleco	Vuje, ONET, Westinghouse Nuclear, VF Slovakia, Amec Slovakia	AREVA Germany; Westinghouse; NUKEM Simpelkamp; EWN Entsorgungswerk für Nuklearanlagen GmbH; JEN Jülicher Entsorgungsgesellschaft für Nuklearanlagen mbH; NucTecSolutions GmbH; sat. Kerntechnik GmbH	COMEX Nucléaire (ONET Technologie), NUVIA PROCESS, STMI (AREVA), Westhinghouse, Veolia, BCSN	Nuvia, NSG, Cavendish, Jacobs, Wood (AMEC), GDES AECOM, Inutec, Doosan Babcocks, Cavendish, NSG Kurion (Veolia), Atkins (Energy Solutions), Matom, Radwise, KDC

ISDC N°	ISDC Item	Italy	Slovakia	Germany	France	United Kingdom
4.4	Removal of materials requiring specific procedures	Nucleco; Belli	Metrostav; ROBO Piešťany	Babcock Noell GmbH; Balke Dürr GmbH; E-On Anlagenservices GmbH; EWN-Energiewerke Nord GmbH; Forschungs-zentrum Jülich GmbH Nuklear Service; Kraftanlagen Heidelberg GmbH; Nukem Technologies GmbH; RIS Industrie- und Kraftwerksservice GmbH; Siempelkamp Nukleartechnik GmbH; Studsvik GmbH & Co KG; Norbert Braun Industrieservice GmbH	COMEX Nucléaire (ONET Technologie), ONET Technologie, NUVIA PROCESS, STMI (AREVA), AMALIS (AREVA), ASTERALIS (VEOLIA), BCSN (Bouygues), D§S, DAHER Nuclear technologie, DERICHEBOURG Services et ingénierie nucléaire, GDES (Grupo Dominguis Energy Services, RAZEL BEC (Groupe Faya), ROUMEAS Services, SAT France, SECHE Energie, SNEF, SPIE DEN, SRA SAVAC, Westinghouse, Efinor, ADF	Keltbray, Cape, Hertel, KDC, Earith, Moulds, Kaefer, Franks, Portlock Consulting

ISDC N°	ISDC Item	Italy	Slovakia	Germany	France	United Kingdom
4.5	Dismantling of main process systems, structures and components	GD Energy Services, Equipos Nucleares, Despe Ansaldo, ONET Technologies	Westinghouse	AREVA;Westinghouse; Babcock Noell GmbH;Balke Dürr GmbH;E-On Anlagenservices GmbH; EWN-Energiewerke Nord GmbH; Forschungs-zentrum Jülich GmbH Nuklear Service ;Kraftanlagen Heidelberg GmbH;Nukem Technologies GmbH; RIS Industrie; Simpelkamp Nukleartechnik GmbH; Kraftwerksservice GmbH;Studsvik GmbH & Co KG; AKB Greifswald GmbH, Nukem Technologies GmbH; GNS Gesellschaft für Nuklear-Service mbH; AREVA/DSR Ingenieur-gesellschaft mbH; EWN Entsorgungswerk für Nuklearanlagen GmbH	ONET Technologie, NUVIA PROCESS, STMI (AREVA), BCSN (Bouygues), Endel, Spie, Westinghouse, Nukem and **numerous local companies for mundane tasks**	Westinghouse, UKAEA, James Fisher, Nuvia, Rolls Royce, AREVA, REI Nuclear, NSG, Cavendish, Jacobs, Wood (AMEC), GDES, KDC, NNL, Urenco Nuclear Stewardship, JGC

ISDC N°	ISDC Item	Italy	Slovakia	Germany	France	United Kingdom
4.6	Dismantling of other systems and components	Despe, Ansaldo, General Smontaggi, Carlo Gavazzi Impianti, Nucleco	ROBO Piešťany, Vuje	SIEMENS;Cegelec Kraftwerk Service GmbH; KAEFER G+H Isolierung GmbH; Norbert Braun Industrieservice GmbH; Kaefer GmbH; Isoliertechnik GmbH & Co. KG, Babcock Noell GmbH; Balke Dürr GmbH; E-On Anlagenservices GmbH; EWN-Energiewerke Nord GmbH; Forschungs-zentrum Jülich GmbH Nuklear Service; Kraftanlagen Heidelberg GmbH; Nukem Technologies GmbH; RIS Industrie- und Kraftwerksservice GmbH; Simpelkamp Nukleartechnik GmbH; Studsvik GmbH & Co KG; AKB Greifswald GmbH; **Numerous smaller local companies in the neighbourhood of the NPP units**		Nuvia, Cavendish, Wood (AMEC), Doosans, Rolls Royce, Jacobs, Atkins, NSG, Aquilla, Asystem, NSG, James Fisher, Shepley Engineers
4.7	Removal of contamination from building structures	Nucleco	Vuje	EWN Entsorgungswerk für Nuklearanlagen GmbH; Studsvik GmbH & Co KG; Jülicher Entsorgungsgesellschaft für Nuklearanlagen mbH; HOCHTIEF Solutions AG;Hinneburg GmbH; NucTec Solutions GmbH;		Nuvia, NSG, Cavendish, Jacobs, Wood (AMEC), GDES, AECOM

