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Decommissioning of Nuclear Facilities

Market Overview and Forthcoming Challenges for Plant Operators

Forthcoming Decommissioning Projects worldwide

The global framework for the nuclear energy market and its facilities has been facing radical changes over the past decade. After the dramatic incident at the Fukushima Daiichi NPP in 2011, ongoing construction projects for NPPs were stopped and new construction projects are becoming increasingly difficult to implement, especially in western countries. Concerns relate in particular to massive project delays, changing governmental safety assessments as well as increasing initial investments and uncertain profit prospects. Instructive examples include the European new construction projects Flamanville (France) and Hinkley Point (England).

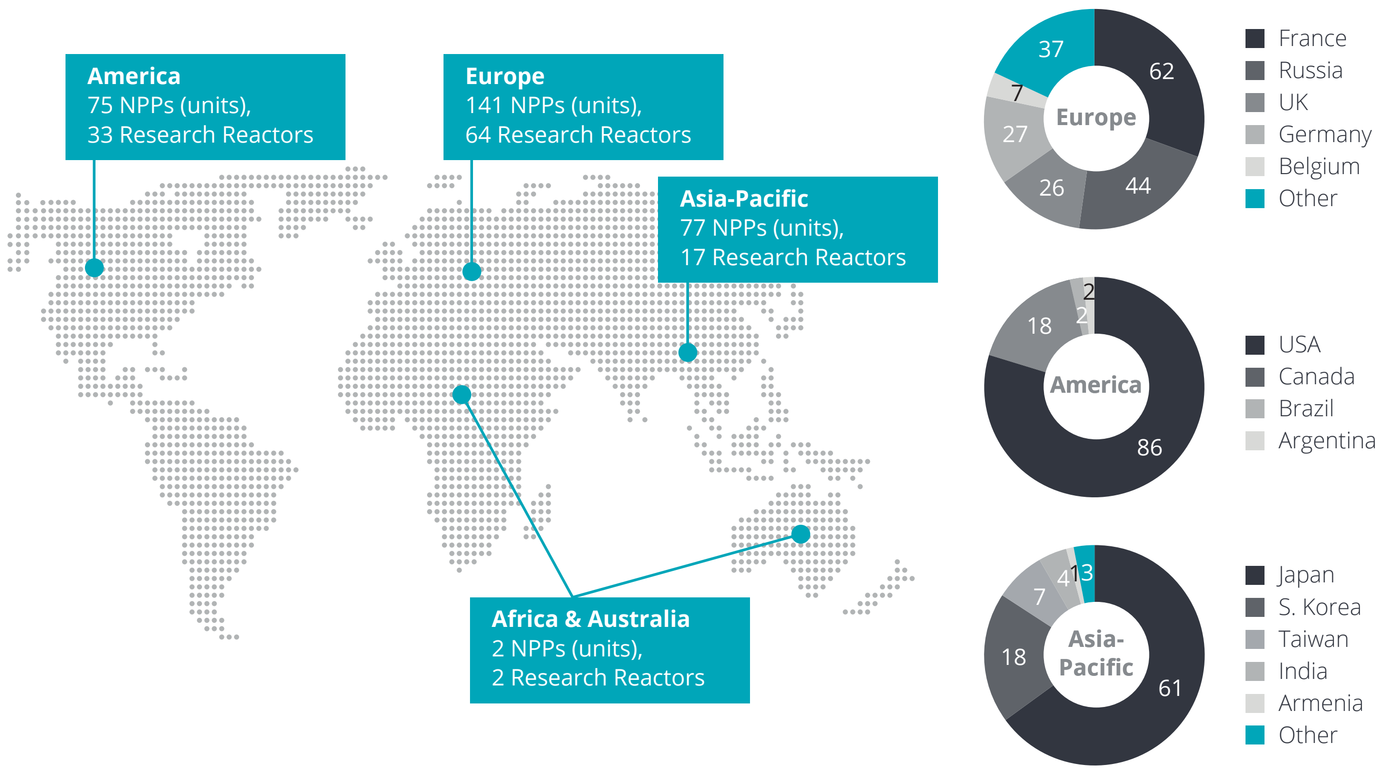
At the same time, a large number of NPPs are reaching the end of their service life, and political decisions based on security concerns as well as social constrains are likely to accelerate the wave of shutdowns in the following two decades. Apart from new construction projects in a few countries of Asia (e.g. China, India and the UAE), the dismantling of NPPs in many other countries will strongly predominate activities in the nuclear sector for years to come. The following section will provide a brief market overview of forthcoming decommissioning projects worldwide and the challenges plant operators are going to face.

