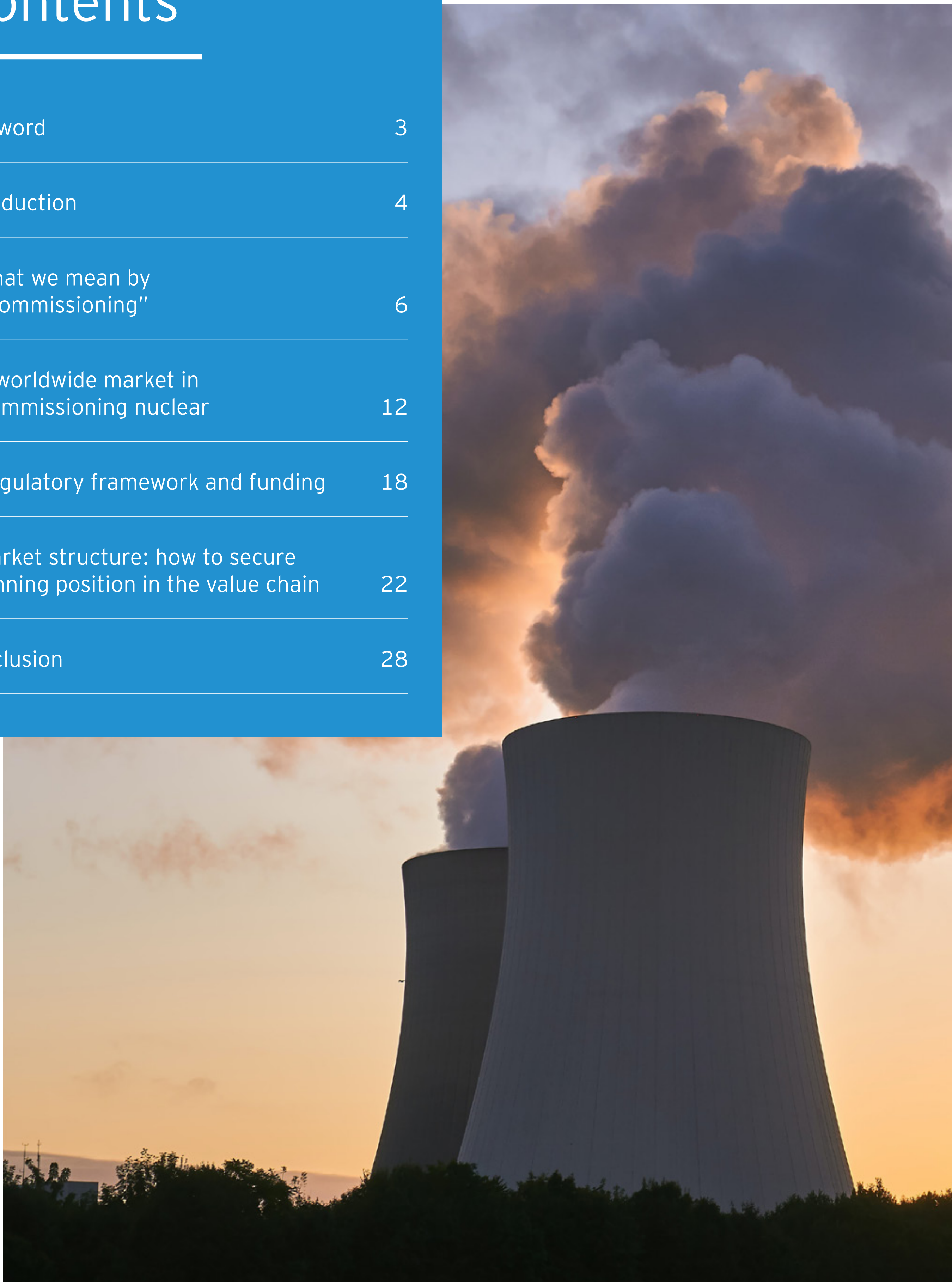
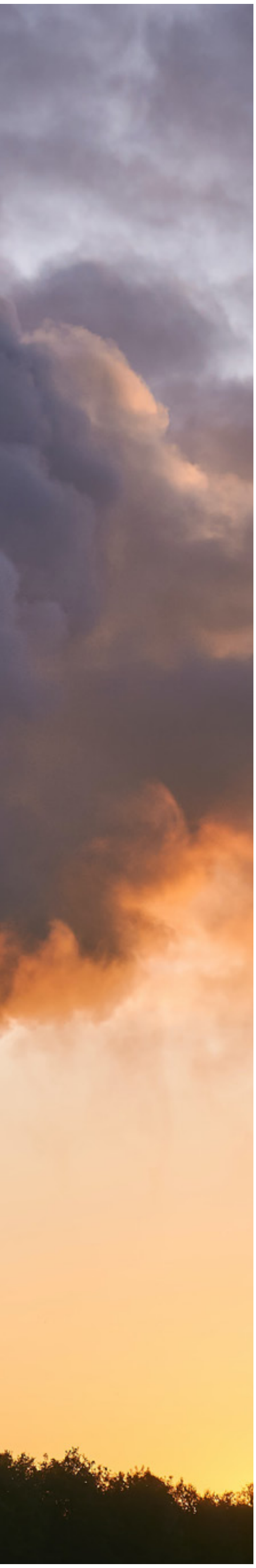
The economic potential in nuclear decommissioning

December 2022

EY Parthenon
Building a better working world

Contents





Foreword

The oil shocks of the 1970s gave rise to massive investment in oil and gas exploration and production. But they also prompted a ramp-up in the generation of electricity from nuclear origins to diversify the energy mix. Fast-forward several decades and those large oil platforms, deep-sea operating facilities and nuclear power plant parks have now reached, or are reaching, the end of their useful lives.

The shift is both industrial and political. Ongoing public controversy about the safety of facilities and their role in the green transition has accelerated the decommissioning process, particularly for nuclear power plants. There is also greater scrutiny from regulators as understanding of the nuclear decommissioning process and tools increases.

At the same time, the act of decommissioning nuclear facilities, which can take between 17 and 20 years to execute, is creating a key value pool in the energy markets. Globally, the market is worth an estimated US$125b to US$135b over the 2021 – 2050 period. In this report, due to ongoing geopolitical circumstances, we confine our research to the top 12 countries.

Though the impact on the labor markets and the transformation in business models in the energy industry will be gradual, it will be, nonetheless, significant. In France, for instance, the total market value between 2051 and 2100 is an estimated US$23b, compared with US$8b for the period from 2021 to 2050. Our scenario allows for decommissioning 26 nuclear reactors before 2050 and 33 after this date.

Different markets have different key success factors. Europe, for instance, values technology and cost considerations. In the US market, which is an oligopoly made up of just five large players, project management expertise and additional benefits, such as returning savings to customers, are priorities. To be successful, value chain participants will need to align their capabilities to local designs and business models, rather than adopt a one-size approach to decommissioning and dismantling.

The anticipated size and scale of the nuclear decommissioning market, coupled with its regulatory and technical intricacies, prompted EY-Parthenon to undertake this in-depth analysis. We consider this work to be especially urgent in countries where new nuclear power programs have been decided but sites capable of accommodating installations are scarce.

We believe that complex facility decommissioning, particularly in relation to nuclear infrastructure, will continue to evolve and expand in the coming years.