ISDC N°	ISDC Item	Italy	Slovakia	Germany	France	United Kingdom
				WOMA GmbH; Distra Industrie-Service GmbH; STRADEC Strahlenschutz GmbH; Evantec GmbH; diperso Dienstleistungs GmbH & Co. KG; IABG mbH		
4.8	Removal of contamination from areas outside buildings	Castellano Costruzini Generali	Vuje	EWN Entsorgungswerk für Nuklearanlagen GmbH; Studsvik GmbH & Co KG; Jülicher Entsorgungsgesellschaft für Nuklearanlagen mbH; Hinneburg GmbH; NucTec Solutions GmbH ; WOMA GmbH; diperso Dienstleistungs GmbH & Co. KG		Nuvia, Wood (AMEC), KDC, NSG
4.9	Final radioactivity survey for release of buildings					Radwise, Matom, Aurora, Nuvia, Wood (AMEC)
5	**Waste processing, storage and disposal**					
5.1	Waste management system	Nucleco + Procurement from Siempelkamp, MBRAUN and GNS	Javys	NCC nuclear control & consulting GmbH;sat. Kerntechnik GmbH, Nuclear Utilities: PreussenElectra; RWE Power AG; Vattenfall; EnBW, GNS Gesellschaft für Nuklear-Service together with WTI GmbH, EWN-Energiewerke Nord	CEA, EDF, AREVA	Nuvia, Cavendish, Kurion (Veolia), Wood (AMEC), DSRL Sellafield Limited, NSG

ISDC N°	ISDC Item	Italy	Slovakia	Germany	France	United Kingdom
				GmbH		
5.2-5.11	Management of waste: Characterisation, Retrieval and processing, Final conditioning, Storage, Transport, Disposal, Containers.	Nucleco, Ansalso, Javys, Studsvik	Javys, Vuje, ROBO Piešťany, Amec Slovakia	AREVA; DAHER Germany; DSR Ingenieurgesellschaft GmbH; NCC nuclear control & consulting GmbH; sat. Kerntechnik GmbH, Nuclear Utilities: PreussenElectra; RWE Power AG; Vattenfall; EnBW GNS Gesellschaft für Nuklear-Service together with WTI GmbH, EWN-Energiewerke Nord GmbH BRENK Systemplanung GmbH; sat. Kerntechnik GmbH Support: NCC nuclear control & consulting GmbH	Tier 3: ONET Technologie, NUVIA PROCESS, STMI (AREVA), ASTERALIS (VEOLIA), BCSN (Bouygues), DAHER Nuclear technologie, DERICHEBOURG Services et ingénierie nucléaire, SECHE Energie, SNEF, SPIE DEN, SRA SAVAC, Riba Socomelu, EDF CENTRACO	Nuvia, Inutec, NSG, Cyclife, LLWR, TradeBe, Darchem, Metal Craft, Westinghouse, PC Richardson, Balfour Beatty, Jacobs, Wood, Carrs Engineering, Capula, M+W Group, Kier, Cavendish, Quilter Ha.ll
6	**Site infrastructure and operation**					
6.1	Site security and surveillance	Sogin and contracted local companies. Some of them are: Aurelia, Betasint, Ansaldo, Cesi, Enea, Nucleco, Penta System, PROTEX ITALIA.	Javys and contracted both foreigner and local companies. Some of them are: Canberra, Packard Austria, EFACEC Sistemas de Electronica, MicroStep-MIS, PKE Electronics AG, PPA Controll Slovakia	Nuclear Utilities: PreussenElectra; RWE Power AG; Vattenfall;EnBW;EWN, Support: Securiton GmbH; Alarm- und Sicherheitssysteme; PTA GmbH; Nickel GmbH	CEA, EDF, AREVA subcontracted by EDF	Mitie, G4S, Balfour Beatty Workplace Solutions, Civil Nuclear Constabulary (CNC), Graham Construction Tyco (Johnson Controls), Chubb, ATOS, Thales
6.2	Site operation and maintenance					Mitie, Balfour Beatty, Interserve, Jacobs, Wood (AMEC) Shepley Engineering,