A Wave of Dismantling Projects is just around the Corner

Currently, 56 nuclear facilities are in the phase of decommissioning. Most of the decommissioning projects carried out right now are located in Germany, France and Japan. Simultaneously with those projects, the market for decommissioning services is getting more mature; hence the first companies have already positioned themselves in the dismantling market.

According to estimates of IEA experts, the costs of decommissioning nuclear facilities around the globe will amount to at least USD 100 B by 2040. The credibility of the forecast is underpinned by taking

Fig. 1 – Decommissioning of Nuclear Facilities Worldwide by 2040



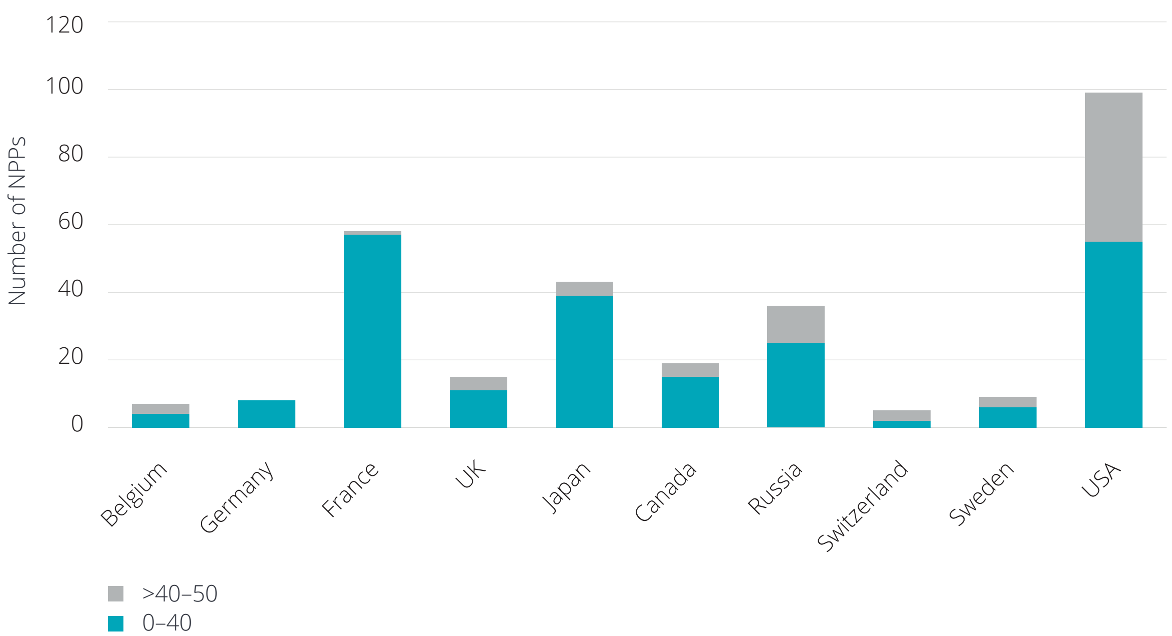
the number of expected shutdowns into account. Figure 1 illustrates the global distribution of upcoming decommissioning projects for NPPs and larger research reactors by 2040 by continent.

Overall, 411 nuclear facilities are expected to be phased out by 2040, whereof 295 are commercial NPPs (units) and about 116 are being operated as research reactors. By shutting down these NPPs, an electricity generation capacity of roughly 260 GW will no longer be available to feed electricity to the grid. This substantial capacity gap will necessarily have to be replaced or compensated by other means of generation.