Bruno Bousquié
Partner, EY-Parthenon France

Anton E. Poryadin
Partner, EY-Parthenon USA

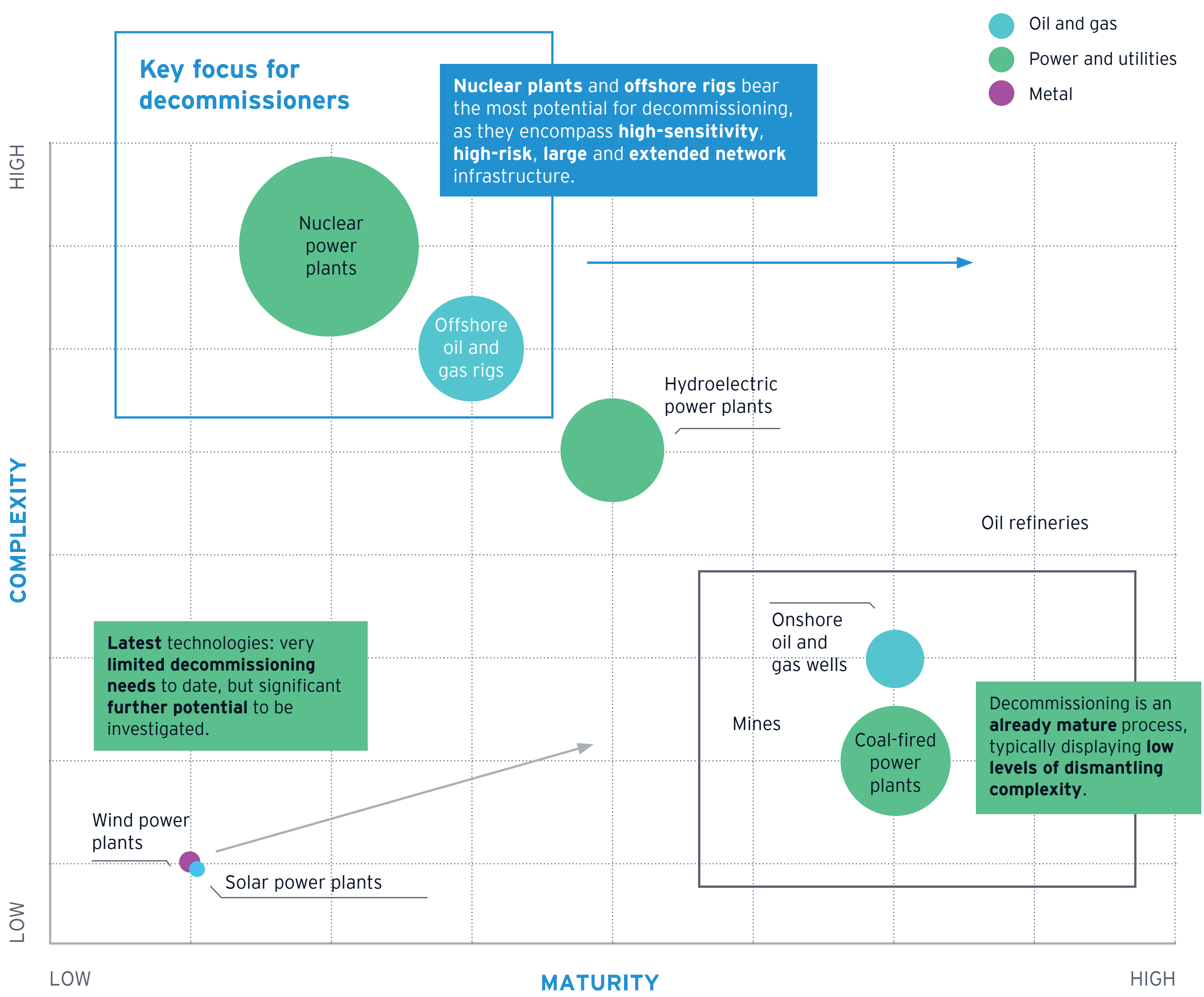
Introduction

Dismantling nuclear power facilities is a long-term process; nuclear waste management is an even longer undertaking. As the world begins to decommission its aging nuclear energy production plants, safely and with due regard for the environment, and to install new capabilities in their place, EY-Parthenon seeks to:

- Shed light on the different stages of decommissioning nuclear installations and the complexity of the process.
- Estimate the size of the market and its expected evolution up to 2050, while acknowledging that decommissioning could continue until 2100.
- Address the regulatory framework and financing.
- Understand the structure of the market, its value chain, the key players and their winning strategies.

Different types of assets to be decommissioned

Matrix maturity x complexity x attractiveness for decommissioning



Facilities in the fields of oil and gas, power and utilities, and mining and metals are to be decommissioned. This graph maps process maturity (x axis) against complexity (y axis). Dismantling higher-complexity infrastructure has not yet reached technical and economic maturity. Nuclear power plants and offshore oil and gas rigs offer the most economic potential and will impact the market significantly.

Source: desk research, EY-Parthenon analysis.

What we mean by "decommissioning"

In its strictest sense, "decommissioning," a nuclear power plant refers to the first step of the process: **phasing out nuclear equipment activity.**

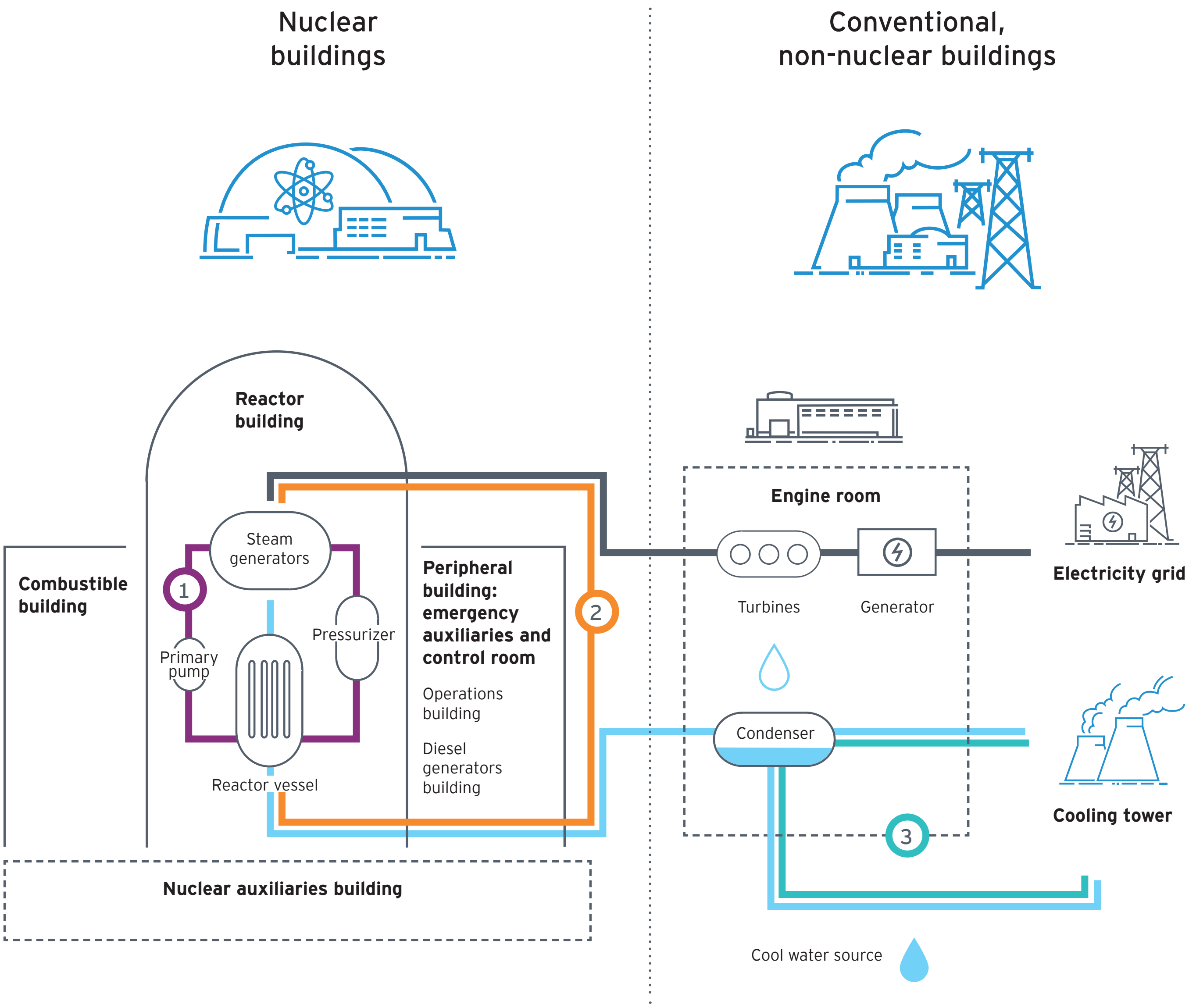
The next step, "dismantling," relates to the physical activities of uninstalling and deconstructing equipment – the reactor and the primary, secondary and tertiary circuits – as well as nuclear and non-nuclear buildings.

Commonly, the term "decommissioning" is used to describe both decommissioning and dismantling (D&D) activities. Decommissioning is the cover-all term we adopt for the purposes of this report.

A nuclear power plant comprises multiple buildings and types of equipment. Some, as illustrated in the diagram opposite, are designated for nuclear activities, such as the combustible building, reactor building and peripheral buildings. Other are non-nuclear or conventional, and include the engine room, the turbines and the generator. All must be decontaminated and demolished as part of the decommissioning process.

Decommissioning scope

Overview of a pressurized water reactor and its main circuits



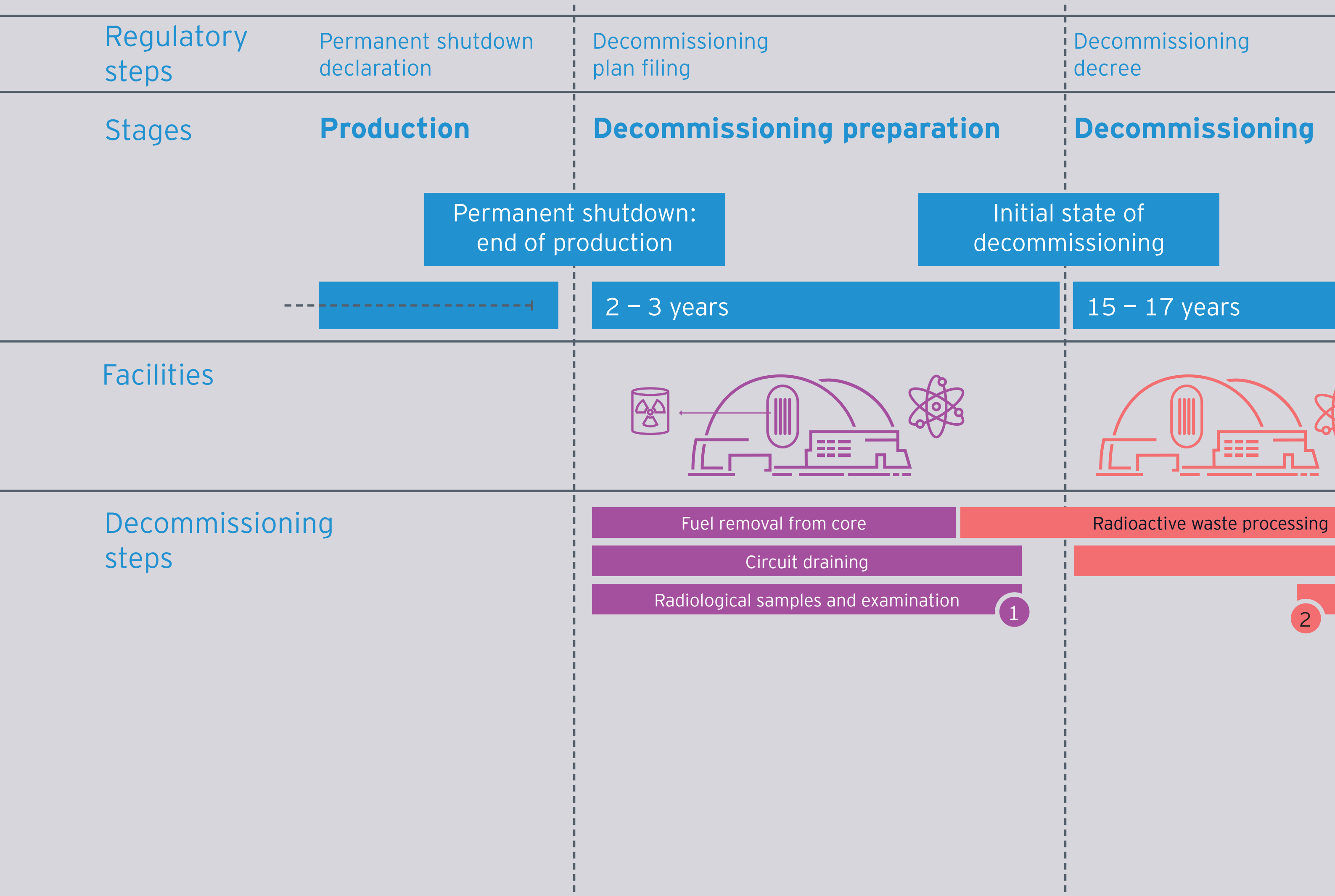
1 Primary circuit
2 Secondary circuit
3 Tertiary (cooling) circuit

——— Set of buildings per tranche[1] (x2)
- - - - - Buildings in common for tranches (x1)

1. The common format in France for a nuclear site is two identical nuclear tranches.
Source: IRSN, desk research, EY-Parthenon analysis.