ISDC N°	ISDC Item	Italy	Slovakia	Germany	France	United Kingdom
						Cavendish, Tyco (Johnson Controls)
6.3	Operation of support systems				Eiffage energie, Vinci energies, SNEF, ADF, VINCI Energy, AXIMA, BCSN (Novi), OTND(Spiral), Eiffage Energie (Ouest), Areva (Msys), Cegelec, EMCC	Site owners and Infrastructure Services Alliance - Arup and Morgan Sindall
6.4	Radiation and environmental safety monitoring			Kerntechnischer Hilfsdienst GmbH; Mirion Technologies (Canberra) GmbH; MHC Anlagentechnik GmbH, **Nuclear Utilities:** PreussenElectra; RWE Power AG; Vattenfall;EnBW ;EWN	CEA, EDF, AREVA+ 6.4.1 Nuvia, SDEC, HTDS, Mirion, Saphymo 6.4.2. Nuvia, Saphymo, Mirion, HTDS, Aemco	Nuvia, Radwise, Matom, SL, AWE, PHE, Cavendish Omniflex, Ultra Electronics, Canberra UK, James Fischer Nuclear, Psycho Scientific, Laboratory Impex John Caunt Scientific, Ametek GB Limited
7	**Conventional dismantling demolition and site restoration**					
7.2	Dismantling of systems and building components outside the controlled area	Several local companies. Some of them are: Corbat; EDAM; Despe; General Smontaggi,	Chemcomex, Despe, Petr Březina – APB Plzeň, Metrosav, EZ-Elektromont, ViOn Slovakia	Alpin Technik und Ingenieurservice GmbH; AKB Greifswald GmbH; IABG mbH, Siemens; numerous local electrical companies	BCSN (Bouygues), PRESTOSID, RAZEL BEC (Groupe Faya), ROUMEAS Services, SAT France, Cardem, Delair Navarra,	Nuvia, Moulds, KDC, Earith, Squibb, Keltbray, Thompsons, Prudhoe, Cuddy, DDP Consortia

ISDC N°	ISDC Item	Italy	Slovakia	Germany	France	United Kingdom
7.3	Demolition of buildings and structures from the formerly controlled area	Ftc di Tarantino Rocco		Hochtief; Züblin;Strabag; Heitkamp Construction GmbH; Implenia; Alpin Technik und Ingenieurservice GmbH; numerous local construction companies; IABG mbH; Caverion Deutschland/Krantz-Systeme; Käfer Industrie GmbH	Derichebourg, Entreprises de Vinci Energies, Eiffage, Cofely	
7.4	Final cleanup, landscaping and refurbishment					KDC, Earith, Squibb, Hydrock Cognition, AECOM
8	**Project management, engineering, and support**					

ISDC N°	ISDC Item	Italy	Slovakia	Germany	France	United Kingdom
8.1-8.8	Project management and support services	Sogin + supports (Ansaldo, CCR Internazionale, S.R.S. Engineering Design, S.R.S. Servizi di Ricerche e Sviluppo, PROTEX ITALIA S.P.A. and several environmental engineering companies)	Javys + supports (Vuje, NESS Technologies, AITEN) + Project management unit companies (Iberdrola Engineering and Construction, Sogin, ..)	**Nuclear Utilities:** PreussenElectra; RWE Power AG; Vattenfall; EnBW, GNS Gesellschaft für Nuklear-Service together with WTI GmbH, EWN-Energiewerke Nord GmbH + supports (AREVA; BRENK, Brenk Systemplanung GmbH; ABG Nuklear Service AG; DBE Technology GmbH; DSR Ingenieurgesellschaft GmbH; Fichtner Management Consulting AG; IGN consult mbH; INGENIEURE Prof. Sturm + Partner GmbH; Ingenieurgesellschaft für Stilllegung und Entsorgung mbH; MHC Anlagentechnik GmbH; Green German Reengineer.ing GmbH; NCC nuclear control & consulting GmbH; Pöyry Deutschland GmbH; sat. Kerntechnik GmbH; TÜV NORD ENSys;TÜV Sued;TÜV Rheinland, E.ON Business Services GmbH;RWE IT GmbH)	CEA, EDF, AREVA + supports (ONET Technologie, STMI (AREVA), ALTRAN Technologie, AMEC FOSTER WHEELER, ASSYSTEM, ASTARE, ATR Ingénierie, BURGEAP, D7. MILLENIUM, SOM, SPIE DEN, TRACTEBEL, WESTINGHOUSE, Eurodoc, Technodoc)	Nuvia, Jacobs, Wood (AMEC), Cavendish, Aecom Turner & Townsend, Mace, Gardiner & Theobald, WSP, DSA Consortia - Axiom and Progressive, and Capita, CH2MHILL (now Jacobs), URS now AECOM
9	**Research and development**					