The United States (86), France (62), Japan (61) and Russia (44) in particular, all countries that belong to the pioneers of nuclear technology, will face a dramatic decline of their nuclear industry, if new constructions are not realized in the near future. By 2040, just within these four countries a total of 253 nuclear facilities will be entering the phase of decommissioning. This large number of dismantling projects will challenge operators and policymakers on a national and international level in the same way. The process of establishing an efficient dismantling infrastructure and a national nuclear repository for highly active nuclear waste, which is not yet available for operation in any country, will be crucial.

Most nuclear power plants have been designed for an operational lifetime of about 40 years. However, some NPPs are operated for much longer periods, where timeframes of 50 years or longer can be observed. The graph below illustrates the age distribution of existing NPPs that are still in operation in 2018 per country.

Fig. 2 – Age Distribution of NPPs in Operation or Ready for Operation per Country



On a global scale, already today, 77 NNPs exceed the presumed lifetime of 40 years. With increasing operational lifetimes, the deterioration processes of the plants are progressing, in particular with regard to mechanical and electrotechnical components. This leads to increasing maintenance costs and in some cases, particularly for large components such as reactor pressure vessel and steam generator, to an increased material fatigue. Additionally, in most countries, regulatory requirements that have significant effects on administrative and technical efforts, have increased over the last years. In this context, a recent study of the Carnegie Mellon University has examined the nuclear energy market in the US, categorizing more than 50 nuclear power plants as being overaged and too expensive in order to continue their operation. At the same time, electricity from renewable energy sources such as wind and sun would become cheaper and natural gas would furthermore strengthen its position as a reliable and affordable alternative in the U.S.; consequently, the operation of NPPs would become increasingly unprofitable.

Besides technical and economic assessments, politics and regulation plays a central role in the generation of nuclear power. Germany, for example, conducted a reassessment of the risks associated with nuclear energy after the major incident at Fukushima Daiichi NPP in 2011. This assessment resulted in the decision of the German federal government in June 2011 to decommission all NPPs by 2022 (eight NPPs had their operating licenses revoked immediately) and in the reinforcement of safety requirements.

By passing the 'Energy Transition for Green Growth' act in 2015, France also announced its plan to decrease its share of nuclear power from 75 to 50% by 2025. Although the target date was postponed, whereby the proposed 50% reduction shall now only be achieved by 2035, it is a clear sign that France will also divest itself of its nuclear assets in the medium term. A further example is Switzerland. In 2017, a referendum on nuclear energy resulted in the planned withdrawal from nuclear energy in the foreseeable future, but without naming a specific date.

However, not only policymakers in Europe start to think about the future role of nuclear energy. Taiwan used the incident in Fukushima in 2011 as a catalyst to rethink its nuclear policy. In 2016, the cabinet passed an agenda forcing the entire phasing out of nuclear energy by 2025.

In line with a general decrease of nuclear technology for power generation, research projects on nuclear technology will not be extended. Various research reactors have fulfilled their original purpose and are now waiting to be decommissioned.

The reasons for abandoning nuclear energy generation are manifold. Therefore, this question arises: What are the challenges that operators and individual countries will face if they want to manage their nuclear legacy successfully?

Efficient Decommissioning Requires a Smooth Transition from the Operational into the Dismantling Organization

The first dismantling projects have already been completed and valuable experience has been gained. However, these initial dismantling projects brought to light that planning values (budget and time) differed very strongly from reality. A few examples underpin these insights.

- The German NPP Stade, located in Lower Saxony, started its phasing out in 2003. Initially, the green field phase should have been reached by 2015. In the meantime, the targeted time frame for the process of complete dismantling has been changed to 2023 and cost estimates had to be raised from originally EUR 500 M to EUR 1 B.
- The last unit of the Lithuanian NPP Ignalina was taken off the grid in 2009. Nearly 10 years later, its fuel elements have yet to be removed from the reactor core. According to current plans, the removal will be undertaken in 2022 at the earliest. Additionally, the construction of major decommissioning infrastructure elements, such as a solid waste retrieval facility or a solid waste treatment and storage facility, is subject to further massive delays.
- Significant budget overruns also occurred during the dismantling of the US NPP Haddam Neck in Connecticut. When the project was completed in 2006, dismantling costs of over USD 900 M had been incurred, which stands in sharp contrast to the initially estimated costs of roughly USD 500 M.