Decommissioning a nuclear power plant comprises complex activities, such as decontaminating and dismantling radioactive buildings and equipment, as well as more conventional activities, such as demolishing non-nuclear buildings.

Decommissioning process

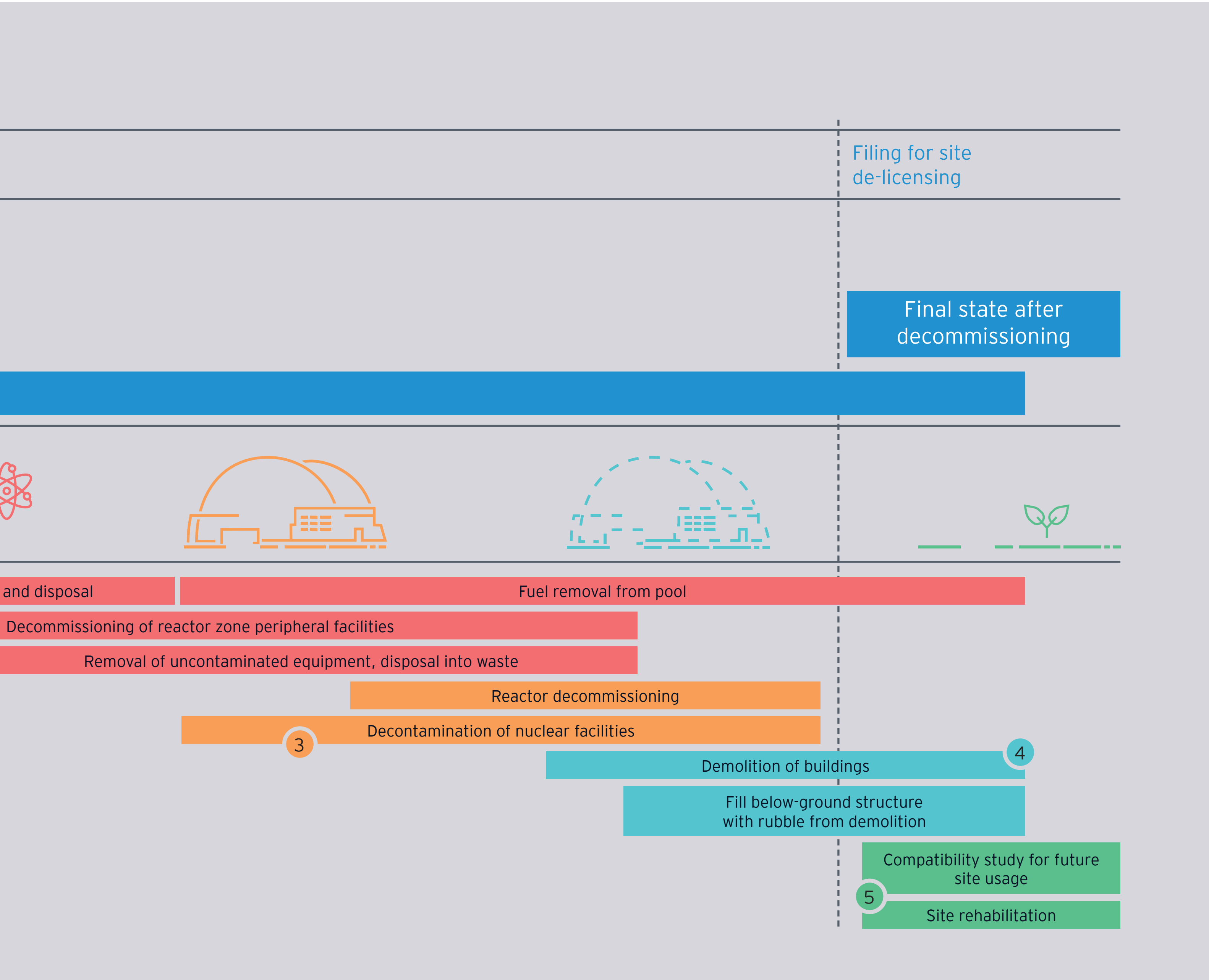


Source: desk research, EY-Parthenon analysis.

The decommissioning process typically starts once the nuclear reactor is permanently shut down. It ends when the site is rehabilitated. Getting to this end point involves several step-by-step activities:

- **Drain circuits and remove the remaining fuel** from the nuclear core for further treatment of radioactive waste.
- **Dismantle and treat the radioactive equipment** installed in the reactor zone (primary pump, steam generators, pressurizers, etc.)
- **Dismantle the nuclear island** and decontaminate the nuclear components.
- **Demolish the buildings** (both nuclear and non-nuclear).
- **Rehabilitate the site** in accordance with its future purpose (e.g., greenfield or brownfield). Rehabilitation requirements for former nuclear sites vary from country to country. France is especially stringent, requiring that former nuclear sites are made fit for industrial purpose.

The overall decommissioning process lasts around 17 to 20 years. It includes a preparation phase (around two to three years) and the works phase (around 15 to 17 years). Simple and conventional tasks, such as the demolition of non-nuclear buildings no longer in use, may be performed in parallel. The most complex tasks, such as the removal of fuel and decontamination of equipment, must be performed in strict order before undertaking any other activity.



Throughout the nuclear decommissioning process, the disposal of waste materials is a major challenge. **A decommissioned nuclear facility emits different types of waste, each with different levels of toxicity and different treatment needs:**

1

Standard demolition waste

This is conventional rubble from demolished buildings and non-radioactive dismantled equipment.

2

Last cores

Once permanent shutdown is officially complete, partially consumed fuel remains and must be treated like spent nuclear fuel.

3

Spent nuclear fuel

This fuel is combustible and has been irradiated but can no longer trigger a nuclear reaction. It needs to be evacuated from the nuclear sites, transported and stored in specialist locations for treatment. Part of the waste is recycled for further use in operating sites; the remainder constitutes long-term radioactive waste.

4

Long-term radioactive waste

This waste remains after the treatment of nuclear fuel and the dismantling of radioactive equipment. It will include, for instance, metallic elements from the reactor building and parts of the primary and secondary circuits.

The radioactivity of nuclear waste decreases naturally over time. The radioactivity level of the waste dictates the strategies and approaches available:

- **High-level radioactive waste (HLW) is typically stored for centuries before disposal to allow for radioactivity decay.**
- Low-level radioactive waste (LLW) may be sent to land-based disposal sites immediately or within just a few years.

The treatment of spent nuclear fuel and long-term radioactive waste occurs during both the operational phase of the nuclear plant and at the decommissioning phase. As the activities are performed by specialist players on a different value chain, we have excluded them from the scope of the decommissioning market, as analyzed in this paper.

A worldwide market in decommissioning nuclear

Estimated at US$125b – US$135b over the period (2021-50)

For every nuclear power plant that nears the end of its useful life, hundreds of millions of dollars will be spent on decommissioning activities over the coming decade. In turn, a huge worldwide market and value chain is evolving to service these activities.

Over the second half of the 20th century, leading economies, including the US, France, the UK and Japan, Sweden implemented significant nuclear development programs. The legacy of their heavy investment in complex technological capabilities is recognized expertise in the civil nuclear field. Now, 50 years on, those capabilities are to be leveraged for the final phase in the lifecycle of the earliest power plants: decommissioning.

Nuclear decommissioning presents a major opportunity for the whole nuclear industry over the coming decades. Decommissioning equates to around 17 to 20 years' worth of projects, estimated at hundreds of million dollars, per nuclear power plant. These projects will bring together multiple players: operators; contractors; local; national and international authorities, and regulatory bodies. They will leverage capabilities as distinct and essential as radioactivity treatment, complex project management and financing, across an emerging global value chain.

EY-Parthenon values the total worldwide nuclear decommissioning market at around US$125b to US$135b over the (2021-50) period. This period – a reflection of the lengthy duration of decommissioning projects and the variety of activities they entail – is, we believe, more meaningful than yearly analysis of the size or growth of the decommissioning market.