ISDC N°	ISDC Item	Italy	Slovakia	Germany	France	United Kingdom
9.1-9.2	Research and development of equipment, techniques and procedures	Sogin, Nucleco, ENEA	Javys,Vuje	RWTH Aachen (Aachen University); KIT – Karlsruher Institut für Technologie; Forschungs-zentrum Jülich GmbH Nuklear Service; AVR GmbH; Helmholtz-Zentrum Dresden-Rossendorf (HZDR); Technische Hochschule Hannover; Fraunhofer Gesellschaft/ Institut für Keramische Technologien und Systeme (IKTS); Friedrich Schiller Universität Jena; Helmholtz-Zentrum Berlin für Materialien und Energie GmbH ZRA	CEA, EDF, AREVA	NNL, NAMRC, UKAEA RACE, Bristol University, Southampton University, Manchester University, Wood (AMEC), Atkins, Capita Symonds, Cavendish, EPI Consulting, Nichols Group, North West projects, NSG Environmental, Quintessa, REACT Engineering, Tenet Consulting, Nuclear Technologies (TUV Sud), Westlakes Engineering, Nuvia
10	**Fuel and nuclear material**					
10.1	Removal of fuel or nuclear material from facility to be decommissioned		Nuclear utility	Nuclear Utilities: PreussenElectra; RWE Power AG; Vattenfall; EnBW GNS Gesellschaft für Nuklear-Service EWN-Energiewerke Nord GmbH	CEA, EDF, AREVA	Site Licence Companies (DSRL, Magnox, INS, EDF, NNL, Urenco)
10.2	Dedicated buffer storage for fuel and/or nuclear material	Deposito Avogadro (FIAT), Sogin	Javys		Asterailis , Areva	Vinci Construction, Balfour Beatty, Holtec, Sir Robert McAlpine, Trant, Interserve (EDF as nuclear site operator)
10.3	Remediation of old storage areas	Sogin	Javys		Vinci (soil, environment)	Nuvia, KDC, NSG
11	**Miscellaneous expenditures**					

ISDC N°	ISDC Item	Italy	Slovakia	Germany	France	United Kingdom
11.1	Owner costs					Gardiner & Theobald, Earnst & Young, Deloitte, Turner & Townsend, Gleeds
11.2	Taxes					KPMG, PWC, Deloitte
11.3	Insurances	Unipol Sai, Great Lakes Insurance UK, Generali Italia		Deutsche Kernreaktor-Versicherungsgemeinschaft (DKVG)		Willis Towers Watson, AIG

Appendix 5: Zion Units 1&2 D&D deal

Zion Units 1 and 2 were permanently shut down on February 13, 1998. The fuel was transferred to the spent fuel pool, and the owner submitted the certification of fuel transfer on March 9, 1998. He also submitted the PSDAR, site-specific cost estimate for the fuel management plant on February 14, 2000. Decontamination and dismantling began in 2011 and is still on-going. Final site survey and license reduction to the Independent (onsite) Spent Fuel Storage Installation (ISFSI) is currently planned for 2019 - 2020.

On September 1, 2010, the facility license was transferred from Exelon to ZionSolutions for the express purpose of expediting the decommissioning of the site. ZionSolutions is using a “rip and ship” process that reduces the labour-intensive separation of contaminated materials and transports the facility in bulk to the EnergySolutions disposal site in Utah and to WCS in Texas. Completion of fuel transfer to the ISFSI was completed in January 2015. Submittal of the License Termination Plan (LTP) was in December 2014, and an NRC LTP public meeting was held in April 2015. License termination is slated for 2020.

The advantage of having an owner of a waste LLW/ILW disposal/repository as being responsible for the D&D project is that a “rip and ship” (or “waste driven”) process is more easily implemented. Such a process consists of shipping the amount of waste (VLLW/LLW/ILW and “cleared” waste) offsite to the repository as soon as it is generated after dismantling and decommissioning of the plant components, systems and structures. Transport regulations allowing for such an approach must nevertheless be in force, which is the case in the USA. “Rip & ship” eliminates time-consuming onsite waste logistics problems (characterization, decontamination, interim storage, …) and optimizes and reduces project duration and costs as compared to projects where LLW/ILW and cleared waste management remains a problem (see for instance German case in this document).