Therefore, this question arises: which factors significantly influence the success of the dismantling progress? To this day, 21 dismantling projects worldwide have been completed successfully, dealing with all common reactor types. From a technical point of view, nuclear decommissioning is controllable, especially in cases of NPPs that were constructed with a high degree of standardization. Hence, budget and time requirements should be plannable for the single dismantling stages based on previously gained experience.

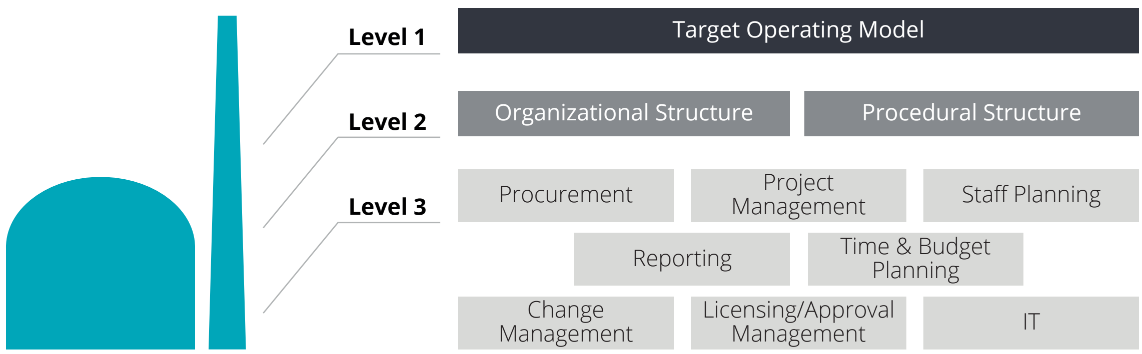
Further elements that influence the dismantling progress to the same extent are smooth processes, transparent structures as well as intelligent and intense change management. While the operational organization is designed for stable and reliable processes, dismantling companies need to convert fundamentally to agile, project-oriented organizations. This transformation affects both corporate structures and corporate culture.

Clear communication of the change processes can create acceptance and support employees in developing a commitment to the development of the company. On the other hand, shaping the transition inconsistently is one of the reasons that cause the above-mentioned budget and time overruns for dismantling projects. For a smooth transition, there are a couple of success factors to be considered, which are outlined below.

Three transformation levels which need to be looked at are the foundation of a successful organization for the dismantling of NPPs: from the target operating model to the organizational design down to the operational level – all levels are substantially affected by the enterprise transition (see Figure 3).

The target operating model requires careful consideration in order to establish a successful collaboration between the power plant director and the respective project manager (in as far as these positions are not staffed with the same person). Furthermore, guidelines for collaboration between the departments with nuclear responsibility and the relevant project and dismantling teams have to be laid down. The dismantling phase also requires an organizational structure with the capacity to handle complex and dynamic projects in an efficient manner. This requires an analysis of the tasks to be performed by decentralized project teams; on the other hand, where centralized, crosssectional units can create synergies. In practice, it has become evident that dismantling organizations often do not carry out the required organization transformation in all the required details and consequences. Instead, hybrid forms arise, with parallel structures causing conflicts and inefficiencies. The target operating model, however, forms the starting point for further organizational development.

Fig. 3 – Fundamental Transformations are Required at Every Transition Level



Once the target operating model has been defined, it is necessary to elaborate on the organizational units, including a precise definition of tasks and personnel capacities. In practice, task structures and priorities must be adapted to the new challenges in the phase of decommissioning. For example, the requirements for project planning and the disposal infrastructure will rise sharply during the dismantling phase. Based on the dismantling organization, management, core and support processes need to be adapted to the new company purpose. In particular, interfaces between organizational units need to be designed in a way that ensures safe and efficient processes as well as the secure and swift flow of information.

The organizational transition pervades the company down to the operational level. Essential business activities such as budgeting, purchasing and staff planning as well as reporting are facing radically different requirements. An adapted set of methods and tools can support business units to manage the challenges in an efficient manner.