Given current geopolitical circumstances, our baseline scenario market estimation is informed by the selected top 12 countries in the world by number of active reactors:

US – **92** reactors	Belgium – **7** reactors
France – **56** reactors	Spain – **7** reactors
China – **55** reactors	Sweden – **6** reactors
Japan – **33** reactors	Switzerland – **4** reactors
South Korea – **25** reactors	Germany – **3** reactors
UK – **9** reactors	Taiwan – **3** reactors

Estimated market size based on nuclear scenarios

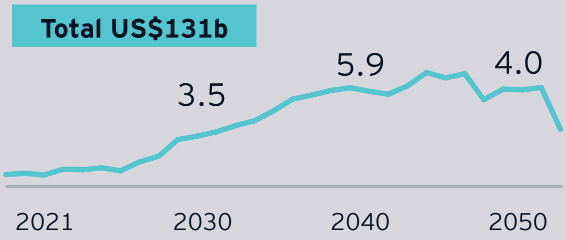
Scenarios and underlying industry trends	Impact on the decommissioning market	Nuclear power plant decommissioning market scenarios in 12 countries,[2] US$b (constant prices)

A

Baseline:

- Hundreds of nuclear power plants (NPPs) are nearing the end of their lifecycles
- Some project are delayed due to immaturity of solutions (e.g., graphite reactors, HLW disposal)
- Funding is channeled toward economic support, not decommissioning projects

Gradual growth due to planned decommissioning of NPPs with expired service life

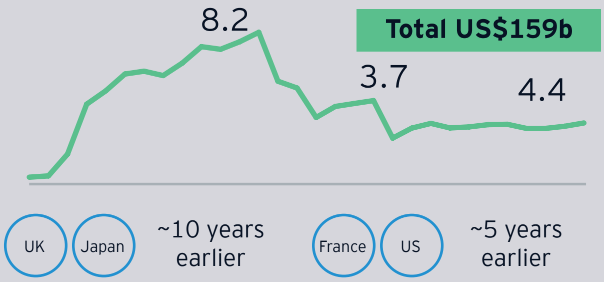


B

Accelerated decommissioning[1] policies:

- Renewable energy and fast industrial battery storage development
- Low oil prices
- Fear of nuclear disasters

Rapid growth to 2040 due to accelerated decommissioning[1] of NPPs, which have experienced tougher competition from other energy sources, such as renewables

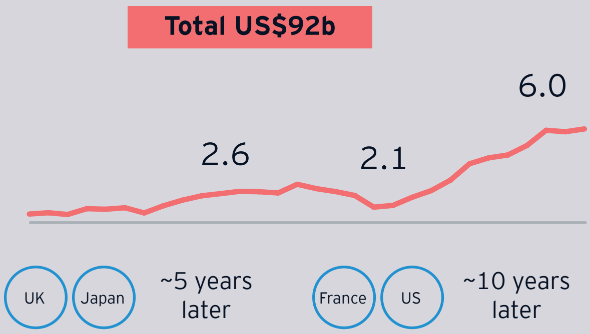


C

Postponed decommissioning[1] policies:

- Lack of stable energy supply from renewable energy sources
- High oil prices
- Energy transition: nuclear energy for decarbonization goals
- Reactor lifecycle extension in the US and France

No significant demand in the coming decade due to the extension of NPP lifetimes



1. Based on markets' dependence on nuclear power: the UK and Japan have a small nuclear share; France has a large nuclear share; the US has strong zero-emission targets.
2. Germany, France, Belgium, the UK, Switzerland, Spain, Japan, Taiwan, South Korea, China Mainland, the US, Argentina.

Source: Decommissioning market model (based on client data, OECD and US Nuclear Regulatory Commission reports and expert interviews), EY-Parthenon analysis.

This estimation comes with caveats. The outlook for nuclear is uncertain and subject to unpredictable political decisions. For instance, a government's decision to launch a new nuclear build program, or extend or reduce the life span of existing reactors, would impact the decommissioning market significantly.

For this reason, EY-Parthenon has worked on two complementary scenarios: an accelerated decommissioning scenario (scenario B) and a postponed decommissioning scenario (scenario C), based on a country's specific circumstances and reliance on nuclear.

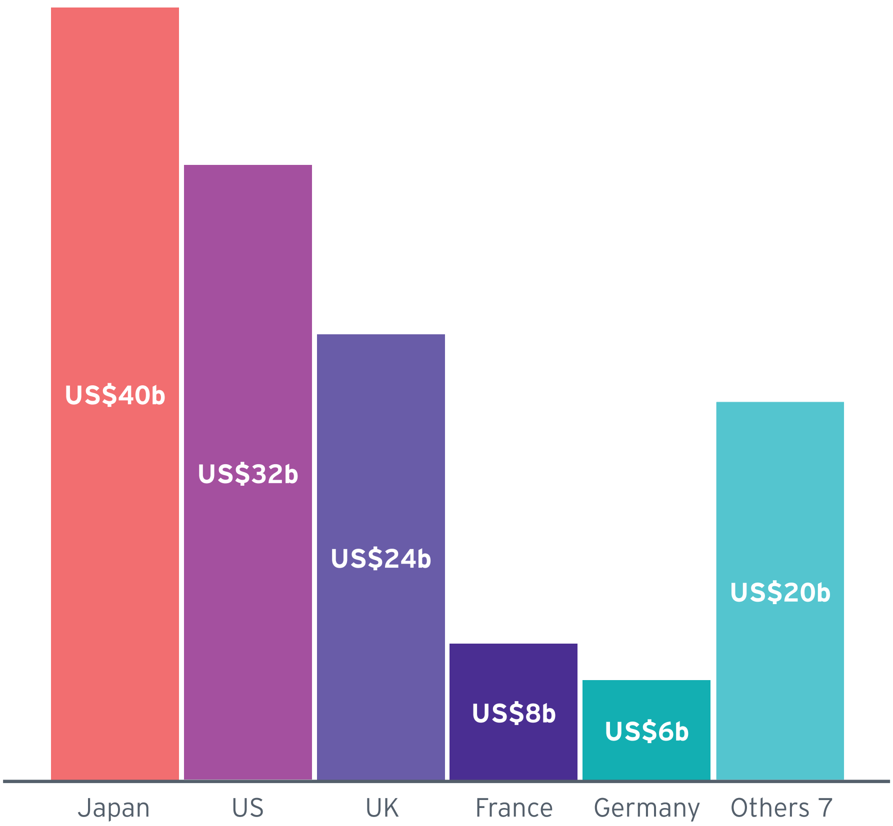
So, for example, a lower share of nuclear in the energy mix in the UK and Japan, compared with France and the US, makes both countries more likely to fast-track their decommissioning start dates. However, the period between the final shutdown of a plant and the launch of decommissioning will depend on many factors, including how quickly the site is needed for a new nuclear plant, the availability of financial and human resources and the political environment.

EY-Parthenon, in its baseline scenario for the period 2021–50, identifies those countries that will contribute most to the evolving market in nuclear decommissioning. Japan is top, with around US$40b, followed by the US at around US$32b and the UK at US$24b. France follows at US$8b and Germany at around US$6b. Together, these countries, which implemented the most ambitious nuclear programs back in the 20th century, now make up more than 80% of the global market. The rest of the market comprises smaller countries or countries with a lower share of nuclear in their energy mix.

Almost all of the front-runners are at the start of their nuclear decommissioning programs. Germany is the exception. Its decommissioning process will be completed by the end of the considered period (2050), due to an early political decision to exit from nuclear and transition to renewables in the aftermath of the 2011 Fukushima disaster.

For some countries, the market for nuclear decommissioning should remain significant throughout the second half of the 21st century too. For instance, in France, the total market value in the period 2051–2100 is estimated at around US$23b, compared with just US$8b in the period 2021–50. Our scenario factors in decommissioning 26 reactors in France before 2050 and 33 after 2050.

Baseline scenario: total estimated market size by country, 2021–50



Globally, between 2021 and 2050, around 200 nuclear reactors will enter the decommissioning process. We base this on the assumption that the average reactor has a lifetime of around 40 years and that decommissioning will start the year after a reactor is shut down permanently.

However, the hypothesis misses two key observations:

- **As new technologies emerge, the longevity of nuclear reactors tends to increase.** The oldest reactors are expected to last 40 years, but newer reactors could remain in service for almost 60 years. The bulk of decommissioning in the 2021–50 period will mostly comprise the oldest reactors.
- **Not all reactors are decommissioned immediately after permanent shutdown.** Some countries, including the UK, may stipulate a "safe enclosure" period and will delay the decommissioning process for years or even decades to benefit from natural radioactivity decay.

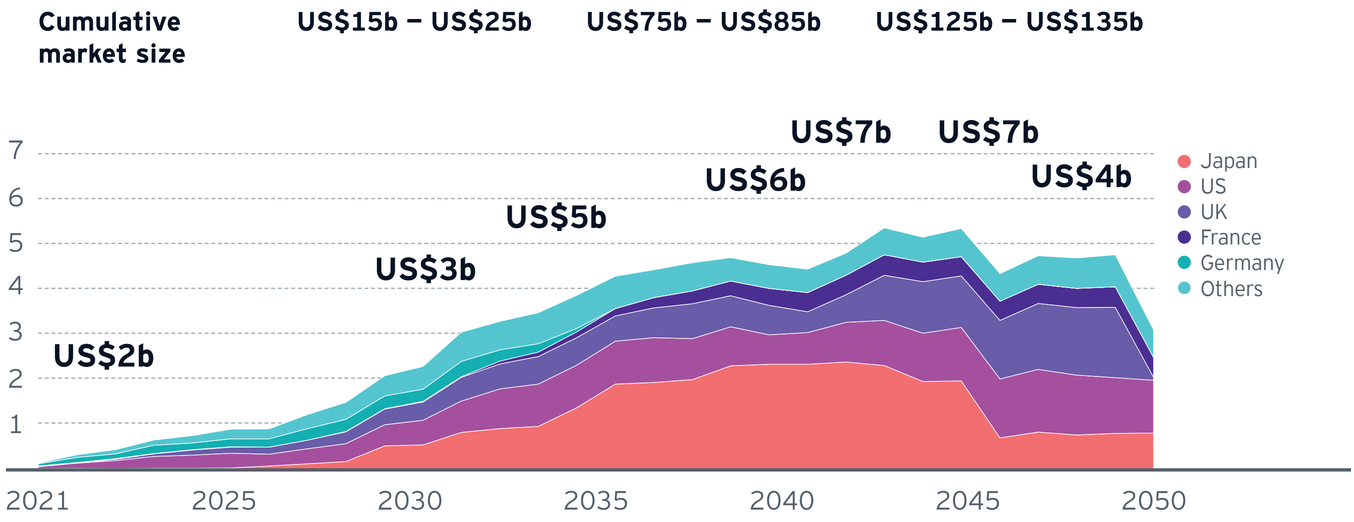
The total cost of decommissioning a nuclear reactor can vary from US$500m to US$2b, subject to geography – Western Europe tends to be least expensive – and other critical factors:

- **Reactor type:** First-generation reactors were not designed to be decommissioned, which triggers additional costs and land issues further down the line. Later reactors were designed to be decommissioned at a future date. So, decommissioning an early gas-cooled reactor (GCR) is likely to cost, on average, twice as much as a later pressurized water reactor (PWR).
- **Labor costs:** A highly skilled workforce is needed throughout the decommissioning process to handle complex tasks associated with dismantling radioactive equipment and buildings. Given the anticipated boom in the nuclear decommissioning market over the next few decades, alongside the possible launch of new nuclear programs, there is a growing likelihood of a nuclear skills shortage, which will increase competition for resources and drive up wages.
- **Regulating policies:** The more stringent a country's nuclear cleanup policy, the greater the impact on total cost. The latest and most efficient technologies for preparing and undertaking decommissioning, treatment of waste and storage, etc. could prove the most costly.