Details of the Zion deal[142]

On January 25, 2008, Exelon Generation Company, LLC (Exelon), the owner, and ZionSolutions, LLC (ZS) submitted an application to the US NRC requesting that the U.S. Nuclear Regulatory Commission (NRC) consent to the transfer of Exelon's Facility Operating License Nos. DPR-39 and DPR-48 for the Zion Nuclear Power Station, Units 1 and 2 ("ZNPS" or the "Zion Units") to ZS, and ownership and management authorities to ZS, so as to implement Exelon's sale to ZS of the assets comprising the Zion Nuclear Power Station, Units 1 and 2 with the exception of title to:

- the real estate encompassing the Zion site;
- ownership of the spent nuclear fuel and the Greater than Class C[143] radioactive waste.

The ZNPS site will be leased to ZS throughout the decommissioning period.

[142] Application for License Transfers and Conforming Administrative License Amendments. Exelon File transmitted to NRC on January 25, 2008

[143] According to the US waste classification. 10CFR61.55

Under the terms of the proposed sale, which are set forth in an Asset Sale Agreement (ASA), ZS will decommission the Zion Units except for the spent nuclear fuel and Greater than Class C Radioactive Waste (GTCC), which will be stored in an ISFSI to be constructed by ZS and maintained onsite until their final disposition. Pursuant to general licenses provided for in 10 CFR 31.9, 40.21 and 70.20, Exelon will retain title to this material, and the ultimate disposition of this material will be provided for under the terms of Exelon's Standard Spent Fuel Disposal Contract with the Department of Energy.

Exelon's sale of the Zion Units to ZS will be structured so that, on or about the date of closing of the ASA, Exelon will transfer the funds in the Zion Units' Qualified Decommissioning Funds and Non-Qualified Decommissioning Funds to Qualified and Non-Qualified Decommissioning Funds established by ZS, segregated from its assets and outside its administrative control, in accordance with the requirements of 10 CFR 50.75(e)(1).

The terms of the ASA require that ZS perform radiological decommissioning, environmental remediation, and other activities relating to the Zion Units such that certain defined contractual conditions are met.

EnergySolutions, LLC (EnergySolutions) specializes in providing nuclear services, such as high-level waste management, spent fuel handling and transportation, and complex decontamination and decommissioning projects, including the decommissioning of both government and commercial nuclear power generation facilities. Among the services provided by EnergySolutions are the packaging, transportation, storage, and disposal of radioactive waste at its disposal facility in Clive, Utah, the largest low-level radioactive waste disposal facility in the US.

ZS is a wholly owned subsidiary of EnergySolutions. ZS has been established solely for the purpose of acquiring the Zion Units and causing the Zion site (except for the ISFSI where the spent fuel and GTCC will be stored) to be decommissioned and released for unrestricted use, while maintaining the spent nuclear fuel and GTCC radioactive waste safely stored in the ISFSI.

EnergySolutions will guarantee the performance of ZS's decommissioning obligations, and EnergySolutions will obtain a USD 200 million letter of credit, payable to a back-up nuclear decommissioning trust (Back-up NDT). In addition, EnergySolutions will grant an irrevocable easement to disposal capacity at the Clive, Utah facility for the disposal of Class A, low level waste from the Zion site, and this disposal capacity asset, together with related contractual rights, will be held by the Back-Up NDT.

Many of the personnel currently assigned by Exelon to the ZNPS and some of the existing support organizations will continue to support the licensed activities at the facility. The information included in the Application demonstrates that ZS will have, at the Closing Date, the requisite technical qualifications to perform the required activities under the Licenses.

ZS is preparing an Amended PSDAR and an Updated Irradiated Fuel Management Plan (U-IFMP) for the Zion Units that is proposed to be effective upon the transfer of ZNPS to ZS, and these documents will be submitted separately for review and consideration by the NRC. In accordance with 10 CFR 50.82(a)(4)(i), the Amended PSDAR will present a description of the planned decommissioning activities to be undertaken by ZS, along with a schedule for their accomplishment and an estimate of expected costs. In accordance with 10 CFR 50.54(bb), the U-IFMP[144] will inform NRC of the program by which ZS plans to manage and provide funding for the management of all irradiated nuclear fuel at ZNPS until title to the irradiated fuel and possession of the fuel is transferred to the Secretary of Energy for its ultimate disposal in a geologic repository.

The financial qualifications of ZS to perform its obligations under the Licenses are demonstrated by:

- the availability to ZS of the Qualified and Non-Qualified Nuclear Decommissioning Funds to pay for the radiological decommissioning of the Zion Units;
- the execution of a guaranty by EnergySolutions of the performance by ZS of its obligations under the ASA and the execution of a guaranty of the obligations of EnergySolutions by its parent company;
- the provision by EnergySolutions of additional financial assurance in the form of a $200 million letter of credit; and
- the disposal capacity easement assuring the availability of disposal capacity at the Clive, Utah disposal facility.