Budget planning and reporting is particularly affected by the changeover to a project organization. In order to establish appropriate transparency regarding cost development and dismantling progress, companies need to adapt their work breakdown structure (WBS). The WBS needs to be very granular in order to allow accurate cost booking to the relevant WBS-elements. Implementation in this way enables executives to determine the projects course based on a profound database.

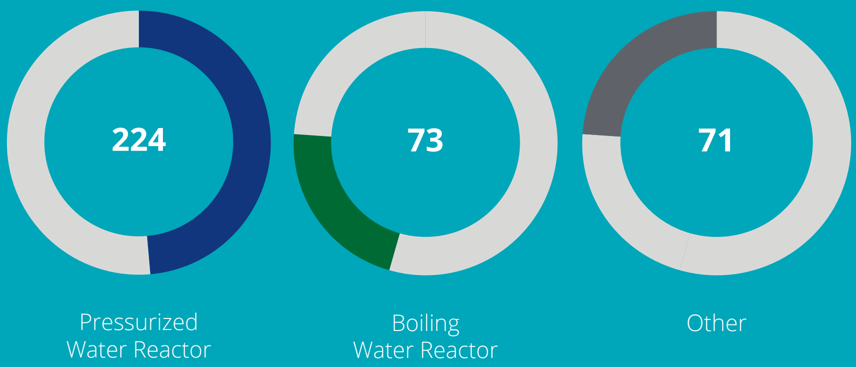
Business units responsible for purchasing activities are in need of proactive purchase planning in order to avoid delivery delays, and therefore provide support for reaching project schedules. Considering the applicable tendering specifications, it is important to identify potential delivery delays and to avoid them by taking countermeasures at an early stage. In addition, the development of commodity group/ supplier management, analysis of supply bottlenecks and availability of suppliers, analysis and verification of contracts or the awarding system should be considered in the transition phase. In practice, by using smart purchasing tools and working in close collaboration with other departments, purchasers can achieve significantly shorter procurement lead times.

HR departments need to consider a more complex and dynamic planning process for relevant staff planning and recruiting activities. Future gross personnel requirements are subject to increased uncertainty, as the dismantling progress cannot be completely and accurately predicted. Consequently, a personnel development concept is required which prepares employees for future challenges in the field of dismantling. Additionally, resulting net personnel requirements need to be identified systematically and staff marketing has the task of addressing external expertise precisely. Due to an underserved labor market for nuclear energy experts, it is essential to establish a HR marketing that is capable of attracting specialists to the company. The implementation of such strategic staff planning can absorb losses of key knowledge to ensure smooth project progress on the personnel side.

In the decommissioning phase, operators must seek even more contact with authorities and appraisers. Very often, due to complex and sluggish licensing and approval processes, delays may have a major impact on the project's progress. Systematic licensing and approval management can counteract those project delays and help to improve overall time/ schedule management.

Excursus: Currently Operated Reactor Types
From a technical perspective, the dismantling activities are connected to the type of reactor used. As Figure 4 highlights, most reactor operators rely on pressurized water reactors, PWR (224), followed by boiling water reactors, BWR (73). Further common reactor types particularly are gas-cooled reactors and pressurized heavy water reactors. The mentioned numbers refer to NPPs currently in operation.

Fig. 4 – Global Distribution of Currently Operated Reactor Types



In a BWR, water is heated up in the reactor core and steam then flows to the turbine within a closed circuit. In the PWR, however, a heat exchanger is interposed to feed a secondary stream with heat. By separating the circuits, it is ensured that no contaminated fluid can enter the turbine tract. Hence, from a dismantling point of view, PWRs require smaller control areas and fewer components will become contaminated.

Challenges can be Managed Successfully

Focusing on the technical complexity of nuclear dismantling projects, plant managers often neglect the further development of the organization and business culture. In fact, this can be identified as the turning point for establishing a successful organization. If the dismantling organization is properly designed from the start, one of the root causes for budget overruns and project delays is eliminated right at the beginning. Based on the insights gained from the first decommissioning projects, responsible managers are increasingly pursuing corporate development, integrating technical, economic and regulatory requirements into an agile organization. This becomes particularly relevant in the light of the upcoming dismantling wave that is going to hit the global nuclear industry, as described above. Successfully managing this challenge will be a decisive prerequisite for business prosperity of energy utilities.

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