Other factors may influence the total decommissioning cost. The size and complexity of the site will have a bearing. Some reactors are sited in the open air; others are housed in underground cave-like structures. Some will have on-site nuclear storage facilities; others will not. Understanding the initial state of the existing site and its post-decommissioning target state (greenfield or brownfield, etc.) will help to anticipate delays to the process.

Variations in total cost are also influenced by the activities included within the scope of decommissioning. The inclusion of pre-decommissioning, waste management and treatment (e.g., waste packaging, transportation and disposal) or rehabilitation costs, for instance, will impact the cost reported for decommissioning a reactor.

Estimated market size by country



The total value of a decommissioning project can be schematically spread over the duration of the project.

Projects usually start with the highest-value tasks (e.g., treatment of irradiated equipment and automated technology). However, they represent a minor share – around 1% to 2% – of the total project's value per year over the first five years. As the project advances, the yearly value of the project ramps up to around 7% to 10% of total value (depending on the country and reactor type).

The lowest-value tasks tend to be performed at the end of the project. At this point, secondary markets may arise, and activities may be undertaken by companies with less nuclear-specific expertise and a different cost structure.

Decommissioning project cost structure (PWR reactor)

Cost structure	Phases	Cost range	Main drivers	Sources
100%	Total budget	US$0.5b – US$1.5b		• Cases from experts and public documents
0-30%	Non-addressable (captive)[1]	US$500m	• NPP operator's policy (US, Japan <10%, EU up to 25%)	• Experts in decommissioning projects in the US and UK
70-100%	**Addressable (tenders)**	US$0.3b – US$1.5b (graphite up to US$3b)	• Addressable part depends on regulatory rules, labor cost, type of reactor, applied technologies, disposal facilities and other drivers	
10%-40%	Preparation (project management)[2]	US$30m – US$600m	• Country labor costs (wages and taxes)	• OECD • US Electric Power Research Institute • US Nuclear Regulatory Commission • Experts in decommissioning projects in the US, UK and Japan
20%-40%	Decontamination and dismantling	US$60m – US$600m	• Type of reactor: Boiling Water Reactor (BWR), Pressurized Water Reactor (PWR) • Applied technologies	
15%-25%	Radioactive waste management	US$50m – US$400m	• Availability of disposal facilities • Strictness of cleanup policy • Type of reactor (BWR, PWR)	
10%-20%	Spent nuclear fuel management	US$30m – US$300m	• Volume of spent nuclear fuel • Prices for casks, country labor costs	
2%-6%	Other[3]	US$5m – US$100m		

1. Operator maintenance expenses: operations, security, electricity, taxes, insurance, etc., management of the decommissioning project, preparatory works (for instance, data collection by NPP employees).
2. Planning, scheduling, budgeting.
3. E.g., rehabilitation costs
Source: OECD, NRC and EPRI reports, expert interviews, client data, EY-Parthenon analysis.

Focus on the main reactor technology types

	PWR	BWR	GCR
Share of installed reactors	55%	22%	3% (all operational reactors located in the UK)
Coolant	Water	Water	Carbon dioxide gas
Moderator	Water	Water	Graphite
Fuel	Enriched uranium (higher level than in BWR)	Enriched uranium	Natural uranium
Additional information	Cooling water is kept under pressure so that it cannot boil. The primary coolant does not drive the steam turbine: Heat from the primary water-cooling system is captured in a heat exchanger and transferred to water in a secondary system. The core is filled with water pressurized to 150 atmospheres, allowing water to reach 325°C without boiling.	In the reactor core, water boils under a pressure of 75 atmospheres, raising the boiling point to 285°C. Steam is generated to drive a turbine.	Carbon dioxide circulates through the core and reaches 650°C. Gas then flows to gas-to-water heat exchangers (located outside the reactor) to boil the water flowing through it.
Estimated total cost of decommissioning, including waste management and treatment (in Western Europe)	US$600m	US$670m	US$1,200m

Regulatory framework and funding

The decommissioning market in each country is directed by the regulatory framework that prevails within it.

The framework shapes the rules that apply to the preparation, structuring and implementation of decommissioning projects. It underpins the way in which funding and financial responsibility for nuclear plants is split in the host country.

This is critical because funding schemes for decommissioning projects, and the division of responsibilities across players, depend on the makeup of the energy sector. Some countries adopt an operator-based model; for some, it is government-based, using funds specifically earmarked for decommissioning; others operate a hybrid model.

MODEL N° 1

Operator model

Notably used in France and Belgium, this model sees the costs for decommissioning and waste management covered by the operator of the nuclear power plant.

Decommissioning is financed by the lifetime activity of the power plant. It is incorporated into the energy tariff, as a kilowatt/hour cost, from construction through to decommissioning the nuclear site, and is passed onto the end user.

Under this financing scheme, nuclear operators must hold internal provisions in the form of segregated and dedicated funds, which are backed by assets of sufficient security and liquidity to cover their liabilities for decommissioning and waste management.

MODEL N° 2

Government-run model

Under this model, governments bear responsibility for decommissioning costs. Indirectly, however, decommissioning is funded by public spending and, ultimately, taxes.

Take the UK, where a nuclear plant operator is responsible for defueling the site and verifying that it is fuel-free before ownership of the site can be transferred. For first-generation reactors, costs are reported in the accounts of the Nuclear Decommissioning Authority (NDA). The NDA is mostly funded directly by the UK government. For second-generation reactors, a segregated fund (Nuclear Liabilities Fund (NLF)) meets the long-term costs of cleaning, waste management and decommissioning. If the NLF cannot bear the costs and liabilities, the UK government will take ultimate responsibility for them.

MODEL N° 3

Hybrid model

In hybrid models, the management and financial liabilities for decommissioning the plant, and for packaging nuclear waste, lie entirely with the plant operator. Public authorities will make sure that sufficient funding is secured by the operator from nuclear power plant activity.

In Germany and the US, for instance, the operator is obliged to build up financial reserves for decommissioning during the lifetime operation of the plant. Yet financial responsibility for waste management transportation and final storage rests with government. In exchange for the transfer of responsibilities, the nuclear operator pays a one-off fee to finance a public and external fund and comply with the "polluter pays principle".

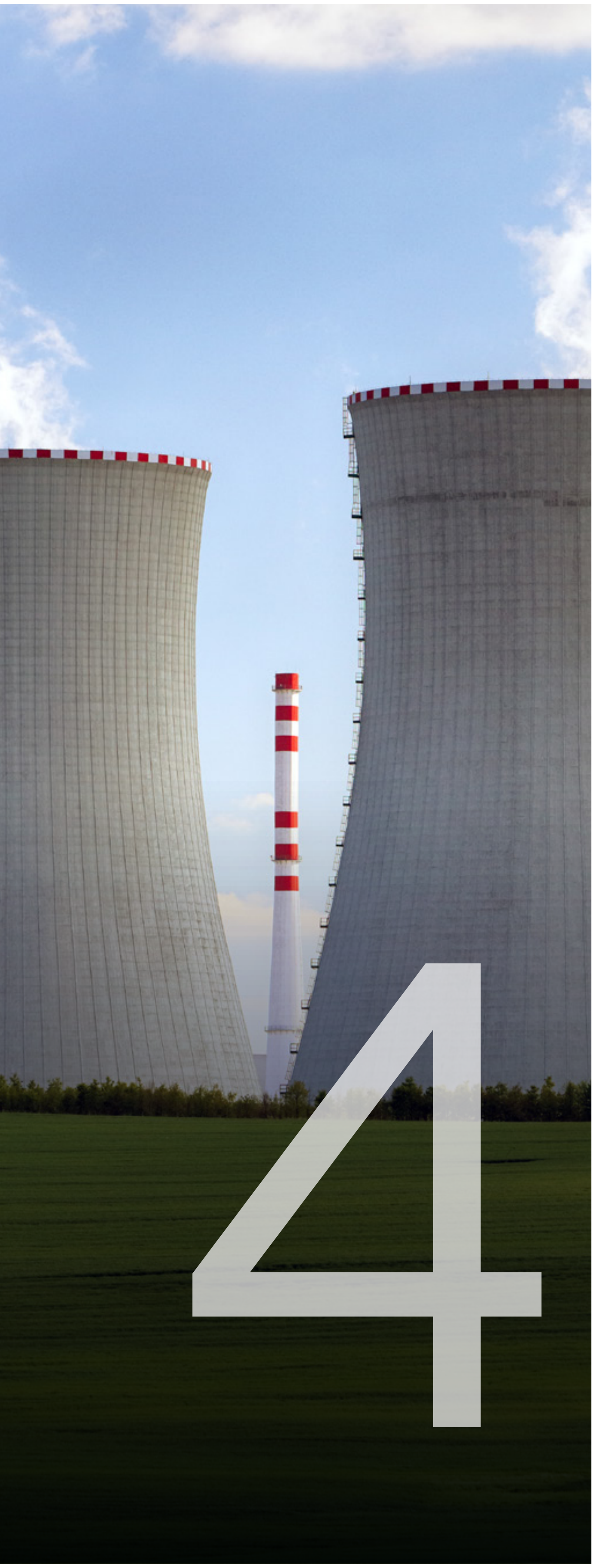
Irrespective of the model adopted, the sheer scale of decommissioning projects, and the 17 to 20 years they take to complete, means that the responsible party — whether operators or governments or both — must secure financing by recording significant provisions during the power plant's operational phase.