As the Application shows, there will be sufficient assets in the Qualified and Non-Qualified Nuclear Decommissioning Funds to pay for the calculated costs of decommissioning the Zion Units. In addition, the further financial assurances provide ample assurance that ZS will have adequate resources to carry out its responsibilities under the licenses.

The information supplied to the NRC demonstrates:

- the proposed transfer of the Zion licenses to ZS will accelerate the timely decommissioning of the Zion site;
- ZS has the requisite managerial, technical, and financial qualifications to be the licensed owner of the Zion Units;
- ZS will provide reasonable assurance of decommissioning funding for the units;
- the material terms of the license will not be affected; and
- ownership by ZS will not result in foreign ownership, control or domination of the licensee.

Applicants also request NRC approval of certain administrative amendments to conform the Licenses and the units' Permanently Defueled Technical Specifications (PDTS) to reflect the proposed transfers. Administrative changes to documents other than the Licenses and the PDTS will be necessary upon ZS's assumption of control over the Zion Units. Changes to documents such as the Defueled Safety Analysis Report, Physical Security Plans, and Emergency Plans will be achieved in a timely fashion during periodic or routine updates as required by NRC regulations, such as 10 CFR 50.71.

[144] Irradiated fuel management plan.

Appendix 6: Site clearance after D&D[145]

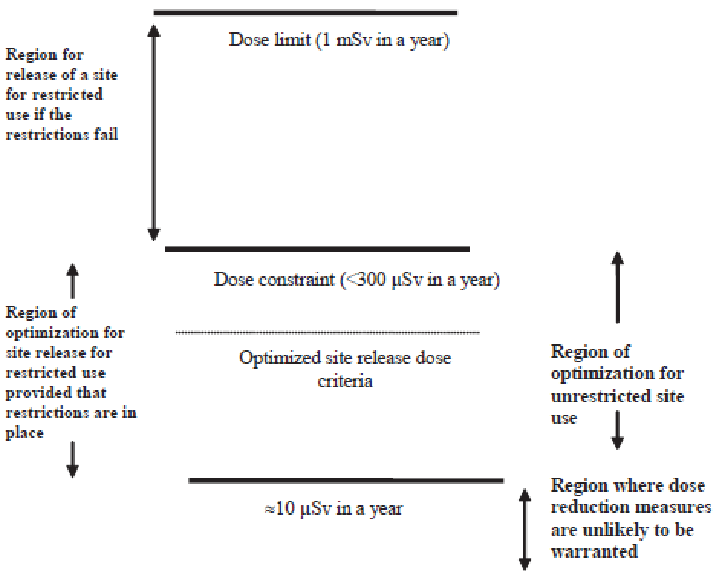
The question of the site clearance after D&D is addressed differently by the diverse safety authorities and may represents a major concern for utilities/owners.

IAEA Guidance on Site Release Criteria

This guidance was expressed in IAEA WS-G-5.1, "Release of Sites from Regulatory Control on Termination of Practices", 2006. According to this guidance,

> *"It is reasonable and appropriate to have different dose constraints for the release of sites than for the clearance of material from regulatory control. Clearance of material may take place frequently over the lifetime of a practice, as well as at the termination stage. The cleared material may enter into trade with a broad range of potential uses and therefore should comply with clearance criteria, which are of the order of 10 µSv in a year. The dose criteria for the release of land from regulatory control should be optimized and can be higher than those for the clearance of material, because land remains in place and hence the degree of certainty about the potential uses of the land is higher than the degree of certainty associated with the uses of material after its release from regulatory control. Thus it is reasonable to allow a larger fraction of the individual dose limit for the release of sites (i.e. the dose constraint (less than 300 µSv in a year)) than for the clearance of material (of the order of 10 µSv or less in a year).*"

Such position is in terms of effective dose for the members of the critical group[146]:

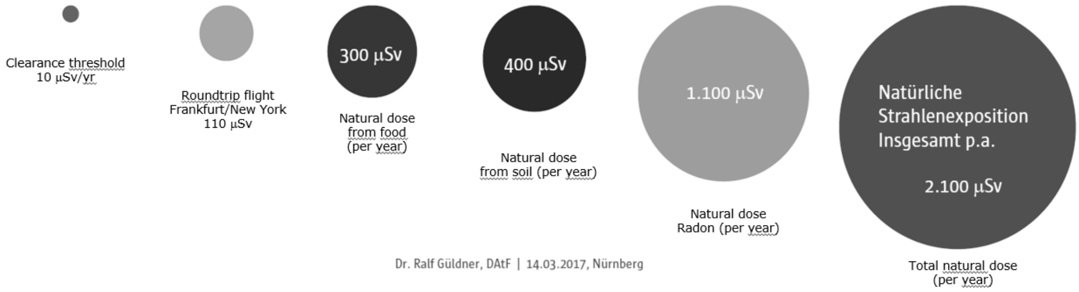


[145] Evaluation of Dose and Risk in the Site Release Process for Commercial Power Reactors. Richard Reid (EPRI). Waste Management Symposium 2014, March 5, 2014.
[146] IAEA WS-G-5.1, "Release of Sites from Regulatory Control on Termination of Practices", 2006. Page 6.