Financing can be achieved by drawing down on segregated and earmarked assets. However, the value and liquidity of these hived-off assets may fluctuate with the economic, political and geopolitical environment. Specific financing schemes can help to mitigate risks associated with the availability of cash.

The regulatory framework also sets out how radioactive materials are treated in decommissioning projects. Some countries, such as France, apply a caution principle to every object or material originating from a nuclear site, requiring that it is treated and stored as an item exposed to radiation. Other countries, such as Belgium, differentiate between radioactive waste and what otherwise might be considered conventional waste, using radioactivity thresholds. Regulatory differences, even between two EU countries, exist and can impact significantly on the design of a decommissioning project.

Furthermore, the regulatory framework defines whether a decommissioning process will start immediately after the permanent shutdown of a nuclear power plant, as in France, or after a few decades of "safe enclosure" to benefit from natural radioactivity decay, as in the UK.

Regulation makes the nuclear decommissioning market very local in nature, with rules varying between one country and the next. Players must therefore adopt local and country-specific strategies for engagement in the decommissioning market.



Market structure: how to secure a winning position in the value chain

In the complex nuclear decommissioning market, opportunity is increasing. A value chain of stakeholders has grown up around it, innovating and building efficiencies and best practices into the end-to-end processes. It comprises diverse players, skill sets and competencies.

Players in the nuclear decommissioning value chain tend to be highly specialist, typically engaging in a few niche activities. **In this nascent sector, there is an urgent need for industry-wide networks to mobilize on projects and to bring together available know-how.** As knowledge of decommissioning projects increases globally, delivery models and the way in which projects are structured will evolve.

The nuclear decommissioning value chain is mostly made up of nuclear experts. In France, they include plant operators such as EDF, fuel producers and managers such as Orano, and specialists in the irradiated environment and materials such as Andra. **However, non-nuclear companies, such as construction and demolition specialists** VINCI and Eiffage, **or decontamination experts** such as Veolia, also occupy a place **in the value chain**. Though the latter come from outside the nuclear domain, and may be limited to low-value, conventional or non-nuclear tasks right now, there are burgeoning opportunities.

New-era nuclear programs are ready to be launched, and the resources of nuclear experts will be largely concentrated on new-build strategies and installations. Meanwhile, fringe players that have been building competencies in the decommissioning market are now well positioned to develop winning disruptive technologies and capture larger market share. There is both a need and an opening for these non-nuclear players to move to the higher value-add rungs of the decommissioning ladder.

Decommissioning value chain

	Key activities	Decommissioning products and job types	Main providers	Examples of players
R&D	• Conception of new **techniques or products** for decommissioning jobs	• Development of **disruptive technologies** for each job type (e.g., analysis tools, decontamination	• Research organizations • Start-ups • R&D service companies • Conglomerates	• EDF • CEA • Createc • Deep Isolation
Equipment manufacturing	• Manufacturing **tools, containers, parts,** etc. for specific job types	• Manufacture of **cutting and remote equipment** for decommissioning	• Equipment manufacturers • Solution and container	• Graham • Robatel Industries • Groupe Gonzalez
Engineering and consulting	• **Studies** on nuclear facilities (overall condition, contamination) and land • Identification of **industrial hurdles**	• Comprehensive engineering and **radiological surveys**	• Engineering specialists	• Orano • AINS Group • EDF • REACT Engineering • Nukem Technologies • ATS Industrial Automation
Decommissioning works	• **Manual works,** decontamination and dismantling of facilities	• **Dismantling** in low radiation • **Rehabilitation** of sites	• Construction companies • Waste treatment companies	• Veolia • Eiffage • Orano • Bilfinger • VINCI • Fortum • Cyclife (EDF)
Project management	• Management of the decommissioning **process and agenda,** and regulatory filings • High-intensity project management **through the whole process**	• Pre-feasibility study • Project **documentation**	• Project managers • Nuclear plant operators	• EDF • RSCS • APTIM
Radioactive waste management	• Waste **collection and evacuation** from sites • **Storage** of waste (interim or final) • Design of material disposal or **recycling** processes	• **Packaging** and transportation • **Storage** and disposal	• Downstream nuclear companies • National agencies	• Orano • Duke Energy • Andra • Cyclife (EDF)

The value chain for nuclear decommissioning projects is fragmented into six main activities, as described in the blue left-hand column of the graphic. They range from R&D through to decommissioning works and waste management. The project typically lasts around 17 to 20 years, and decommissioning is overseen throughout by a project management office.

Disruptive technologies, and their role in increasing the speed of decontamination and dismantling reactors, minimizing radioactive waste and optimizing safety and costs, may be central to creating a winning value proposition for decommissioning projects.

Technology is expected to make a significant impact in key areas of the process:

Preparation

During the preparation phase, comprehensive engineering, radiological surveys and project documentation may be improved with robotics and digitization for both data collection and analysis purposes. This may involve the use of drones for radiological surveys, laser scanning and digital engineering, which can be leveraged on nuclear sites. Players that come up with these new solutions might already participate in the nuclear field or have expertise in other hostile environments, such as subsea terrains.

Works

During the decommissioning works phase, the biggest risks for decommissioners are activities that include decontamination and dismantling of high-radiation equipment or buildings. New technologies that employ, for instance, cryoblasting or remotely controlled robotics could be game changers.

Radioactive waste management

Robotization and digitization are set to have a major impact on waste processing, storage and disposal activities.

Disruptive technologies to make big impact on decommissioning

Phase	Preparation			Works	
Decommissioning products and job types	Concept, pre-feasibility study, supply chain	Building supporting infrastructure	Comprehensive engineering and radiological survey, project documentation	Decontamination	Dismantling in high radiation
Technology impact	Low	Low	**High**	**High**	**High**

Attractive technologies

Data collection
Robotics and digitization of the comprehensive engineering and radiological survey: drones, laser scanning (LiDAR), gamma-vision, spherical photography, point cloud plotting

Analysis tools
Building information modeling, digital engineering and radiation model (DIMRM)

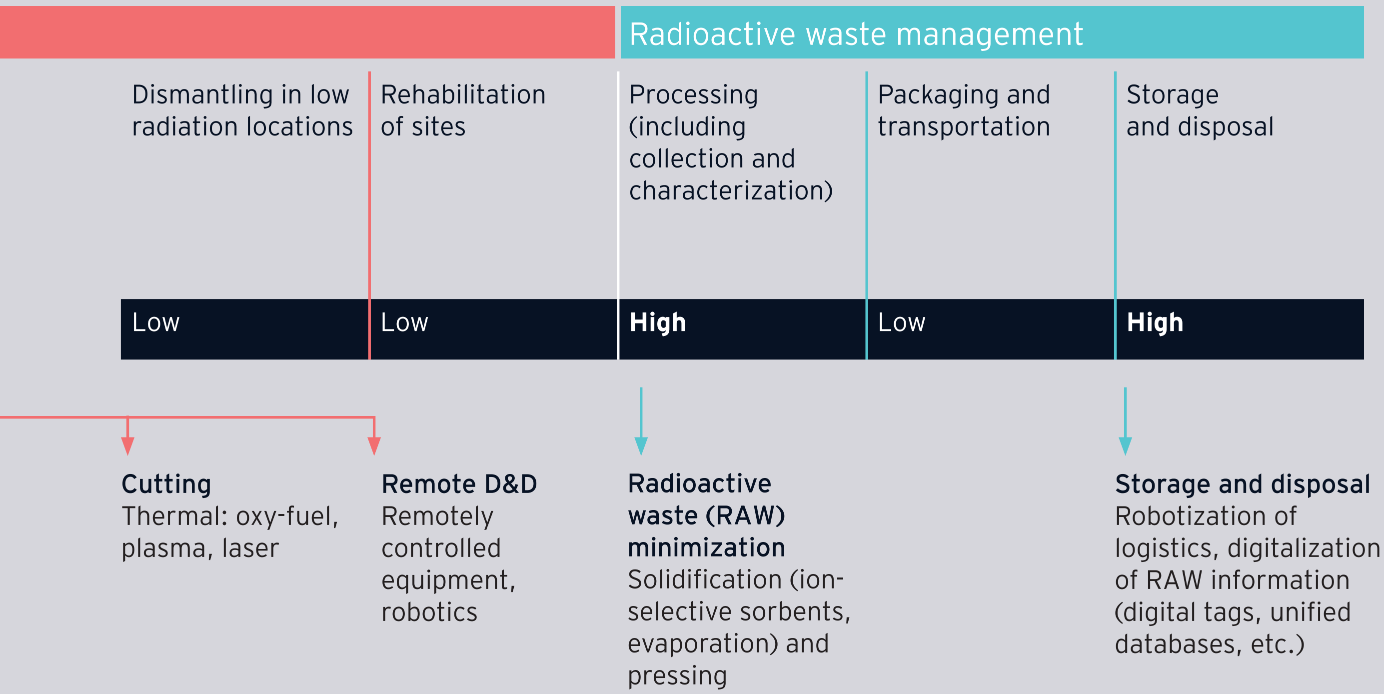
Decontamination
Chemical, film, plasma, laser, dry abrasive, cryoblasting

Given the complexity of the technologies to be developed and leveraged at nuclear sites, it's likely that new solutions will come from players already participating in the nuclear field or with expertise in other hostile environments, such as subsea terrains.

Though decommissioning represents a billion-dollar-sized global market, regulatory frameworks and funding mechanisms are very country specific. To be successful in the decommissioning value chain, a local outlook is critical. Understanding country nuances, in terms of operator, government or joint responsibilities, and acknowledging that what works in one jurisdiction might not be relevant over the border, will determine success in this nascent market.

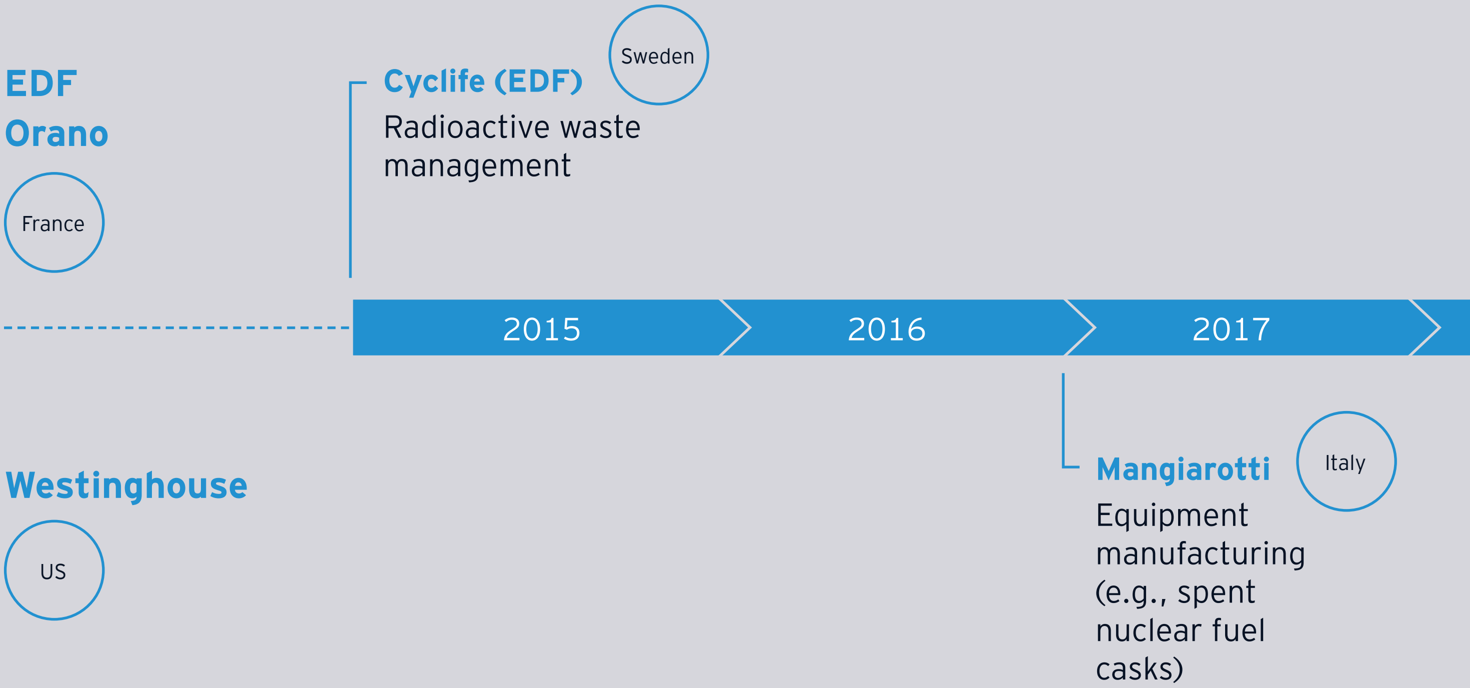
Examples:

- The UK, which has several gas-cooled reactors, may be especially receptive to value chain partners that are able to process graphite.
- The French market may be more structured around an incumbent player, such as EDF.
- Smaller EU markets, such as Spain or Belgium, may put emphasis on price.
- Foreign companies might struggle to enter the US and Japanese markets without a national partner.



M&A and JV activity on the up in nuclear decommissioning

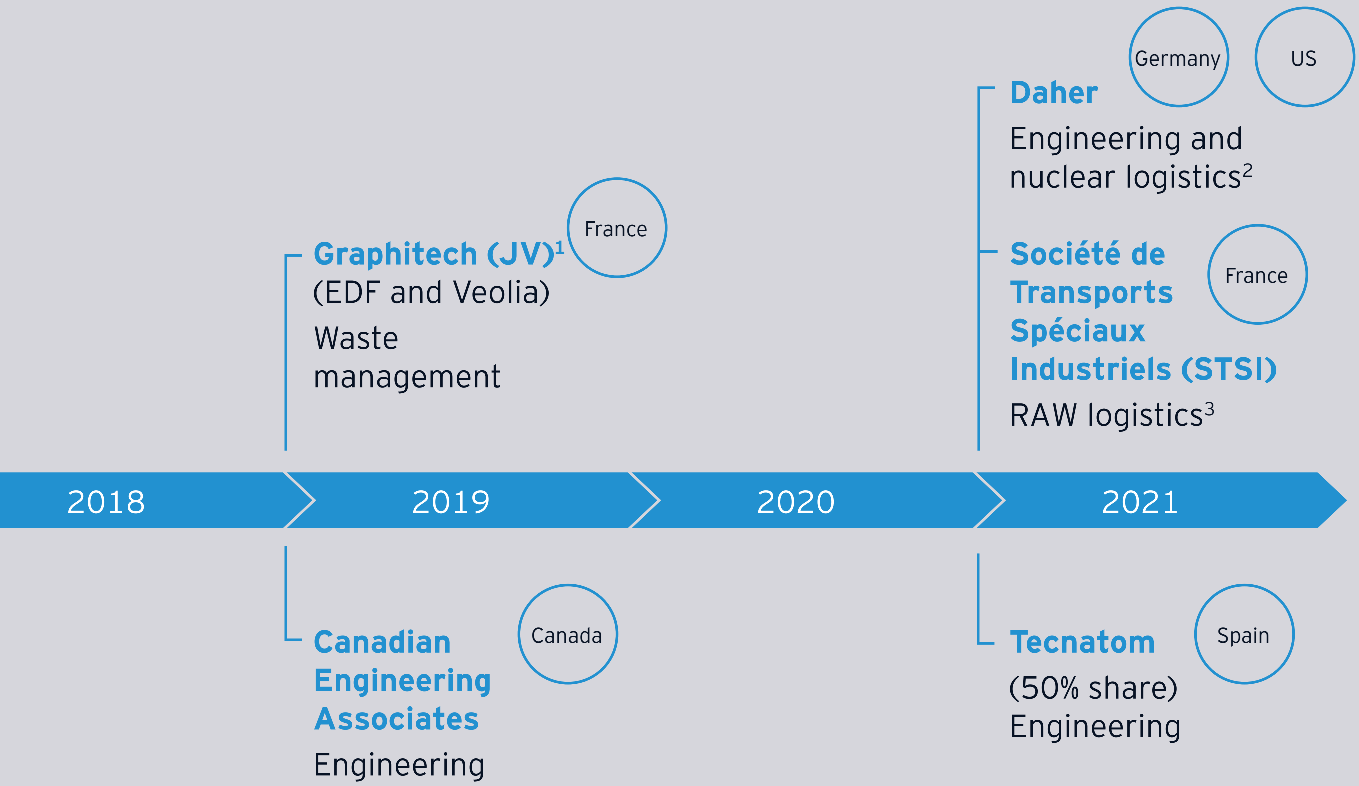
Disruptive technologies emerge in engineering and radioactive waste management



Companies along the value chain seek disruptive technologies and geographical expansion. In pursuit of those dual ambitions, growth via merger and acquisition (M&A) and joint venture (JV) is starting to characterize the decommissioning marketplace. The trend continues, with M&A likely to bring about rapid consolidation in the most profitable and technologically advanced business models.

Ultimately, the decommissioning market will be highly concentrated. The top five players hold around 45% market share, which could rise to 65% by 2030. By then, the top 10 players could occupy around 90% of the market.

Even so, consolidation in the global market may be limited due to national preferences and local agendas. It means the market in each country may have room for just a few major players.