In addition, IAEA states:

- Restricted Release: < 1 mSv/yr if restrictions fail;
- Unrestricted Release: < 0.3 mSv/yr;
- (however) "Optimisation" may be performed to determine if lower dose criteria is appropriate;
- Remediation to < 0.01 mSv/yr "likely not warranted on radiological protection grounds".

Indeed, such low value can be compared to other exposition sources:



US situation

The site release criteria are set by the regulator. They may be expressed as:

- allowable dose to a future user of the site (i.e., mSv/yr);
- concentrations for various radionuclides in soil, concrete or groundwater, which may have originally been determined from dose based criteria.

If the Site Release Criteria are dose based, Site Release Limits (i.e., concentrations) need to be determined by dose modelling.

The US NRC site release criteria are:

- 0.25 mSv/yr for Unrestricted and Restricted Release;
- if Restricted Release, also need to demonstrate that if institutional controls fail, dose will be:
    - < 1 mSv/yr, or
    - < 5 mSv/yr if remediation to 1 mSv/yr is:
        - not technically achievable;
        - prohibitively expensive; or
        - will result in net public or environmental harm.

This means that ALARA evaluation is required to evaluate further remediation to satisfy to lower dose criteria.

The future use of the site is determined by utility. For establishing the site future use, assumptions are taken:

- for land areas:
    - "greenfield": the site assumed to be used by a "Resident Farmer" family. This is the most conservative scenario/lowest release limits;
    - "industrial Use": the licensee continues to own the site; occupant is assumed to be licensee employee (works 2000 hrs/yr). This leads to higher site release limits than "Resident Farmer Scenario";

- for the buildings, office worker in concrete structure (2000 hrs/yr);
- other use scenarios can be assumed such as:
  - public park – recreational (less occupancy hours/yr);
  - non-farming use and/or groundwater consumption not allowed.

As an example, when the site is retained by the utility (Rancho Seco Experience):

- site is to be re-powered and reused;
- the "Industrial Worker Scenario" is applied;
- control by the Utility allows limitation of assumed worker time on site (hours/year);
- groundwater table is 40 meters below the site;
- dose pathways modified or eliminated:
  - plant ingestion;
  - meat ingestion;
  - ingestion of aquatic foods (e.g. fish).

Such approach allowed Rancho Seco to demonstrate that residual radioactivity for "Industrial Worker Scenario" dropped to "Resident Farmer" levels after 30 Years after License Termination due to decay and "weathering".

It must nevertheless be mentioned that in the US, other stakeholders intervene:

- State Regulations:
  - For instance, in Maine:
    - 0.1 mSv/yr including < 0.04 mSv/yr from Groundwater;
  - In Connecticut:
    - 0.19 mSv/yr TEDE;
    - Groundwater Criteria – Environmental Protection Agency (EPA) Maximum Contaminant Levels (MCLs).
- EPA/NRC Memorandum of Understanding (MOU):
  - MCLs are defined for groundwater;
  - soil screening levels are defined;
  - exceeding these levels may result in EPA involvement in site release process.

European situation

In Europe, situation is different from the US and also among MS:

- European Union guidance is contained in RP 113:
  - clearance levels are based on 0.01 mSv/yr
  - levels are defined for different cases:
    - reuse of the building;
    - demolition of the building;
    - demolition and recycle or conventional disposal of concrete.
- In France: for buildings, after remediation to a predetermined depth based on concrete characterization results, the rule is "no detectable contamination can be measured in post-remediation survey"
- In Germany:
  - clearance Levels published in German Radiation Protection Ordinance for buildings, soil and metals;
  - based on a Dose of 0.01 mSv/yr;
  - levels are defined for different cases:
    - soil in land areas;

        - reuse of buildings;
        - demolition of buildings;
        - demolition and recycle or conventional disposal of solids.
- In Spain:
    - buildings to be remediated to the RP 113 clearance levels:
    - for land areas, total dose from surface and subsurface soil surface water and groundwater : < 0.1 mSv/yr;
    - dose must be < 1 mSv/yr if land use restrictions fail.
- In Sweden:
    - dose criteria "on the order of 0.01 mSv/yr";
    - buildings to be remediated to the RP 113 clearance levels.
- In United Kingdom:
    - buildings and land areas: approval of the IAEA clearance levels has been obtained at some sites;
    - alternately, a site specific analysis can be performed:
        - based on maintaining the maximum dose <0.01 mSv/yr;
        - trend in the UK is to use the IAEA clearance levels.