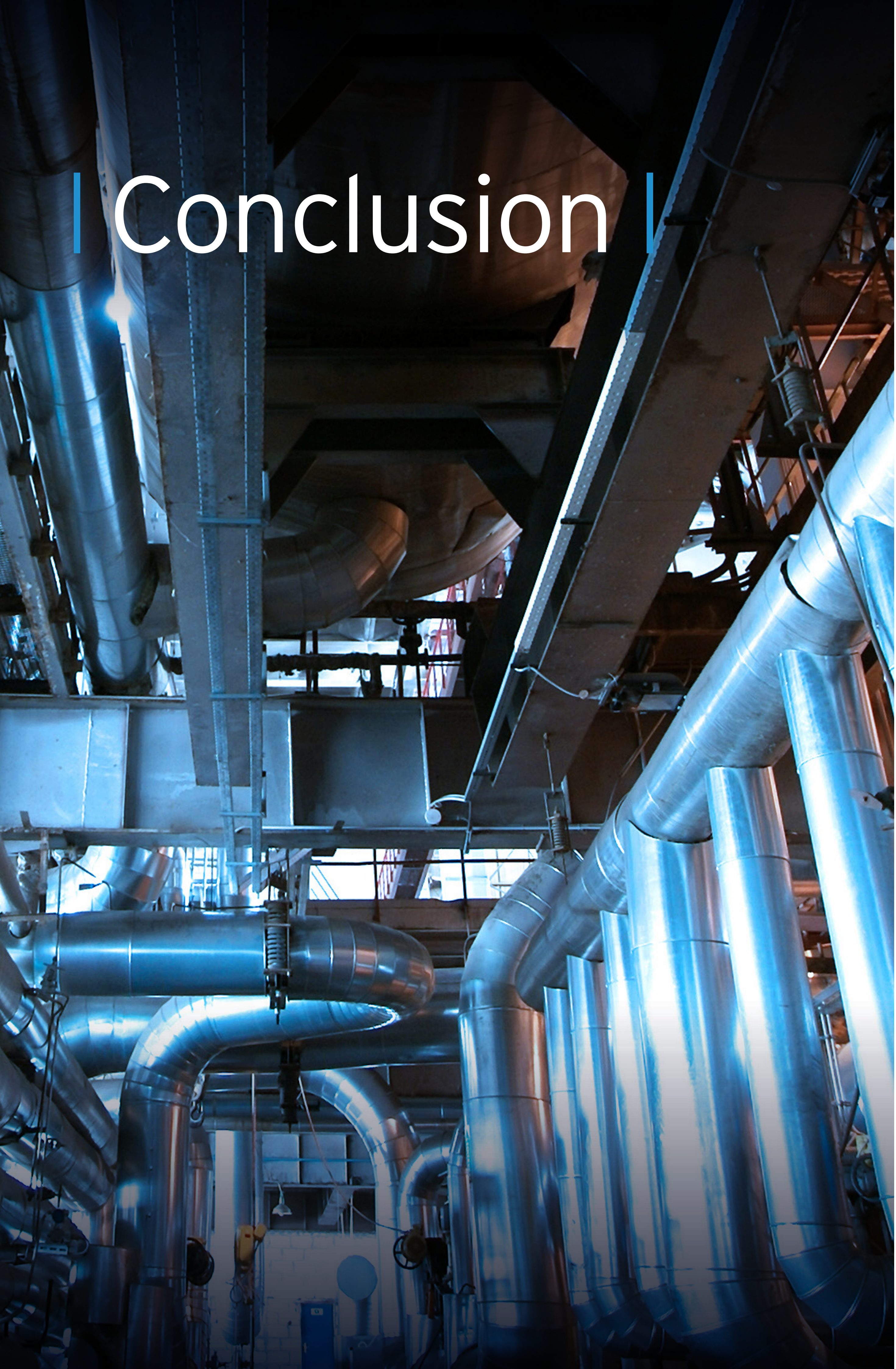
Source: EY Embryonic and Mergermarket databases, data from official company websites, EY-Parthenon analysis.

The decommissioning market offers huge potential. But players wanting to become leaders in this future market need to act now. They need to start building capabilities and capacity today.

Some have already started, as illustrated by the recent trend in M&A activity. But further technological progress, as well as the need to harness synergies and expand geographically, is necessary if value chain participants are to seize the opportunity and lead the field.

1 – Graphite nuclear reactors.
2 – Announced in October 2021.
3 – Ensure safe and timely transportation of contaminated tools, fuels, and RAW.

Conclusion



Nuclear decommissioning is a nascent market, but it is large. Aging reactors will reach the end of their useful lives, and decommissioning activity will continue. Even an unlikely halt to nuclear power plant construction will not damage the attractiveness of this market, because decommissioning demands input from specialists, and corresponding margins, over a long time frame.

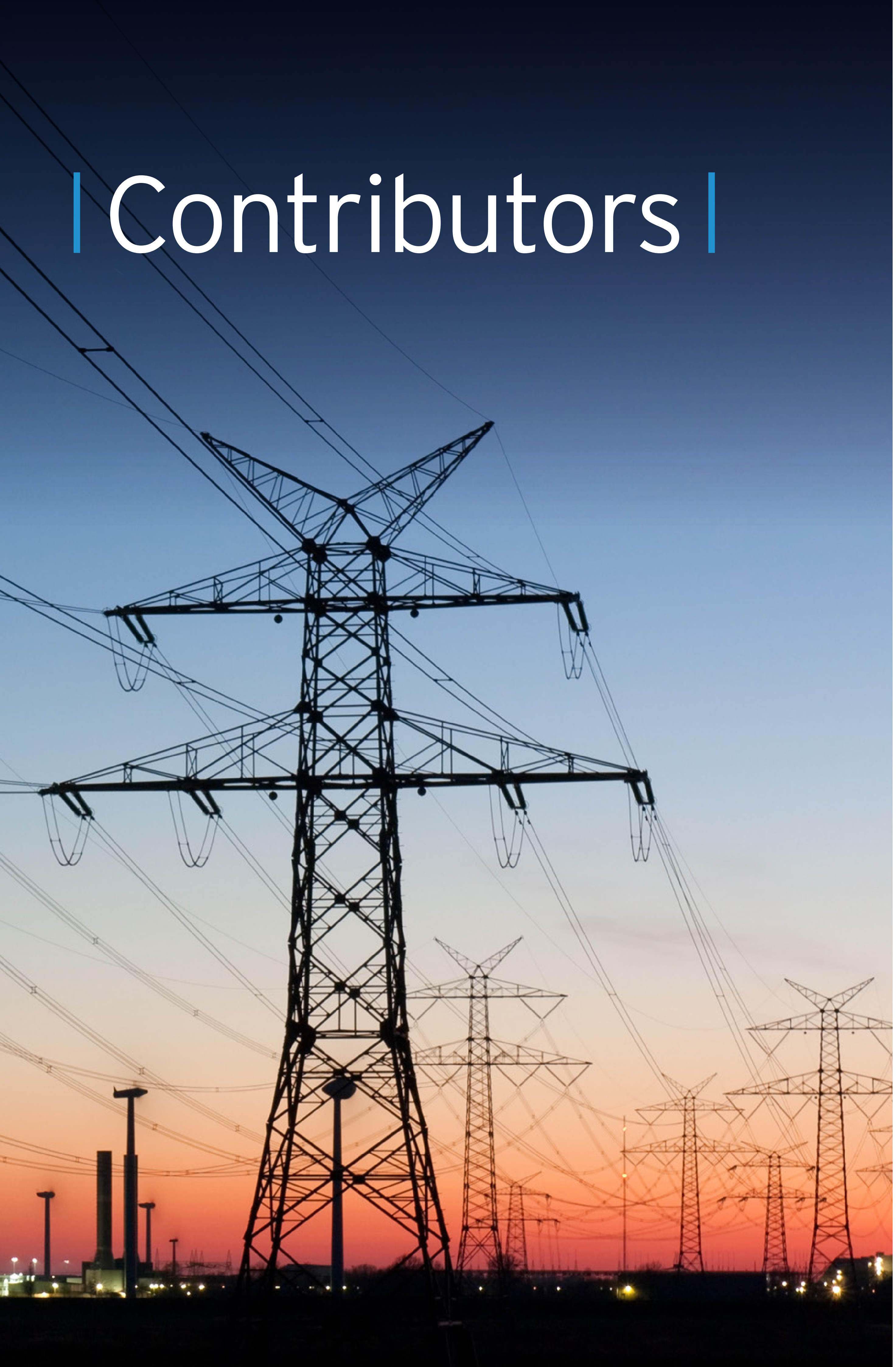
Each of these conditions means that nuclear decommissioning is highly likely to attract investment. It is still too early to quantify sources of profit and expected returns, but some things are certain: **Technology and expertise in managing complex programs will be critical in coordinating a large number of contractors with very different profiles, and in delivering hundreds of thousands of related projects.**

Specialists in engineering procurement construction will transform into experts in engineering procurement decommissioning. Application of competencies in technology, digital and data science will be essential for carrying out highly complex and sensitive projects safely and securely. Capitalizing on early achievements to populate the experience curve will bring learnings and transparency to all operations.

Innovative players with technological niches may emerge. However, due to the extreme conditions relating to the use of equipment, as well as security and risk hedging obligations, they will need backing from either power plant operators or investment funds with robust financial balance sheets, just like companies operating in the defense, space, deep-sea exploration and production sectors. To get these niche technology businesses on board, and secure competitive advantage, the major players should expect to share their profit pools to create an attractive commercial proposition.

In this emerging market, businesses, investors and individuals are securing their positions today. Innovation will be critical to the enablement of future carbon-free electricity sources, both renewable and nuclear. The war for talent is on in a market that will hinge on creating high value-add jobs and attracting the most brilliant engineers.

Contributors



Thanks to contributors

Issam Taleb
France

Jean-Christophe de Noinville
France

Jackson Perry
US

Rémi Worms
France

EY Nuclear Center of Excellence

Jamie Andrews
UK

Birute Bobrovaite-Jurkone
United Arab Emirates

Adrian Bocher
France

Bruno Bousquié
France

Guillaume Bouvard
France

Christian Grauers
Sweden

Jérémie Haddad
France

Andrew Horstead
UK

Paul Rees Jones
UK

Antony W. Jones
UK

Chris Lewis
UK

Nicola L. Marsh
UK

Anton E. Poryadin
US

Issam Taleb
France

Pierrick Vaudour
France

Andre Winarto
Australia

EY | Building a better working world

EY exists to build a better working world, helping to create long-term value for clients, people and society and build trust in the capital markets.

Enabled by data and technology, diverse EY teams in over 150 markets provide trust through assurance and help clients grow, transform and operate.

Working across assurance, consulting, law, strategy, tax and transactions, EY teams ask better questions to find new answers for the complex issues facing our world today.

EY-Parthenon France recruitment contact info:

paris.recruitment@parthenon.ey.com

www.parthenon.ey.com

About EY-Parthenon
EY-Parthenon teams work with clients to navigate complexity by helping them to reimagine their eco-systems, reshape their portfolios and reinvent themselves for a better future. With global connectivity and scale, EY-Parthenon teams focus on Strategy Realized — helping CEOs design and deliver strategies to better manage challenges while maximizing opportunities as they look to transform their businesses. From idea to implementation, EY-Parthenon teams help organizations to build a better working world by fostering long-term value. EY-Parthenon is a brand under which a number of EY member firms across the globe provide strategy consulting services. For more information, please visit ey.com/parthenon.

Studio BMC France — 2206BMC119.
Photos credit: None.
SCORE N°: EYG no. 011013-22Gbl
ED None.

In line with EY's commitment to minimize its impact on the environment, this document has been printed on paper with a high recycled content.

ey.com