Such variable regulations may have large consequences in terms of logistics burden (inducing costs and schedule overruns) given the huge VLLW/LLW volumes (concrete, soils) at stake. These volumes are to be characterized, possibly decontaminated, packaged, stored (onsite or offsite), shipped and disposed of. Surface disposal capacities may not be sufficient, and situation is even worse when the national rules prescribe deep geological disposal for any kind of waste.

This brief international overview shows the complexity and the variability of the rules and regulations applied for site release and may explain why, in some European countries, utilities/owners seem somewhat reluctant to conduct D&D activities until the "greenfield" status of the site is reached.

Appendix 7: Safety reference levels harmonization in Europe[147]

The Western European Nuclear Regulators Association (WENRA) currently comprises the following countries: Belgium, Bulgaria, the Czech Republic, Finland, France, Germany, Hungary, Italy, Lithuania, the Netherlands, Romania, Slovenia, Slovakia, Spain, Sweden, Switzerland and the United Kingdom. The original objectives of the Association were:

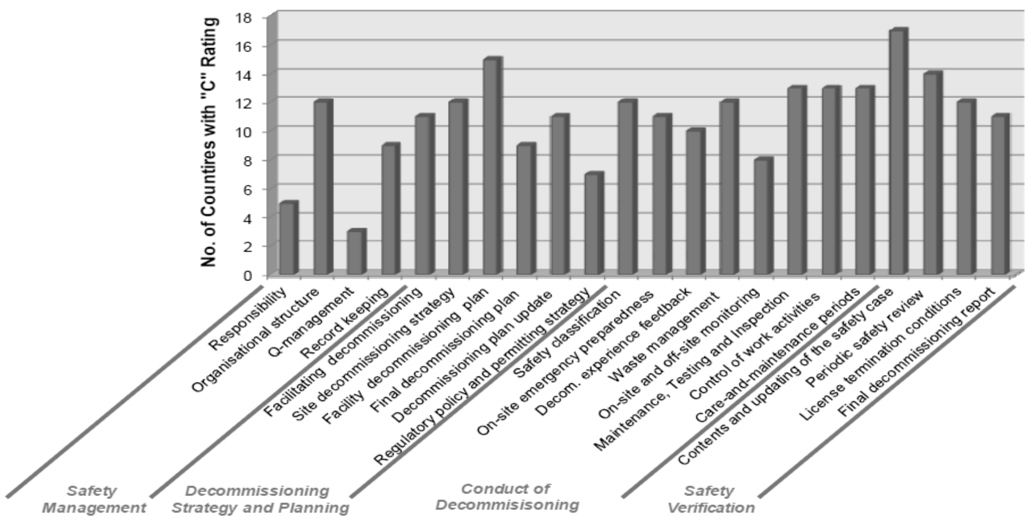
- to develop a common approach to nuclear safety and regulation, in particular within the EU;
- to provide the EU with an independent capability to examine nuclear safety and regulation in candidate countries;
- to evaluate and achieve a common approach to nuclear safety and regulatory issues which arise.

In the D&D domain, a Working Group on Waste and Decommissioning (WGWD) was launched in 2002.

On the basis of the safety reference levels (SRLs) defined by this group, generally coherent with IAEA recommendations, WENRA members started in 2007 a self-assessment of the compliance of their national regulations with the 81 SRLs. Each country ranked its regulation as compared to the SRLs in the following way:

A – the requirement is covered explicitly by national regulatory system;
B – a difference exists, but can be justified from the safety point of view;
C – a difference exists and should be addressed for harmonisation in the national action plan.

The table below, extracted from the referenced report, gives the number of WENRA countries with C-ratings, sorted by safety issues.



[147] Decommissioning Safety Reference Levels. WENRA Report 2015

This table shows the large discrepancies, which existed in 2007 among the WENRA members regulations when compared to the Safety reference level benchmark.

After conclusion of the regulatory benchmarking procedure in 2009, the WGWD members were requested to develop and present national actions plans (NAPs) of their countries, in order to demonstrate the planned activities and efforts for harmonising their national regulatory requirements with the WENRA safety reference levels (SRLs). Countries convened that C-ranked items were the basis for development of their national action plans (NAP).

The deadline for implementation of NAP-actions had originally been set at the end of 2012 but was by later decision of WENRA directors extended to the end of 2013 and later until 2014 for various reasons.

The WENRA report lists the detailed situation of each country as of today, showing that harmonization is progressing well, but not achieved.